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Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Fifth Rice Technical Working Group

New Orleans, Louisiana • February 18-21, 2014

Edited by: Michael E. Salassi, Eric P. Webster and Charles E. Wilson, Jr.

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.

35th RTWG
New Orleans Louisiana
February 18-21, 2014
LSU AgCenter Research & Extension

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station

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PROCEEDINGS ... THIRTY-FIFTH RICE TECHNICAL WORKING GROUP

RICE TECHNICAL WORKING GROUP

Organization and Purpose

The Rice Technical Working Group (RTWG) functions according to an informal memorandum of agreement among the State Agricultural Experiment Stations and the Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, and the Agricultural Research Service, the Economic Research Service, the 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 months 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 2014 Meeting

The 35th RTWG meeting was hosted by Louisiana and held at the Sheraton New Orleans Hotel in New Orleans, Louisiana, from February 18 to February 21, 2014. The Executive Committee, which coordinated the plans for the meeting, included Charles E. Wilson, Jr., Chair; Eric P. Webster, Secretary; and Timothy W. Walker, Immediate Past Chair. Geographic Representatives were Robert Scott (Arkansas), Zhonli Pan (California), Ronald Rice (Florida), Dustin Harrell (Louisiana), Jason Bond (Mississippi), Donn Beighley (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 (Tennessee). Website coordinator was Chuck Wilson. The Local Arrangements Coordinators for Louisiana were Steve Linscombe (Chair), Eric Webster, Michael Salassi, Karen Bearb, and Dustin Harrell.

Location and Time of the 2016 Meeting

The 2016 RTWG Meeting Location Committee recommended that the 36th RTWG meeting be held by the host state Texas. The meeting will be held from March 1 to March 4, 2016, at Moody Gardens in Galveston, Texas.

2014 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. Johnny Saichuk. The team award was presented to the Entomology Team, whose members included Drs. John Bernhardt, Gus Lorenz, Luis Espino, Larry Godfrey, Mike Stout, Jeff Gore, and Mo Way.

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. Robert Fjellstrom and Mr. Jeffrey Oster.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 35th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2014 proceedings. The 2014 proceedings was edited by Michael E. Salassi, Eric P. Webster (Secretary), and Charles E. Wilson, Jr. (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 36th RTWG (2016 meeting) proceedings are included in these proceedings.

Committees for 2016

Executive:

Chair:	Eric Webster	Louisiana
Secretary:	Lee Tarpley	Texas

Geographical Representatives:

Gregory Berger	Arkansas
Bruce Linquist	California
Ronald Rice	Florida
Mike Stout	Louisiana
Jeff Gore	Mississippi
Donn Beighley	Missouri
Ted Wilson	Texas

Immediate Past Chair:

Charles E. Wilson, Jr.	Arkansas

Administrative Advisors:

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

Publication Coordinator:

Mike Salassi	Louisiana

Web Page Coordinator:

Eric Webster	Louisiana

Industry Representative:

Frank Carey	Tennessee

2016 Local Arrangements:

M.O. Way (Chair)	Texas
Fugen Dou	Texas
Rodante Tabien	Texas
Yubin Yang	Texas
Shane Zhou	Texas
Lee Tarpley (ex officio)	Texas

Location and Time of 2018 Meeting:

Chris Greer	California
Bruce Linquist	California

Nominations:

Fugen Dou (Chair)	Texas
Charles E. Wilson, Jr.	Arkansas
Larry Godfrey	California
Ronald Rice	Florida
Ida Wenefrida	Louisiana
Jason Bond	Mississipppi
Donn Beighley	Missouri
Frank Carey	Industry

Rice Crop Germplasm:

Farman Jodari, Chair	California
Georgia Eizenga	USDA-ARS
James Correll	Arkansas
Karen Moldenhauer	Arkansas
Xueyan Sha	Arkansas
Jim Oard	Louisiana
Tim Walker	Mississippi
Rodante Tabien	Texas
M. O. Way	Texas
Qiming Shao	Bayer Crop Science
Ex Officio:	
Harold Bockleman	USDA-ARS
Jack Okamuro	USDA-ARS
Anna McClung	USDA-ARS
Clarissa J. Maroon-Lango	USDA-ARS
Wengui Yan	USDA-ARS
National Germplasm Resources Laboratory:	
Gary Kinard	USDA-ARS

Rice Variety Acreage:

Dustin Harrell, Chair	Louisiana
Chuck Wilson	Arkansas
Kent McKenzie	California
Bobby Golden	Mississippi
Donn Beighley	Missouri
Ted Wilson	Texas

2016 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:	
Rodante Tabien	Texas
Economics and Marketing:	
Michael Salassi	Louisiana
Plant Protection:	
Shane Zhou	Texas
Processing and Storage:	
Ming Hsuan Chen	USDA-ARS
Rice Culture:	
Fugen Dou	Texas
Rice Weed Control and Growth Regulation:	
Muthukumar Bagavathiannan	Arkansas

RESOLUTIONS
35th RTWG – 2014

The 35th meeting of the RTWG, held in New Orleans, Louisiana, February 18 to March 21, 2014, 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 35th meeting.

1. Charles E. Wilson, Jr., RTWG Chair, and all other members of the Executive Committee who organized and conducted this very successful meeting. We recognize Eric P. Webster 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 Sheraton New Orleans, New Orleans, Louisiana, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements Committee chaired by Steve Linscombe for the site selection and overseeing arrangements. To the faculty and staff of the Louisiana State University AgCenter Rice Research and Extension Center, Crowley, Louisiana, and the LSU AgCenter, Baton Rouge, Louisiana, 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 LSU AgCenter staff who contributed time and effort for numerous vital tasks that made sure this meeting was a success.

5. The Panel Chairs, Jim Oard, Michael J. Stout, Mike Salassi, Joan King, Dustin L. Harrell, and Eric P. Webster, 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, Blast Symposium, General Session, and the Breeding, Genetics, and Cytogenetic 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 35th Rice Technical Working Group meeting possible.

RTWG Conference Sponsorship

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Rice Foundation
USA Rice Federation

Distinguished Rice Research and/or Education Award

Johnny Saichuk

Dr. Johnny Saichuk is the 2014 Distinguished Rice Research and/or Education Award recipient. Dr. Saichuk is the rice extension specialist with the LSU AgCenter and in that role has worked closely with rice research and extension scientists from all of the rice-producing states. He is an excellent writer and speaker, making many presentations to a wide variety of audiences on issues related to rice production. He has become a skilled photographer of rice weeds, insects and diseases/disorders and his photos are widely used by many scientists. Dr. Saichuk also has a long history of working closely with industry and regulatory partners to help make available new and more effective pest management tools for stakeholders, helping to collect data and convey to these partners the benefits and disadvantages of these tools at the field level to procure for his clientele product registrations for numerous herbicide, insecticide and fungicide products.

Dr. Saichuk was the first scientist to document rice seed midge damage to water-seeded rice in Louisiana, and he helped develop a management program for this early season pest. He developed a quick method of diagnosing phosphorus deficiency and identified hydrogen sulfide toxicity as a recurring problem in Calcasieu and Cameron parishes. He worked to save Furadan 3G for rice water weevil control and simultaneously investigated alternative tactics such as timing of application of pyrethroids. Dr. Saichuk organized the response to salt water intrusion due to Hurricane Rita which made landfall near the Louisiana/Texas border in 2005. This was a huge effort requiring collecting and analyzing countless soil and water samples from numerous farms impacted by Rita. He also confirmed the presence of the Mexican rice borer in Louisiana, which currently continues to spread eastward and is becoming an increasing pest of concern.

Dr. Saichuk routinely makes 125-150 visits annually to inspect and conduct research/extension programs with cooperating farmers and/or clientele. He has developed a signature outreach program – The Rice Research Verification Program – throughout the rice-growing regions of Louisiana. His program has been on-going since 1997 with a total of 135 fields comprising 5,000 acres in 19 Louisiana parishes. Dr. Saichuk sets up experiments and observational studies in these fields across Louisiana and monitors them on a weekly basis. This requires a tremendous amount of time and effort. He reports results verbally, electronically and digitally in a real-time manner to help growers make critical pest management and other agronomic decisions. Rice producers not directly participating in the Verification Program also derive benefit through observation and communication with Dr. Saichuk, and participating growers learn about the problems, solutions and novel/recommended practices applied in the verification fields. Thus, the impact of Dr. Saichuk's verification program extends much farther than the immediate vicinity of participating farms.

Dr. Saichuk created *Field Notes,* which is a weekly electronic publication emphasizing current rice production topics in Louisiana. This publication has a multi-state, multi-discipline readership and includes excellent photographs of current subjects (i.e. weeds, insects and diseases) of interest. His photos have been widely used by rice scientists and teachers around the world. Dr. Saichuk has also worked with Dr. Natalie Hummel to create and improve the web-based Rice Scout app that helps farmers in real time identify pests and recommend management options.

In summary, Dr. Johnny Saichuk has admirably served his rice clientele for many years. His wisdom, good judgement and dedication to the Louisiana rice industry have helped it remain viable and competitive. He has been a leader in introducing and improving new electronic communication technology for rice producers. Dr. Saichuk has helped solve problems across most aspects of rice production through science-based field research. He is a pioneer in establishing and implementing a rice research verification program designed to carry small plot research to the commercial field level. He also communicates his findings effectively to diverse audiences. Dr. Saichuk's efforts not only directly benefit the Louisiana rice industry but the rice industries in other states as well.

Distinguished Rice Research and/or Education Team Award

John Bernhardt, Gus Lorenz, Luis Espino, Larry Godfrey, Mike Stout, Jeff Gore, and Mo Way

A diverse assemblage of arthropods feeds on U.S. rice, and these pests pose a significant threat to rice yield and quality. This makes the development of cost-effective arthropod management programs essential to the economic viability of U.S. rice production. Over the past 15 years, regulatory actions, invasions of new pests, changes in agronomic practices, and release of new cultivars have necessitated the development of new strategies for managing arthropods in rice. The rice entomology team of University-affiliated entomologists has responded to this need by developing and implementing improved management programs for arthropods in the face of changing conditions.

The most important contribution of the team has been ensuring the availability of effective insecticides coupled with best management practices for use against arthropod pests. This contribution is best demonstated by the team's efforts to evaluate and bring to market effective insecticides for the rice water weevil, the most important insect pest of U.S. rice. Prior to 1997, the only product available for controlling the rice water weevil was the granular insecticide carbouran (Furadan 3/5G), which was applied to rice fields to kill weevil larvae as they fed on rice roots. Furadan is highly toxic to birds and its use in rice in the U.S. was banned by the EPA in the mid-1990s. In the time since this regulatory action, the efforts of the team have resulted in the registration of over 10 new insecticides for rice water weevil control. Included among these are the highly effective insecticidal seed treatments and several widely used pyrethroid insecticides. Team members played a variety of roles in this process, including: evaluating the effectiveness of new products against these pests and providing efficacy and environmental impact data to industry partners; cooperating with industry and state and federal regulatory agencies to register new products, including preparing and submitting provisional registration applications; developing recommendations based on economic thresholds for using new insecticides in a manner consistent with regional agronomic practices; evaluating activities of new insecticides against pests other than the rice water weevil as well as non-target species; and evaluating efficacy of products in commercial fields. These new insecticides are at least as effective as was Furadan; most are also used at lower rates and have reduced impact on non-target organisms compared to Furadan. In addition, costs of many of these new insecticides are comparable to Furadan. Thus, insecticidal management of the rice water weevil today is more cost-effective and less damaging to the environment than when Furadan was used.

The team has worked to insure that insecticides are used in a manner consistent with the principles of sustainable integrated pest management. This is illustrated by the team's ongoing efforts to revise the management programs for the rice water weevil, rice stink bug, chinch bug, aphids, thrips, grape colaspis, rice seed midges, armyworms and tadpole shrimp by re-evaluating thresholds for insecticide use, incorporating cultural controls and integrating reduced-risk insecticides into these programs. Members of the team have also been active in investigating effects of insecticides on non-target organisms and in evaluating the effects of agronomic practices such as fertilization, varietal selection, planting date, seeding rate, and water management on pest management. More recently, efforts have intensified to develop host plant resistance as a tactic against both rice water weevils and stem borers. These University-affiliacted entomologists have also played critical roles in identifying and responding to new arthropod and invertebrate threats that have emerged over the past decade. These emerging threats include the Mexican rice borer in Texas and Louisiana, the panicle rice mite in all states, and tadpole shrimp in Missouri and Arkansas. Team members have served as advisors to regulatory and rice industry agencies charged with dealing with invasive pests and have rapidly developed methods for scouting and managing them. Finally, these University-affiliated entomologists have served key educational roles in their states. All of the entomologists on the team give frequent talks to growers (on average, 15-20 per year), conduct training sessions for consultants and extension agents, write extension publications, and develop and contribute to on-line and smartphone-based extension material. Some of the team members have also been active in training the next generation of rice entomologists.

The accomplishments of this team were made possible by collaboration and communication among team members. For many years, team members met annually to share results and discuss new directions for research. Investigations by the team have been supported by several collaborative, multi-state USDA grants that have resulted in numerous joint papers. The efforts of the team have ensured the availability to U.S. rice producers of effective, affordable and safe methods for managing arthropod pests and have thereby significantly contributed to the profitability and sustainability of the U.S. rice industry.

Distinguished Service Award

Robert Fjellstrom

One sign of a truly effective researcher is increased productivity of those around them. This is the kind of scientist Dr. Robert (Bob) Fjellstrom is. Dr. Fjellstrom is a proactive dreamer. He did not just imagine a future in which molecular markers would be readily available and affordable enough for them to be used regularly for rice marketing, breeding, and research; but he spent the last decade dedicated to creating the infrastructure and knowledge base necessary for that dream to become a reality. Largely due to technological advances and knowledge created and communicated by Dr. Fjellstrom, use of molecular markers by the U.S. research community increased exponentially in the last decade, increasing the speed and efficiency at which new varieties and scientific advancement are accomplished.

Dr. Fjellstrom is known as one of the first at using genomic sequence data to develop markers of especially high value. To name a few, Dr. Fjellstrom developed markers that filled critical gaps in the first saturated rice SSR map, that identified functional portions of the starch synthesis genes linked to key end-use qualities, and that detected DNA differences among closely related U.S. elite as was necessary for the creation of the five RiceCAP mapping populations. The genes for blast resistance, cooking and eating quality, and aroma that were identified and molecularly-tagged by Dr. Fjellstrom have become important selection tools for rice varietal improvement programs. Use of these markers is making U.S. breeding programs more efficient and reducing the time needed to release improved varieties. Dr. Fjellstrom has also organized and presented at in several training workshops that educated breeders and their technicians in methods for collecting and using molecular data in a timely manner as required to truly support breeding decisions. Based on advice from Dr. Fjellstrom, all public U.S. rice breeding programs have now established their own DNA analysis laboratories.

Dr. Fjellstrom began his career as a Molecular Geneticist with the USDA-ARS Rice Research Unit in Beaumont, TX, in 1998 by establishing the first-ever molecular analysis laboratory located on a rice field research facility. Since that time, he has worked closely with rice researchers in breeding, genetics, pathology, physiology, and cereal chemistry to identify associations between gene sequence/marker variation and traits critical to the U.S. rice industry. In 2008, Dr. Fjellstrom assumed responsibility for the rice genomics program at the Dale Bumpers National Rice Research Center in Stuttgart, AR, and also continued to supervise research conducted in the Texas lab. The molecular genetics program at these two locations became the centerpiece for much of the research conducted at these centers. In addition to the research advances accomplished by Dr. Fjellstrom, he provides marker data on all entries into the Uniform Rice Nursery, making him an integral part of rice variety improvement in the U.S.

Genetic markers allow plant breeders to directly detect the presence of a desirable gene in plants so they can make selections with greater precision. Since the evaluation of some characteristics can be difficult or must be postponed until quantities of seed are not limiting, genetic markers can increase the efficiency of trait selection. Because it is difficult to combine numerous important traits simultaneously into cultivars, marker-assisted breeding can augment, as well as verify, traditional selection techniques. Thus, Dr. Fjellstrom's research and training efforts have significantly impact the U.S. rice industry in shortening the development and release of new cultivars with desirable traits, which is of vital importance for the rice industry to remain competitive in the global marketplace and continue sustainable rice production in the United States.

Distinguished Service Award

Jeffrey J. Oster

Mr. Jeffrey Oster has served the Rice Experiment Station in Biggs, California, for 33 years as a rice pathologist and has been an essential member of the rice breeding team in California. His hard work and dedicated service are an inspiration to those who have benefited from his scientific endeavors. He has been involved in disease screening of thousands of breeding lines yearly for blast, stem rot, aggregate sheath spot, and Bakanae and has contributed in the registration and release of 29 rice varieties developed by the California Cooperative Rice Research Foundation since 1982. He has been part of the team that developed a seed treatment recommendation to effectively control the spread of Bakanae disease, a rice disease that may cause 30 to 40% grain yield loss if not controlled. This method is routinely being used by California rice growers today. He initiated the development of near-isogenic lines of rice with blast resistance using M-206 as the genetic background. These lines are an essential germplasm resource for breeding durably resistant blast rice lines. Yield loss in California due to the blast disease is estimated at 10 to 20% in conducive years. His proactive research approach to control blast disease in California will help the growers in the years to come.

He took part in the development of 87Y550, a stem rot resistant long-grain line with resistance derived from *Oryza rufipogon.* 87Y550 is the progenitor of most of the stem rot resistant, high yielding rice lines currently under development at the Rice Experiment Station in California. Yield loss due to stem rot disease may be a high as 25% if not managed properly. He is involved in genetic studies and a backcross project to develop medium-grain lines with stem rot resistance. Breeding for stem rot resistance in rice is very difficult to do, especially in the medium grains. Recently, some medium grains resistant to stem rot were isolated because of his efforts. He also started working on the transfer of aggregate sheath spot resistance in M-206 and L-205 backgrounds. His efforts paved the way for breeders to incorporate resistance to these diseases in their respective breeding programs. With his long career as a rice pathologist and significant contributions to varietal development, Jeffrey Oster has been an inspiration to young rice researchers as well as to those who have had the priviledge of working with him for a long time.

Minutes of the 35th RTWG Meeting

Opening Executive Committee Meeting

In attendance: Chuck Wilson (Chair), Eric Webster (Secretary), Tim Walker (Immediate Past Chair), Anna McClung (USDA-ARS Administrative Advisor), Chris Greer for Zhonli Pan (California Rep.), John Russin (Experiment Station Administrative Advisor), Robert Scott (Arkansas Rep.), Frank Carey (Industry Rep.), Dustin Harrell (Louisiana Rep.), Jason Bond (Mississippi Rep.), Mike Salassi (Publication Coordinator), Lee Tarpley (Texas Rep.), Donn Beighley (Missouri Rep) and Steve Linscombe (Local Arrangements).

Chair Chuck Wilson called the meeting to order at 8:00 a.m. on February 18, 2014, at the Sheraton New Orleans in New Orleans, Louisiana.

Old Business

Chuck Wilson reported that the previous meeting was held at the Embassy Suites Hotel in Hot Springs, Arkansas. Mike Salassi discussed the cost of publishing the proceedings.

Chuck Wilson presented the minutes from the 34th RTWG in 2012. Tim Walker moved that the minutes be approved as printed and dispense with reading and Chris Greer seconded.

New Business

Award recipients for the 2014 meeting included Johnny Saichuk, Research and Education Award, and Jeffery J. Oster and Robert G. Fjellstrom, Distinguished Service Awards. The Team Award was presented to the Entomology Team. Members of that team included John Bernhardt, Gus Lorenz, Luis Espino, Larry Godfrey, Michael Stout, Jeff Gore, and M.O. Way.

Chuck Wilson asked for individuals that should be included in the necrology report.

Anna McClung presented Mark A. Bohning. Chuck Rush was presented by Steve Linscombe.

Eric Webster discussed the program and layout of the Conference Hotel. He also brought up tax exempt status and how the RTWG is set up. It is not a 503(C) non–profit status organization, so tax exempt status is not award to the RTWG multi-state project.

Lee Tarpley suggested new wording in the MOP for the necrology report. The new wording: "The RTWG necrology report honors our colleagues who passed away since the last RTWG meeting. These RTWG colleagues provided noteworthy service to the rice industry in areas of research, education, international agriculture, administration or industrial rice technology." Lee moved to accept the wording for the MOP and Tim Walker seconded. The measure was approved.

Lee Tarpley announced the 2016 meeting to be held in Galveston, TX, on March 1 to 4, 2016, at the Moody Gardens Resort.

Tim Walker discussed the RTWG Web-site and Steve Linscombe agreed that LSU would pay for the site for two years.

Tim Walker moved that the meeting be adjourned and was seconded by Bob Scott. Meeting was adjourned at 8:45 a.m.

Opening Business Meeting

Chairman Chuck Wilson called the meeting to order at 8:35 a.m. on February 19, 2014, at the Sheraton New Orleans in New Orleans, Louisiana.

Chairman Chuck Wilson asked attendees to recognize those colleagues who have passed away since the previous RTWG meeting.

Eric Webster was asked to read the minutes from the last RTWG meeting. Steve Linscombe moved to dispense with the reading of the minutes and Ronnie Levy seconded the motion. The motion was approved.

Fugen Dou, chair of the Nominations Committee, recommended the following individuals for leadership for the 36th RTWG:

Eric Webster – Chair
Lee Tarpley – Secretary
Chuck Wilson – Immediate Past Chair

Geographical Representatives
Gregory Berger – Arkansas
Bruce Linquist – California
Ronald Rice – Florida
Mike Stout – Louisiana
Jeff Gore – Mississippi
Donn Beighley – Missouri
Ted Wilson – Texas
Frank Carey – Industry

Nominations Committee
Charles Wilson, Jr. – Arkansas
Larry Godfrey – California
Ron Rice – Florida
Ida Wenefrida – Louisiana
Jason Bond – Mississippi
Donn Beighley – Missouri
Fugen Dou - Texas
Frank Carey – Industry

Steve Linscombe moved to accept the nominations and seconded by Paul Counce, motion passed.

Lee Tarpley announced that the 2016 RTWG meetings would be hosted by Galveston, Texas. The dates of the meeting would be March 1 to March 4, 2016.

Eric Webster announced the sponsors for each level - Cypress, Catahoula, Cocodrie, and Magnolia. Appreciation was also given to all those aiding in organizing the meeting.

Tim Walker moved that the business meeting be adjourned and seconded by Jason Bond.

Meeting was adjourned

Closing Executive Committee Meeting

In attendance: Chuck Wilson (Chair), Eric Webster (Secretary), Tim Walker (Immediate Past Chair), Anna McClung (USDA-ARS Administrative Representative), Joe Street (Extension Service Administrative Advisor), Chris Greer (California Rep.), Robert Scott (Arkansas Rep.), Mike Salassi (Publication Coordinator), Lee Tarpley (Texas Rep.), Jason Bond (Mississippi Rep.), Donn Beighley (Missouri Rep.) and Steve Linscombe (Local Arrangements).

Chairman Chuck Wilson called the meeting to order at 7:13 a.m. on March 1, 2012, at the Sheraton New Orleans in New Orleans, Louisiana.

Old Business

Steve Linscombe stated we had 396 attendees. Forty of the registrants were on-site.

The website costs were discussed. Steve Linscombe will handle payment for the next two years.

New Business

Eric Webster brought up the costs of the receptions and meals. Several options were discussed. Lee Tarpley said the 2016 had already contracted two meals for the meeting.

Anna McClung suggested a student contest. Eric Webster suggested to just have a poster contest the first year the contest was to be held. It was agreed that the Southern Weed Science Society Contest format would be used as a guideline. Jason Bond, Bob Scott, Eric Webster, Steve Linscombe and M.O. Way would serve on the contest committee. Jason Bond would be Chair.

There was discussion concerning placing presentations on the website, and it was decided not to do this due to needing permission from all presenters.

Tim Walker (Immediate Past Chair) announced he will be moving to the industry side from the university side of the RTWG. He was thanked for his service.

Tim Walker made a motion that the business meeting be adjourned and seconded by Lee Tarpley.

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

Closing Business Meeting

Chairman Charles Wilson, Jr. called the meeting to order at 8:30 a.m. on February 21, 2014, Sheraton New Orleans in New Orleans, Louisiana. He extended his gratitude to Louisiana for hosting the 35th RTWG and to Michael Salassi for his efforts at publishing the proceedings.

Mike Salassi, publication coordinator, gave a report on the preparation of the proceedings for 2014 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.

Johnny Saichuk, chair of the Rice Variety Acreage Committee, gave a report of the committee's meeting. It was reported that all states decreased rice acreage in 2012. Additional information was provided relating acreage changes and major rice varieties produced in each state.

A motion was made to accept the Variety by Acerage Committe report by Kent McKenzie and seconded by Chris Greer. The report was accepted.

Anna McClung presented the Rice Germplasm Committee report on behalf of Farman Jodari. Rice Germplasm Committee met on February 18, 2014. Farmin Jodari was re-elected as chair. The minutes from the previous meeting were presented and approved. Discussion revolved around USDA funding for Germplasm exploration in different countries. There was more discussion concerning the distribution of germplasm collections, over 200, to the U.S. research community. There have been recent introductions from diverse lines from IRRI from the genome sequencing project, and discussions occurred on how these introductions can be made available to U.S. research community.

A motion was made to accept the report by Kent McKenzie and seconded by Jarrod Harke. The report was accepted.

Eric Webster reported on behalf of Industry Representative, Dr. Frank Carey. The Rice Technical Working Group Industry Committee again held a successful luncheon at the 35th RTWG meetings in New Orleans, Louisiana, on Wednesday, February 19, 2014. The luncheon was attended by approximately 300 guests, with Mr. Bobby Hanks, Director of the Louisiana Rice, as the luncheon speaker addressing the challenges of providing a good quality rice grain meeting expectations from many different customers. The Industry Committee would like to thank Eric Webster and Steve Linscombe for their invaluable assistance in coordinating the luncheon.

A motion was made to accept the report by Chris Greer and seconded by Jason Bond. The report was accepted.

Charles Wilson, Jr. presented an executive committee report. There would be a poster competition for graduate students at the 2016 meeting and Jason Bond would serve as contest chairman. There was discussion concerning placing presentations on the website, and it was decided not to do this due to needing permission from all presenters.

He extended his gratitude to Louisiana for hosting the 35th RTWG and to Michael Salassi for his efforts at publishing the proceedings.

Chairman Charles Wilson, Jr. again thanked the RTWG for the opportunity to serve as Secretary and Chair. He thanked Eric Webster and Steve Linscombe for the successful 35th meeting. He then passed the gavel to Eric Webster, incoming Chair. He presented a plaque that illustrates the history of the RTWG leadership since 1950 to Eric Webster.

Eric Webster presented a plaque to Charles Wilson, Jr. in recognition of his service to the RTWG. Eric Webster thanked the faculty and staff of the LSU AgCenter Rice Research Station who were instrumental for making the 35th RTWG a success.

A motion was made to adjourn the 35th RTWG meeting by Kent McKenzie and seconded by Tim Walker.

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 2016 RTWG Executive Committee and Nominations Committee:

Executive Committee:

Eric Webster	Chair
Lee Tarpley	Secretary
Charles Wilson	Immediate Past Chair

Geographical Representatives:

Arkansas	Gregory Berger
California	Bruce Linquist
Florida	Ronald Rice
Louisiana	Mike Stout
Mississippi	Jeff Gore
Missouri	Donn Beighley
Texas	Ted Wilson
Industry	Frank Carey

Nominations Committee:

Texas	Fugen Dou, Chair
Arkansas	Charles Wilson
California	Larry Godfrey
Florida	Ronald Rice
Louisiana	Ida Wenefrida
Mississippi	Jason Bond
Missouri	Donn Beighley
Industry	Frank Carey

Submitted by
Fugen Dou, Chair

Rice Crop Germplasm Committee

The 34th meeting of the Rice Crop Germplasm Committee was held February 18, 2014, in New Orleans, LA. Members in attendance were Farman Jodari (Chair), Harold Bockelman, Georgia Eizenga, Tim Walker, Jim Oard, Jack Okamura, Anna McClung, Karen Moldenhauer, Xueyan Sha, Qiming Shao, and Rodante Tabien. Members participating via conference call were Peter Bretting, Gary Kinard, and Clarissa Maroon-Lango. Members not present were M.O. Way, James Correll, and Wengui Yan. Guests in attendance were Don Beighley, Ted Wilson, David Becker, Zongbu Yan, and Kent McKenzie.

The minutes of the 33rd Rice Crop Germplasm Committee held January 30, 2013, at LSU, Baton Rouge, LA, were read and approved by a motion from Karen Moldenhauer, seconded by Tim Walker, and supported by the other committee members.

Peter Bretting (USDA/ARS NPGS) reported on the status of the National Plant Germplasm System. Priorities are given to updating the assessment of crop vulnerability in each crop including rice. Narrowing of genetic base in crops is a concern and periodic assessment is needed. A template has been developed to use for crop vulnerability statements. Genotypic characterization data are being compiled using large number of SNP markers. The soybean germplasm collection at Urbana, IL, is using the genotyping and phenotyping information to define the genetic differences among soybean accessions. The fiscal year 2013 funding for USDA-ARS had a 7.8% reduction, which affected hiring of vacant positions. The 2014 budget has been proposed at 2.7% above 2012 level which was approved in January. USDA germplasm collections and demand for germplasm continues to grow. Collection and identification of crop wild relatives is being pursued. For rice, Arab-speaking countries, North Africa, and former Soviet countries offer best chance for getting additional germplasm.

Next on the agenda was the report by Gary Kinard and Ned Garvey from National Germplasm Resources Laboratory (NGRL). Gary reported that proposals are being accepted for 2015 plant exploration and exchange. Deadline for submissions is July 25, 2014. Proposals need to go through CGC's and curator for crop to get approval. Database management unit (DBMU) of the NGRL continues development of GRIN-Global. The unexpected loss of staff and retirements pose challenges to launching of this database, which is expected to be in 2014. NPGS personnel at Ames, IA, and Beltsville, MD, are leading this project.

Harold Bockelman (USDA/ARS NSGC) reported there were two new PI assignments for rice this year, for a total of 18,733 accessions. The NSGC rice core collection includes 1,794 accessions. In 2013, 1409 rice accessions were distributed. Jim Oard commented that IRRI through the BGI is currently re-sequencing 3,000 accessions. Discussion followed as to whether it would be useful to import these accessions. The consensus of the members was to select a subset and request seed from IRRI for introduction. Georgia Eizenga offered to obtain the list and to work with Clarrissa Maroon-Lango regarding the quarantine grow-out.

Georgia Eizenga commented that the SSR genotypes for the Rice Diversity Panel 1 (RPD1) were published as part of the J. Plant Registrations (2014) 8:109–116. RPD2 set is currently in quarantine process. In 2013, 1,333 lines from RDP2 were received from IRRI and seed has been harvested from 833 (April 2014) after the quarantine grow-out. Anna McClung reported that a *tropical japonica* core collection, consisting of 700 lines, is being assembled. This project is in the early stages. The objective is to capture the allelic variability in the *tropical japonica* pool.

Anna McClung (USDA-ARS, DBNRRC) provided an update on the status of Genetic Stocks-*Oryza* (GSOR) at the DBNRRC. There are 3,500 accessions in GSOR. New additions are 42 M-202 x Katy backcross lines with the blast gene, *Pi-ta*, in the M-202 background and the 14 Jefferson NILs with *O. rufipogon* incorporated into the Jefferson background. Also, the NSGC mini-core has been phenotyped for protein and stem rot. Disscussion followed on the need for archiving phenotypic information of U.S. germplasm collection as well as advanced breeding material within URRN. Expanding genomics information will require sufficient phenotypic data for future association mapping. Members discussed several sources of phenotypic data that can be accessed for this purpose, including the GRIN database, URRN agronomic data for the past 30 years, disease information from California, and historic weather data. Anna McClung commented that a new molecular geneticist, Jeremy Edwards, has been hired at the DBNRRC and will be starting in June 2014.

Clarissa Maroon-Lango (APHIS, PPQ) reported all rice core collection accessions from EMBRAPA, Brazil, have been processed through quarantine facility at Beltsville. There were 182 accessions from RDP2 also released from quarantine in 2013. Additional accessions from RDP2, as well as new IRRI Panel will be introduced in 2014. Members asked Clarissa the status of the proposed APHIS policy change for importation of rough rice from Argentina. Clarissa commented that there is no policy change at this time. However, a new round of PPQ notice will be announced for public comment in Argentina.

Jack Okamura (USDA-ARS, Office of National Programs) outlined the importance of the germplasm resources in the national picture. New staff changes at USDA leadership was discussed, as well as the emphasis of the administration in providing genetic resources database tools and support. The objective is to move molecular information to the field, similar to CAP projects, which is termed as translational work.

Members whose terms expire in 2014 were Farman Jodari and Xueyan Sha. Both members were nominated for another six-year term. The motion was made to accept the proposed nominations by Karen Moldenhauer, seconded by Tim Walker, and supported by all members.

The 4th International Rice Congress will be held in Bangkok, Thailand, on October 27-31, 2014.

The 35th Rice CGC meeting will be held in Houston, Texas, in 2016. Karen Moldenhauer made the motion to adjourn, Georgia Eizenga seconded the motion, and the motion was supported by all members.

Rice Crop Germplasm Committee members as of February 18, 2014, with year term ends in parentheses:

Dr. Farman Jodari, Chair (2020)
California fjodari@crrf.org

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

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

Dr. Timothy Walker (2018)
Mississippi twalker@horizonseed.com

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

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

Dr. Xueyan Sha (2020)
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

Dr. Gary Kinard, ex-officio
USDA-ARS Gary.Kinard@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
Farman Jodari

Publication Coordinator/Panel Chair Committee

Publication Coordinator Michael Salassi communicated by email with the panel chairs before the 2014 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 2016 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 3:30 p.m. on February 18 in the Nottaway Room at the Sheraton Hotel in New Orleans, Louisiana. Committee members for the 2014 RTWG included Chuck Wilson, Arkansas; Kent McKenzie, California; Johnny Saichuk, Louisiana; Tim Walker, Mississippi; Donn Beighley, Missouri; and Ted Wilson, Texas.

Minutes of the 2012 Acreage Committee meeting were distributed by Johnny Saichuk. It was reported that all states decreased rice acreage in 2012. Minutes of previous meeting were presented and approved. Arkansas reported 1.1 million acres of rice in 2013, down from 1.3 in 2012, with average yield of 7,560 lb/A. Arkansas is expected to grow 1.4 to 1.5 acres in 2014. Louisiana reported 395,000 acres in 2012 and increased acreage to 405,220 in 2013, with an average yield record of 7,514 lb/A. Majority of the acreage was planted to long-grain rice. Louisiana acreage is expected to increase 10 to 20,000 acres in 2014. California reported 562,000 acres in 2012 and 566,000 acres in 2013. Long grain and specialty rice accounted for less than 1% of the acreage. Three new varieties were released: A202 (an aromatic long-grain), Calhikari 202, and M105. Yield in 2013 was approximately 8,500 lb/A. Acreage for 2014 will hinge on availability of water. The range presented was between 350,000 and 550,000, with an emphasis on the lower end. Mississippi reported 126,000 acres had been grown in 2012 and dropped to 122,000 in 2013. Yield in 2013 was 7,400 lb/A. Mississippi planted 65% of the acreage in 2013 to Clearfield varieties and hybrids, with CLXL745, CL152, and CL111 leading the way. In 2014, rice acreage could be from 200,000 to 250,000. Missouri reported acreage in 2012 of 177,000 acres but declined to 150,000 in 2013. Clearfield varieties and hybrids occupied 60% of the 2013 acreage in Missouri. Yield for 2013 averaged 6,900 lb/A. Missouri acreage for 2014 is expected to be 190,000 and 200,000. In Texas, rice acreage in 2012 was 133,000 and increased to 143,000 acres in 2013. Yield in 2013 was a phenomenal 9,349 lb/A with 7,700 pounds in the first crop and 2,400 in the ratoon crop. Leading varieties grown in Texas in 2013 were Presidio, XL723, CLXL745, and XP753. Acreage in 2014 could increase by 10 to 15% to 164,000 if water supplies are available.

Submitted by
Johnny Saichuk

Industry Committee

The Rice Technical Working Group Industry Committee again held a very successful luncheon at the 35th RTWG meetings in New Orleans, Louisiana, on Wednesday, February 19, 2014. 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 2014 Industry luncheon met all of these goals. The luncheon was attended by approximately 300 guests who heard Mr. Bobby Hanks, Director of the Louisiana Rice Mill. He spoke of the challenges of providing a good quality rice grain meeting expectations from many different customers. The severity of the issue came to the forefront following the 2010 crop but was significantly better in 2013 due mostly to favorable weather. The wide diversity of varieties being grown currently leads to increased challenges for the millers and ultimately customers. 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 Eric Webster and Steve Linscombe for their invaluable assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 36th RTWG meetings in Texas in 2016.

Submitted by
Frank Carey

2012 ARKANSAS RICE ACREAGE[1] BY VARIETY SUMMARY

COUNTY/ PARISH	2011 ACREAGE	2012 ACREAGE	MEDIUM GRAIN			LONG GRAIN							
			Jupiter	CL261	Others[2]	CL111	CL151[3]	Rice Tec CL XL729	Rice Tec CL XL745[3]	Rice Tec XL723[3]	Roy J	Wells	Others[2]
Arkansas	90,106	88,891	1,113	6,154	527	1,420	4,969	6,566	30,522	14,995	7,010	2,307	13,309
Ashley	9,476	7,432	0	0	0	0	0	2,532	958	0	0	0	3,943
Chicot	26,981	26,443	0	0	0	2,138	1,425	5,806	10,239	158	2,481	0	4,196
Clay	59,946	77,474	599	6,243	0	2,042	17,356	5,290	25,803	10,488	0	6,404	3,249
Conway	1,237	1,715	0	0	0	0	893	0	0	0	0	415	406
Craighead	65,831	67,871	0	5,770	0	7,846	18,443	0	16,028	402	14,016	3,957	1,408
Crittenden	22,215	31,673	1,380	2,534	0	0	2,481	436	11,633	5,699	2,883	1,039	3,587
Cross	73,681	71,825	0	2,540	0	9,294	13,589	2,394	24,855	3,873	3,661	4,718	6,900
Desha	16,970	14,358	0	313	0	2,247	492	1,348	3,483	1,124	0	0	5,351
Drew	7,921	8,529	0	0	0	0	0	4,916	3,556	28	0	0	28
Faulkner	2,412	2,685	0	0	0	0	0	332	403	106	855	868	121
Greene	57,797	79,625	1,000	1,356	0	1,159	12,054	27,817	15,686	6,954	695	8,345	4,559
Independence	6,382	11,632	0	264	0	0	1,076	2,603	946	0	0	0	6,743
Jackson	68,905	76,208	1,606	12,282	44	219	10,136	9,553	19,543	5,250	11,959	1,386	4,230
Jefferson	57,199	59,832	0	647	0	0	0	3,018	23,852	25,627	0	0	6,688
Lafayette	2,011	2,676	0	0	0	107	642	268	803	0	187	0	669
Lawrence	91,045	96,131	5,371	9,166	0	9,009	11,569	6,757	30,611	2,150	3,890	5,119	12,490
Lee	11,570	18,372	0	90	0	0	1,409	0	8,546	0	2,086	0	6,240
Lincoln	19,372	18,441	0	0	0	0	0	2,748	9,202	2,508	2,950	1,033	0
Lonoke	77,783	77,697	624	2,933	0	393	2,984	12,330	35,970	6,047	3,848	550	12,016
Mississippi	24,888	34,093	91	400	0	0	7,071	0	1,818	9,528	0	14,040	1,145
Monroe	42,512	50,141	301	3,413	0	2,298	1,253	1,932	11,489	8,356	1,515	5,484	14,101
Phillips	18,345	16,140	0	47	0	0	0	5,681	8,144	0	0	0	2,269
Poinsett	98,692	106,696	1,076	21,165	0	1,462	25,078	10,346	14,057	3,261	9,784	10,233	10,233
Prairie	53,244	54,432	221	7,035	28	2,701	3,758	8,514	19,611	1,820	2,525	470	7,750
Pulaski	4,375	3,333	0	0	0	167	767	400	1,333	0	333	333	0
Randolph	30,608	34,028	0	6,710	0	1,310	10,875	4,291	2,719	7,370	753	0	0
St. Francis	32,413	30,283	0	2,979	0	2,513	6,155	0	169	791	4,179	2,993	10,503
White	9,142	12,348	0	405	0	251	549	3,305	5,727	1,122	0	0	990
Woodruff	44,196	53,219	637	1,274	0	3,396	6,367	12,044	12,999	3,449	2,653	5,677	4,722
Others[4]	5,929	6,370	0	0	0	338	571	633	1,485	458	400	312	2,172
Unaccounted[5]	21,818	44,407											44,407
2012 Total		**1,285,000**	**93,719**	**14,019**	**599**	**50,309**	**161,963**	**141,861**	**352,192**	**121,566**	**78,665**	**75,682**	**194,427**
2012 Percent		100.00%	7.29%	1.09%	0.05%	3.92%	12.60%	11.04%	27.41%	9.46%	6.12%	5.89%	15.13%

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

[2] - Other cultivars: AB647, Arize QM1003, Bengal, Catahoula, Cheniere, CL131, CL142-AR, CL152, CL161, Cocodrie, Cypress, Della, Dellrose, Francis, Jazzman, JES, Koshihikari, Neptune, Nortai, Presidio, RiceTec CL XL746, Spring, Taggart, and Templeton.

[3] – CL151 acreage numbers include CL152; RiceTec CL XL745 acreage includes RT CL XL751 and CL XL756; RiceTec XL723 acreage includes RiceTec XL753.

[4] - Other counties: Clark, Crawford, Franklin, Hot Spring, Johnson, Little River, Franklin, Miller, Perry, Pope, and Yell.

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

2013 ARKANSAS RICE ACREAGE[1] BY VARIETY SUMMARY

COUNTY/ PARISH	2012 Acreage	2013 Acreage	MEDIUM GRAIN		LONG GRAIN									
			Jupiter	Others[2]	CL111	CL151	CL152	RiceTec CL XL729	RiceTec CL XL745	RiceTec XL723	RiceTec XL753	Roy J	Wells	Others[2]
Arkansas	88,891	71,885	5,433	44	1,666	1,579	3,078	2,593	22,649	3,972	10,362	9,766	1,248	9,496
Ashley	7,432	4,533	0	0	257	0	391	931	1,085	0	1,245	242	0	382
Chicot	26,443	25,107	0	0	1,424	0	2,163	5,155	6,009	3	6,896	1,341	0	2,116
Clay	77,474	64,740	5,953	54	938	13,053	8,453	6,755	19,549	1,337	4,783	1,105	2,215	545
Conway	1,715	1,704	0	0	0	596	166	0	0	0	76	301	0	565
Craighead	67,871	57,987	4,765	1,776	7,109	14,956	5,952	0	7,857	2,014	825	9,094	2,468	1,172
Crittenden	31,673	21,568	2,038	1,346	0	658	591	1,452	5,213	1,780	1,395	4,125	749	2,223
Cross	71,825	65,315	4,673	0	10,420	8,486	2,967	2,769	13,737	1,932	1,604	12,428	2,225	4,075
Desha	14,358	9,605	229	0	0	0	4,188	202	4,231	0	0	756	0	0
Drew	8,529	7,116	0	0	403	0	613	1,461	1,703	1	1,955	380	0	600
Faulkner	2,685	1,815	0	0	0	0	201	0	470	0	0	969	0	174
Greene	79,625	62,804	2,945	107	0	11,895	6,358	0	21,093	1,594	7,941	5,709	797	4,364
Independence	11,632	7,764	201	0	0	234	0	2,335	389	0	3,670	934	0	0
Jackson	76,208	68,299	16,670	1,066	1,672	8,404	2,788	7,863	13,454	1,939	1,171	9,279	121	3,871
Jefferson	59,832	55,438	697	0	4,447	13,898	7,848	0	14,231	0	0	13,685	0	632
Lafayette	2,676	3,164	0	0	316	396	396	0	949	0	316	475	0	316
Lawrence	96,131	83,775	11,676	0	17,940	10,970	15,367	1,618	1,147	4,110	772	8,470	0	11,705
Lee	18,372	16,540	161	63	1,702	331	0	2,839	5,518	600	925	3,315	0	1,087
Lincoln	18,441	12,104	193	0	10	10	10	856	8,265	10	2,729	10	0	10
Lonoke	77,697	68,474	2,290	307	0	2,711	4,806	8,299	38,285	2,461	3,180	3,381	4	2,747
Mississippi	34,093	27,261	295	0	1,476	1,212	3,211	0	1,487	1,137	0	1,487	12,458	4,499
Monroe	50,141	37,199	1,921	108	0	606	857	943	1,457	497	960	13,528	2,451	13,872
Phillips	16,140	18,177	231	0	0	0	0	2,496	4,544	0	0	7,271	0	3,635
Poinsett	106,696	86,445	30,118	3,251	947	6,737	5,377	1,871	10,765	139	3,094	14,164	4,173	5,808
Prairie	54,432	54,202	5,433	86	5,892	0	2,955	6,425	15,682	2,165	6,623	3,049	0	5,892
Pulaski	3,333	3,371	0	0	0	169	236	438	1,888	135	169	236	0	101
Randolph	34,028	29,145	5,838	0	1,683	0	0	11,257	3,719	4,291	0	1,935	0	421
St. Francis	30,283	26,454	2,290	0	27	2,569	1,852	0	939	1,664	678	8,668	4,340	3,428
White	12,348	9,885	896	0	0	347	0	3,531	811	1,950	0	2,174	0	176
Woodruff	53,219	47,389	1,410	0	5,185	3,970	1,509	5,927	9,718	1,942	4,644	9,263	352	3,469
Others[3]	6,370	5,927	40	0	233	111	570	1,464	1,512	809	462	422	0	304
Unaccounted[4]	39,407	14,808												14,808
2013 Total		**1,070,000**	**106,396**	**8,207**	**63,749**	**103,897**	**82,903**	**79,479**	**238,356**	**36,484**	**66,474**	**147,961**	**33,601**	**98,762**
2013 Percent		100.00%	9.94%	0.77%	5.96%	9.71%	7.75%	7.43%	22.28%	3.41%	6.21%	13.83%	3.14%	9.58%

[1] - Harvested acreage. Source: USDA-NASS, 2014.
[2] - Other cultivars: Antonio, CL131, CL142-AR, CL161, CL261, Caffey, Cheniere, Cocodrie, Colorado, Della-2, Dellrose, Francis, Jazzman, Jazzman-2, Mermentau, Rex, RiceTec CL XP756, RiceTec CL XP4534, RiceTec XP4523, RiceTec XP754, and Taggart.
[3] - Other counties: Clark, Crawford, Franklin, Hot Spring, Little River, Miller, 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.
[5] - CL152 and RiceTec XL753 acreages for 2012 were included in CL151 and RiceTec XL723 acreage numbers, respectively.

2012 & 2013 CALIFORNIA RICE ACREAGE BY VARIETY SUMMARY

	2012			2013		
Variety	Seed Acres[1]	Percentage	Estimated Acres[2]	Seed Acres[1]	Percentage	Estimated Acres[2]
M-104	606	2.8%	13,443	526	2.4%	11,878
M-105	907	4.2%	20,114	1,485	6.9%	33,514
M-202	2,195	10.2%	48,671	2,113	9.7%	47,689
M-205	3,686	17.2%	81,751	3,532	16.3%	79,729
M-206	11,782	55.0%	261,286	11,340	52.3%	255,977
M-208	548	2.6%	12,150	909	4.2%	20,523
M-401	1,483	6.9%	32,894	1,590	7.3%	35,888
M-402	212	1.0%	4,690	180	0.8%	4,052
Medium Grain	21,419	100.0%	475,000	21,674	100.0%	489,250
S-102	376	29.7%	14,157	748	41.3%	15,799
Calhikari-201	168	13.3%	6,313	117	6.5%	2,475
Calhikari-202	50	4.0%	1,888	196	10.8%	4,135
Calmochi-101	670	53.0%	25,242	748	41.3%	15,791
Calamylow-201	0	0.0%	75	2	0.3%	160
Short Grain	1,263	100.0%	47,600	1,811	100.2%	38,250
L-206	123	41.3%	2,352	101	34.7%	1,980
A-201	94	31.7%	1,805	94	32.4%	1,847
A-301	46	15.6%	887	46	15.9%	908
Calmati-202	34	11.5%	656	49	16.9%	965
A-202	0	0.0%	0	4	0.0%	4
Long Grain	298	100.0%	5,700	291	100.0%	5,700
FSA CA Acres						
Medium		89.0%	500,000		91.0%	515,000
Short		10.0%	56,000		8.0%	45,000
Long		1.1%	6,000		1.1%	6,000
Total			**562,000**			**566,000**

[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 the medium and long grains and 85% of the short grain planted acres reported by NASS. The remaining percentage are planted to proprietary, Japanese short grains, or older CCRRF varieties not in seed production.

2012 & 2013 FLORIDA RICE ACREAGE BY VARIETY SUMMARY

Variety	2012 Acreage	2013 Acreage
Cheniere	1,296	2,998
CL111	--	15
Cocodrie	--	196
Cypress	8,679	2,119
Jupiter	777	618
Mermentau	--	196
Roy J	19	297
Taggart	384	2,517
Wells	4,284	7,727
Total Acres	**15,439**	**16,683**

2012 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2012	MEDIUM GRAIN		LONG GRAIN									Other
	Acreage	CL261	Jupiter	Cheniere	CL111	CL151	CL152	CL161	CLXL729	CLXL745	Cocodrie	Cypress	Varieties[1]
Acadia	78,261	695	2,992	8,677	24,343	28,756	1,4454	1,100	850	1,050	3,615	2,169	2,560
Allen	13,961	100	318	400	3,300	4,687	0	0	2,300	2,706	0	0	150
Avoyelles	11,730	200	500	2,370	700	5,010	140	0	0	0	675	0	2,135
Beauregard	1,253	0	0	110	0	219	0	0	0	554	300	0	70
Calcasieu	8,992	0	0	446	895	4,480	106	0	260	2,251	201	0	353
Caldwell	830	0	0	0	0	80	0	0	0	0	0	0	750
Cameron	15,402	0	0	1,350	2,617	6,187	0	0	1,563	2,606	450	0	629
Catahoula	1,406	0	0	0	0	804	402	0	0	0	0	0	200
Concordia	10,608	0	0	0	1,721	1,171	359	0	1,500	2,553	538	0	2,766
East Carroll	2,865	0	0	640	200	215	0	0	0	215	0	0	1,595
Evangeline	36,838	0	1,654	1,400	3,500	6,264	0	200	9,300	8,200	1,250	0	5,070
Franklin	77	0	0	0	0	0	0	0	0	77	0	0	0
Iberia	618	0	0	207	8	143	0	183	0	0	0	0	77
Jeff Davis	80,008	220	6,984	6,500	19,800	28,493	2,800	125	3,300	4,515	4,600	0	2,671
Lafayette	3,365	175	588	300	840	985	150	0	0	77	50	0	200
La Salle	23	0	0	0	0	0	0	0	0	0	0	0	23
Madison	5,500	0	0	626	742	0	379	0	0	0	3,061	165	527
Morehouse	21,286	0	2,017	150	3,270	5,500	0	0	350	7,600	0	0	2,399
Natchitoches	2,786	0	1,686	0	0	0	0	0	0	550	0	0	550
Ouachita	4,577	0	1,740	95	0	1,651	326	0	0	0	194	0	571
Pointe Coupee	1,956	0	0	0	110	1,346	0	0	0	500	0	0	0
Rapides	10,205	0	592	5,259	709	55	0	0	0	0	0	0	3,590
Red River	417	0	0	0	0	0	0	0	0	0	0	0	417
Richland	4,510	0	0	0	0	671	165	0	0	2,280	0	0	1,394
St. Landry	23,661	0	83	6,090	6,130	4,680	1,165	2,989	224	224	1,011	169	896
St. Martin	3,075	0	0	518	0	315	0	220	100	364	325	152	1,081
St. Mary	226	0	0	0	0	0	0	0	0	0	0	0	226
Tensas	1,275	0	0	0	0	0	0	0	0	40	110	0	1,125
Vermilion	46,691	531	431	6,703	13,200	14,677	418	1,210	2,605	580	2,936	585	2,815
West Baton Rouge	73	0	0	0	0	0	0	0	0	0	0	0	73
West Carroll	2,450	0	0	0	0	70	0	0	290	2,090	0	0	0
2012 Total	**394,925**	**1,921**	**19,585**	**41,841**	**82,085**	**116,459**	**7,864**	**6,027**	**22,642**	**39,032**	**19,316**	**3,240**	**34,913**
2012 Percent	100	0.49	4.96	10.59	20.78	29.49	1.99	1.53	5.73	9.88	4.89	0.82	8.84

[1]Other varieties include Caffey, Catahoula, CL131, CL162, Jazzman, Jazzman 2, Milagro, Mermentau, Neptune, Sabine, XL723, XP744, XP753, and XP754.

2013 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2013	MED GRAIN	LONG GRAIN									SPC PRPS	Other
	Acreage	Jupiter	Catahoula	Cheniere	CL111	CL151	CL152	CLXL729	CLXL745	Cocodrie	Mermentau	Jazzman 2	Varieties[1]
Acadia	82,310	2,510	490	9,831	22,939	1,948	2,948	5,737	9,675	3,584	4,475	13,420	4,753
Allen	14,349	0	0	300	1,724	0	0	3,048	5,240	0	275	2,339	1,423
Avoyelles	11,911	0	0	5,251	2,261	0	215	0	0	2,914	518	0	752
Beauregard	1,120	0	0	0	0	0	0	61	671	304	0	0	84
Calcasieu	13,111	30	0	496	4,181	1,545	0	450	2,791	368	186	1,496	1,568
Caldwell	600	0	0	600	0	0	0	0	0	0	0	0	0
Cameron	11,329	0	0	0	4,944	0	0	1,147	1,789	278	0	840	2,331
Catahoula	886	0	0	0	0	0	0	0	0	0	0	0	886
Concordia	7,008	0	0	0	605	463	0	1,100	1,990	0	0	0	2,850
East Carroll	3,012	0	0	402	0	0	512	0	485	1,038	0	395	180
Evangeline	44,669	1,797	0	2,800	11,800	4,750	250	10,875	3,625	2,400	500	0	5,872
Franklin	573	0	0	128	0	0	0	0	0	0	0	445	0
Iberia	701	0	0	146	143	118	133	0	0	0	0	0	161
Jeff Davis	79,981	5,400	200	9,146	18,142	0	210	8,698	14,950	1,500	5,248	12,372	4,115
Lafayette	786	310	0	0	155	0	0	0	120	0	83	118	0
La Salle	81	81	0	0	0	0	0	0	0	0	0	0	0
Madison	5,812	0	1,475	2,200	0	187	414	0	0	300	1,236	0	0
Morehouse	20,681	3,600	0	395	2,000	2,100	0	0	12,130	0	0	0	456
Natchitoches	2,787	1,658	0	0	0	0	0	0	0	0	0	0	1,129
Ouachita	6,509	1,126	0	2,032	1,206	0	1,454	0	0	0	144	0	547
Pointe Coupee	1,590	0	0	0	0	568	0	0	454	0	0	0	568
Rapides	7,200	0	0	3,505	1,715	0	0	0	0	0	1,165	0	815
Red River	430	0	0	0	0	0	0	0	0	0	0	0	430
Richland	4,406	0	0	150	0	0	700	0	1,262	0	0	1,109	1,185
St. Landry	25,441	1,069	1,323	3,188	8,126	1,392	2,615	616	1,628	488	814	249	3,933
St. Martin	3,231	0	0	482	616	0	0	191	250	0	0	108	1,584
St. Mary	143	0	0	143	0	0	0	0	0	0	0	0	0
Tensas	1,960	0	0	160	0	0	0	0	285	0	0	0	1,515
Vermilion	50,789	0	0	8,101	27,885	2,486	4,387	550	37	1,811	1,237	132	4,163
West Baton Rouge	328	0	0	0	0	0	0	0	0	0	0	0	328
West Carroll	1,486	0	0	0	0	0	0	0	0	0	0	0	669
2013 Total	**405,220**	**17,581**	**3,488**	**49,456**	**108,442**	**15,557**	**13,838**	**32,473**	**58,199**	**14,985**	**15,881**	**33,023**	**42,297**
2013 Percent	100	4.34	0.86	12.20	26.76	3.84	3.41	8.01	14.36	3.70	3.92	8.15	10.44

[1]Other varieties include Caffey, CL131, CL161, CL261, Cypress, Hildalgo, Jazzman, Milagro, Neptune, Sabine, Wells, XL723, and XP753.

2012 & 2013 MISSISSIPPI RICE ACREAGE BY VARIETY SUMMARY

County	2012 Acreage	2013 Acreage		Variety	2012 Acreage	2013 Acreage
Adams	192	0		CL111	13,908	13,245
Bolivar	34,956	33,734		CL151	13,908	12,141
Coahoma	8,797	8,109		CL152	--	18,151
De Soto	553	1,190		CLXL729	13,908	2,453
Grenada	282	282		CLXL745	40,461	23,424
Holmes	141	121		CLXP4534	--	9,811
Humphreys	1,955	1,475		CLXP756	--	1,226
Issaquena	890	1,115				
Lee	10	3		Cheniere	--	1,349
Leflore	5,328	3,905		Cocodrie	13,908	8,830
Panola	5,901	5,523		Hidalgo	--	--
Quitman	8,440	8,766		Rex	7,586	18,274
Sharkey	306	433		Sabine	3,793	3,540
Sunflower	14,253	13,635		Wells	--	--
Tallahatchie	6,460	6,964		XL723	10,115	4,906
Tate	828	934		XL753	7,586	4,783
Tunica	21,696	24,603		XP744	--	--
Washington	14,687	11,480				
Yazoo	765	0				
Total Acres	**126,440**	**122,272**				

2012 TEXAS RICE ACREAGE BY VARIETY SUMMARY

County	2012 Rice Acreage	Long Grain										
		Presidio	CL151	Cheniere	CLXL729	CLXL745	XL753	XL723	CL152	Catahoula	Dixiebelle	Other
East Zone												
Brazoria	15,326	15,326	--	--	--	--	--	--	--	--	--	--
Chambers	17,069	887	4,263	4,195	1,450	4,348	--	--	324	461	--	1,143
Galveston	1,506	--	--	1,506	--	--	--	--	--	--	--	--
Hardin	262	--	--	--	--	--	--	--	--	--	--	262
Jefferson	16,917	--	1,707	--	6,422	--	--	--	3,887	--	--	4,901
Liberty	5,652	--	1,006	--	678	509	2,651	--	--	--	--	808
Orange	--	--	--	--	--	--	--	--	--	--	--	--
East Total	**56,732**	**16,279**	**7,010**	**5,728**	**8,592**	**4,881**	**2,662**	**--**	**4,232**	**463**	**--**	**6,886**
Northwest Zone												
Austin	1,182	892	--	--	--	--	--	290	--	--	--	--
Colorado	18,992	1,367	2,488	1,519	589	1,728	4,615	3,342	--	133	95	3,115
Fort Bend	4,807	1,246	--	525	--	260	264	389	--	--	1,512	611
Harris	--	--	--	--	--	--	--	--	--	--	--	--
Lavaca	1,649	228	350	206	--	--	411	--	--	455	--	--
Robertson	--	--	--	--	--	--	--	--	--	--	--	--
Waller	5,141	--	--	--	41	1,028	1,743	2,247	--	--	--	82
Wharton	27,307	7,025	4,838	2,050	1,558	2,461	191	711	328	1,312	547	6,286
Lamar	204	--	--	--	--	--	--	--	--	--	--	204
NW Total	**59,282**	**10,793**	**7,702**	**4,315**	**2,195**	**5,496**	**7,253**	**7,006**	**329**	**1,907**	**2,160**	**10,128**
Southwest Zone												
Calhoun	1,916	834	--	--	--	--	--	433	--	650	--	--
Jackson	10,524	6,261	337	1,400	674	495	--	--	--	547	810	--
Matagorda	1,562	--	--	--	--	--	--	--	--	--	360	1,203
Victoria	2,027	2,027	--	--	--	--	--	--	--	--	--	--
Cameron	--	--	--	--	--	--	--	--	--	--	--	--
SW Total	**16,030**	**9,124**	**337**	**1,400**	**674**	**495**	**--**	**433**	**--**	**1,197**	**1,170**	**1,203**
Northeast Zone												
Bowie	547	--	--	284	--	--	--	--	--	--	--	263
Hopkins	231	--	--	--	--	--	--	--	--	--	--	--
Red River	--	--	--	--	--	--	--	--	--	--	--	--
NE Total	**778**	**--**	**--**	**404**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**263**
State Total	**132,822**	**36,1496**	**15,049**	**11,847**	**11,461**	**10,872**	**9,915**	**7,439**	**4,561**	**3,567**	**3,330**	**16,987**

2013 TEXAS RICE ACREAGE BY VARIETY SUMMARY

County	2013 Rice Acreage	Long Grain										
		Presidio	XL723	CLXL745	XL753	CL152	Cheniere	Risotto	CL151	Catahoula	CLXL729	Other
East Zone												
Brazoria	17,763	2,895	--	--	--	3,126	2,629	9,133	--	--	--	--
Chambers	18,869	--	--	3,887	7,019	3,208	642	--	3,849	--	--	264
Galveston	2,255	--	--	--	--	--	2,255	--	--	--	--	--
Hardin	263	--	--	--	--	--	--	--	--	--	--	--
Jefferson	18,820	3,275	--	12,835	--	1,204	--	--	--	--	--	1,506
Liberty	5,312	--	--	1,333	2,715	--	--	--	1,264	--	--	--
Orange	--	--	--	--	--	--	--	--	--	--	--	--
East Total	**63,282**	**6,196**	**--**	**18,131**	**9,775**	**7,569**	**5,548**	**9,150**	**5,135**	**--**	**--**	**1,777**
Northwest Zone												
Austin	2,159	790	1,036	--	--	--	332	--	--	--	--	--
Colorado	22,554	1,534	9,067	2,278	6,879	1,195	158	--	338	--	925	181
Fort Bend	5,061	1,244	1,457	86	197	677	177	--	278	--	--	946
Harris	--	--	--	--	--	--	--	--	--	--	--	--
Lavaca	1,856	412	241	--	--	304	--	--	--	727	--	171
Robertson	192	192	--	--	--	--	--	--	--	--	--	--
Waller	3,950	--	3,302	95	553	--	--	--	--	--	--	--
Wharton	27,372	5,940	7,609	1,396	1,998	2,244	3,011	--	1,506	1,150	1,013	1,506
Lamar	130	--	--	--	--	--	--	--	--	--	--	--
NW Total	**63,082**	**10,102**	**22,690**	**3,851**	**9,618**	**4,417**	**3,674**	**--**	**2,120**	**1,873**	**1,936**	**2,802**
Southwest Zone												
Calhoun	2,306	2,306	--	--	--	--	--	--	--	--	--	--
Jackson	10,601	5,279	1,770	763	382	--	1,145	--	--	--	--	1,261
Matagorda	1,566	583	204	--	--	--	110	--	--	407	--	262
Victoria	2,041	2,041	--	--	--	--	--	--	--	--	--	--
Cameron	--	--	--	--	--	--	--	--	--	--	--	--
SW Total	**16,514**	**10,210**	**1,974**	**763**	**382**	**--**	**1,254**	**--**	**--**	**407**	**--**	**1,523**
Northeast Zone												
Bowie	--	--	--	--	--	--	--	--	--	--	--	--
Hopkins	217	--	--	--	--	--	--	--	--	--	--	--
Red River	--	--	--	--	--	--	--	--	--	--	--	--
NE Total	**217**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
State Total	**143,095**	**26,508**	**24,664**	**22,745**	**19,775**	**11,986**	**10,476**	**9,150**	**7,255**	**2,280**	**1,936**	**6,102**

RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

J.H. OARD, Chair; RODANTE TABIEN, Chair - Elect (2016); G. BERGER, N. CHOU, G. EIZENGA, K. JOHNSON, K. MOLDENHAUER, J. OKAMURO, S. PINSON, B. SCHEFFLER, and X. SHA, 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 including chalk, head rice recovery, and physio-chemical characteristics required by multiple industry users. 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 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, STS, 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 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 interest from growers, processers, and researchers. Current research is focused on development of 2- and 3-line male sterile germplasm adapted to the southern U.S. and elucidating genetic control of male

sterility/fertility, outcrossing characteristics, general combining ability (GCA), and specific 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. Hybrid rice breeding consortia also provide members with access to improved germplasm and cooperative research focusing specifically on hybrid rice breeding and development. The achievements from genomic research should improve (1) breeding efficiency for hybrid rice cultivars using molecular markers to assist selections of improved male sterile and restoring lines, (2) elite outcrossing characteristics for effective production of male sterile lines and hybrid seeds, (3) GCA as well as SCA for maximum heterosis (4) determining purity of sterile and restorer lines and (5) tagging of genes associated with 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. Separate testing methods for hybrids and inbreds need to be developed to understand the yield potential under nitrogen practices which maximize production and reduce input costs.

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 or other appropriate databases.

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. N-Star utilization should be encouraged so growers can maximize yields with appropriate inputs and help ensure loss of inputs that will not cause run-off issues.

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. Standardization of chalk methods should be worked on with researchers from around the globe to ensure selection and validation is consistent with industry standards and measurements that utilize similar methodologies. 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. Molecular data base information associated with these traits should be made available to public and private rice researchers. 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. With 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

M. SALASSI, Chair; G. KNAPEK, Chair-Elect (2016); E. CHAVEZ, N. CHILDS, M. DELIBERTO, L. FALCONER, J. KEPIRO, G. KNAPEK, S. MAZURKIEWICZ, J. OUTLAW, J. RAULSTON, H. SHARIFI, F. SHORE, T. TAKAHASHI, E. WAILES, B. WATKINS, R. WOOD, and E. YOUNG, 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

M. STOUT, Chair; S. ZHOU, Chair-Elect (2016); M. EDWARDS, C. GREER, D. GROTH, and Y. WAMISHE, 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* (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.; and thrips (various species). 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

J. KING, Chair; MING HSUAN CHEN, Chair-Elect (2016); R. BRYANT, A. BILLIRIS, P. COUNCE, A. SHEFLIN, J. MCCLUNG, A. ROLFE, Y. YANG, T. MCKAY, A. FRANK, S. BOUE, C. GRIMM, K. BETT-GARBER, J. BEAULIEU, P. BECHTEL, B. ADAM, J. CAMPBELL, R. KAHIR, 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, storage, and insect management 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).

Develop methods for modification of rice starch, bran and protein to enhance functionality.

Identify applications for rice components (i.e. starch, protein, bran) 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

D. HARRELL, Chair; F. DOU, Chair-Elect (2016); T. WALKER, L. ATWILL; P. FITTS; D. FRIZZELL, N. SLATON, R. DELONG, B. LINQUIST, L. TARPLEY, R. ROJAS, M. KONGCHUM, C. GREUB, T. ROBERTS, M. REBA, J. HARDKE; 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

E. WEBSTER, Chair; M. BAGAVATHIANNAN, Chair-Elect (2016); D. JOHNSON, M. OOSTLANDER, J. FISH, G. MONTGOMERY, B. SCHRAGE, J. NORSWORTHY, C. MEYER, H. YE, B. MCKNIGHT, J. BOND, J. HARDEN, R. SCOTT, C. SANDOSKI, J. BRAZZLE, 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.

Abstracts of Papers from the Hybrid Rice Symposium
Symposium Moderator: James Oard

Hybrid Rice Production in Asia

Chu, Q.R.

Asia has planted 145.4 MM ha of rice which occupies 92% of total world rice area and output of 465 MM tons milled rice. Hybrid rice technology originated from China in 1966 by Yuan LP which has the potential of yield increase to15-30% relative to varieties. Today, half of all rice area in China is hybrid rice 13.5 MM ha, resulting in improved food security for 60 million people per year. Technology also disseminated to Asian countries via joint effort of China and IRRI since 1980. Germplasm development, international training, hybrid rice symposium, and consortium have facilitated regional gradual increase of hybrid rice production of 7.5 MM ha in 2013, including India 3.5 MM ha, Bangladesh 1.1 MM ha, Indonesian 0.9 MM ha, and Vietnam 0.6 MM ha. The low rate of hybrid adoption compared to China is largely due to less yield heterosis, poor grain quality, high seed production cost, quality seeds supply, and consumers' preferences. Therefore, establishment of research, production, and marketing of integrated strategy become important. Research efforts mainly focused on increasing grain yield heterosis of 3-line and 2-line hybrids; improving milling and cooking quality; breeding biotic (disease and insect, weed) resistance and non-biotic stress (cold, heat, drought) tolerance; and increasing seed production yield. Molecular breeding, marker-assisted selection, SNIP and next-generation sequencing become valuable tools for monitoring elite traits to product portfolio. GMO traits, including insect resistance (Bt) and golden rice (vitamin A), have put into hybrid rice platform and waiting green light to market. Production of hybrid seeds via increasing seed yield and reducing cost is successful factor for sustainable product delivery. Mechanization of seed production, including direct seeding, drill planting, helicopter pollen synchronization, seed harvesting, processing, storage, and packaging, are cyclic events to provide quality products for seed producers. Marketing of hybrid seeds to farmers become challenging with seed pricing, branding, Intellectual Property Protection, and category positioning. With current seed cost $50 per ha in India and $100 per ha in China, market value accounts for $1.74 Billion in Asia. Rapid increase of hybrid rice acreage up to 25% is expected by 2015 and $4 billion market value is estimated when hybrid adoption at 50% like China. Structure change of rice seed industry is underway. Public sectors focus on innovation of principles and mechanisms of enhancing heterosis and improvement germplasm. Private sectors such as LPHT in China and Bayer, Pioneer, and Syngenta in India become main market pushers.

U.S. Commercial Rice Hybrids

Ottis, B.

RiceTec, Inc. first introduced hybrid rice in the United States in 2001 with the commercial launch of XL6. XL6 proved to the rice farming community that hybrid rice may be a viable option for the US rice farmer and that significant yield advantages could be realized with this new technology. XL6 also provided a learning experience in that although high yields could be achieved, improvements in agronomics and milling were needed in order for hybrid rice to be accepted as a mainstream option for US rice farmers. Following XL6 were the releases of XL7 and XL8, and eventually Clearfield XL8 in 2004. In 2005, XL723 and Clearfield XL730 were released, which became widely accepted by rice farmers. Additionally, XL723 and Clearfield XL730 had improved grain quality over previous hybrids, resulting in widespread acceptance by millers and processors. Hybrid rice possesses tolerance to significant diseases of rice, namely blast and bacterial panicle blight. Additionally, research has shown that a rice hybrid has improved nitrogen uptake efficiency over popular pureline varieties. Recent findings suggest that hybrid rice may have a smaller carbon footprint in the field than other rice lines. With the combination of higher yields, improved nitrogen uptake efficiency and a reduced need for fungicide for certain diseases, hybrid rice has a significant opportunity to reduce the carbon footprint of rice production. As of today, hybrid rice has gained a share of the southern long grain market greater than 45%. Additional share gains are expected with the addition of medium grain hybrids, niche quality hybrids, and new proprietary herbicide tolerant offerings.

Economics of U.S. Hybrid Rice Production

Salassi, M.E.

In evaluating the relative economics of hybrid rice varieties produced in the United States, several factors must be considered, all of which have a direct impact on the eventual net returns received from the production and sale of the rice crop. On the revenue side, most of the attention has been focused on the differences in rough rice yield, where in many cases the hybrid varieties have shown a distinct advantage in many rice variety trials. Expected actual rough rice yield differences between hybrids and conventional and Clearfield non-hybrids under large field commercial production situations is the relevant factor to evaluate with respect to harvest yield differences. In addition, any differences in rough rice milling yield must also be included in the evaluation, as rough rice milling yield directly affects the eventual market price received for the rice being sold. Head rice yield is the most important factor in determining the market price of a specific lot of rice, with rice samples having higher head rice milling yields receiving a higher rough rice market price compared to rice samples with lower head rice yield. On the cost side, production cost differences between hybrids and non-hybrids can result from differences in seed cost, nitrogen cost, and drying and hauling charges. Differences in seed cost will be the most significant, with hybrid seed commanding much higher prices on a cost per planted acre basis. In addition, for rice produced on leased acreage, the specific crop land rental arrangement under which the rice is produced, and specifically what expenses the landlord is sharing, can also impact comparative net returns from hybrid rice production.

Quality Issues of U.S. Rice

Morgan, J.

U.S. rice exporters have seen an increased demand recently for quality rice. We are seeing a higher demand for quality rice from our customers and have to strike a balance between a farmer's goal for higher field yields and the market's desire for higher quality rice. A variety has to perform well for the farmer or the farmer will not grow it, and rice has to meet the standards of our markets or the buyers will not buy it. Consistent quality should be a goal for all in the rice industry because quality grain creates stability in the markets. The quality of the final milled rice product directly influences the price differentials observed at the farm level sale. Now the issue of quality is being discussed actively by researchers, breeders, millers, and specialists. This main reason for discussion is that the quality of newer varieties is generally less consistent than older varieties such as Cypress. Major issues for improvement include chalk, uniform grain size, milling yield, and cooking quality. The focus of rice variety development research should be towards developing specific rice varieties suitable of meeting rice quality factors from buyers in the various export markets supplied by U.S. rice production.

U.S. Public Hybrid Rice Breeding

Berger, G.L.

Hybrid rice cultivars have been grown commercially in China for over 30 years, where they have fostered advances in research and development. During this period, hybrid research and development has focused on both 2- and 3-line hybrid rice cultivars depending on the region and type of rice grown. Additionally, international research centers such as the International Rice Research Institute (IRRI) have led the way in hybrid rice research and development. The knowledge gained from these efforts has and will continue to greatly aid U.S. hybrid rice development.

While China has an established hybrid rice community, the U.S. is a relatively new arena. Prior to the mid-2000s, the majority of rice acreage in the U.S. was planted to publically-released inbred cultivars. The U.S. rice farming industry has only adopted hybrids over the past decade. Total acres planted to hybrids vary by state and region within states. During the past decade RiceTec, Inc. has been the only source of commercially available hybrid rice seed in the U.S. Additional sources of hybrid rice seed would greatly benefit both farmers and industry.

Public efforts focusing on hybrid rice development is a relatively new trend that has emerged over the past five years. In 2010, a five-state U.S. hybrid rice development consortium (HRDC) was founded. Members of the consortium include Arkansas, Louisiana, Texas, Mississippi and Missouri, all of which have previously established rice breeding programs. The goal of the HRDC is cooperative hybrid rice research and development. Currently, of the five founding members, only Arkansas and Louisiana have active hybrid rice breeding programs. While these programs are breeding for different environments, joint efforts are aimed at furthering hybrid rice research and eventual release of public hybrid rice cultivars.

Both Arkansas and Louisiana have tested experimental 2- and 3- line hybrids in local and regional nurseries over the past three years. Joint research between these two institutions is currently ongoing. The goal of public hybrid rice development is to provide producers and industry with high quality hybrids that will meet market demands.

Commercial Hybrid Rice Production in the Southern United States

Walker, T.W.

RiceTec, Inc., headquartered in Alvin, TX, sold the first F_1 hybrid seed for commercial production in 1999. In 2013, surveys conducted by rice research/extension personnel in Arkansas, Louisiana, Mississippi, Missouri, and Texas coupled with USDA Farm Service Agency certified acreage reports indicated that approximately 274,720 hectares (680,000 acres) of hybrid rice were planted in the southern USA. This represented approximately 38% of the total long grain acres that were planted. On a percentage basis, hybrids were most popular in Texas with 48% and least popular in Louisiana with 30%. Each of the other states planted approximately 40% of the area to hybrids. Clearfield hybrids are the most popular as growers can achieve the potentially high yields and control red rice concomitantly. Based on these facts, it is apparent that hybrid rice development and the resulting increased adoption have matured to a point where open discussion of the benefits and obstacles can be held. The objective of this paper is to provide a land grant research and extension service perspective on current production of hybrid rice in the southern USA. Specifically, the benefits of 1) greater, and typically more stable, yields, especially in stressful environments, and 2) decreased fertilizer and fungicide recommendations will be provided. Furthermore, challenges such as producing uniform and a sufficient supply for seed, decreased grain quality, and the presence of pubescence and its impact on grain handling personnel and equipment will be presented. Finally, an assessment of the real impact on yield improvement will be attempted.

Abstracts of Papers from the Blast Symposium
Moderator: Jim Correll

Novel Strategies for Managing Blast Diseases on Rice and Wheat

Valent, B.

Blast diseases on rice and wheat are caused by closely-related, but distinct, populations of the fungus *Magnaporthe oryzae*. The ancient rice blast disease is a major constraint to global rice production. The recently emerged wheat blast disease causes yield failures and significant economic losses during epidemic years in South America, but it has not yet occurred in the U.S. For wheat blast, resistance genes are generally lacking and fungicide treatments are unreliable. Blast research over the past 20 years has identified >80 rice resistance genes and provided understanding of the molecular basis for resistance in rice and mechanisms of pathogenesis in the fungus. An interdisciplinary team of research and extension specialists from diverse universities and institutions in the U.S. and South America has come together in an USDA NIFA Integrated Project to leverage this knowledge to improve U.S. rice production and protect the nation's wheat crop. Specific objectives include enhancing resistance in elite U.S. rice varieties through understanding of current pathogen populations and rapid deployment of resistance genes using cisgenic strategies. We are testing host-induced gene silencing for controlling rice blast. We are identifying natural blast resistance in wheat, and we are testing if cloned rice resistance genes function to control blast in wheat. We are developing diagnostics for detection of wheat blast if it occurs in the U.S., and we plan to enhance wheat blast control through understanding of wheat blast genetics, pathology, ecology and epidemiology in South America. Prediction models are being developed for rice and wheat blast for use in regions where these diseases currently occur. Consumer attitudes towards and economics of cisgenic rice and forecasting models are being assessed to guide adoption of new technologies. Results of this research will be disseminated through educational resources and programs for stakeholders. Special training opportunities are planned to attract a new generation of plant pathologists to work on plant biosecurity. These efforts will produce deliverables with immediate impacts on blast control and will generate new knowledge and trained personnel essential for current and future disease management. This project is supported by the USDA NIFA Agriculture and Food Research Initiative Competitive Grant #2013-68004-20378.

Update on Blast in Louisiana and More, 2013

Groth, D.E.

Management of blast is a numbers game based on the number of initial infections, susceptibility, and popularity of a variety. The key two players in this game are the number of spores challenging the rice plant and the effectiveness of the fungicide being used to protect the plant. The earlier and higher the initial infection levels result in more blast infections. The more susceptible a plant is the more lesions it has, and the more spores it produces. Also, as the popularity of a variety increases, the acreage increases, and the number of compatible spores in the area increases. The time period between initial infection to new spore production can be as little as five to seven days, allowing for rapid buildup of disease. As spore numbers increase, the probability of an infection increases because more spores have a greater chance to land on a susceptible plant.

The race of the fungus also plays a part because an incompatible spore will not cause an infection on a resistant rice plant. Of course, if the environment is favorable (i.e. the field is drained), more disease is possible. If the environment is unfavorable (i.e. very dry or very hot), the epidemic will not develop no matter how favorable the host pathogen relationship is. In the crop's favor, lesion production decreases as tissues mature, becoming resistant to infection. If a susceptible host is planted, a compatible blast race infects the crop early, and if the environment is favorable, an epidemic will develop very rapidly and can destroy a crop.

No blast fungicide is 100% effective. Fungicide efficacy is controlled by how active the fungicide is against the pathogen, timing of the fungicide, and coverage. Rice fungicides range from no blast activity to being very active against the blast fungus. It is very important to know that most rice fungicides have no curative activity against blast. This means that they are preventative and must be applied before infection to have activity. Once an infection occurs, it cannot be eliminated by a fungicide application. Fungicide timing, therefore, is critical to blast control because we are trying to protect the emerging head from neck and panicle infections. Applying a fungicide before head emergence provides little if any protection, and applying after emergence allows infections to occur. Rice heads become resistant to infection and potential damage decreases as they age. Therefore, applications after heading are unnecessary. Unfortunately, fungicide applications do not cover all of the head tissues allowing some infections. Poor fungicide distribution, wind, rain, uniformity of heading, and canopy thickness reduce fungicide coverage.

The fewer potential blast infections, the higher the probability a blast fungicide can control blast. This is the reason two fungicide applications are normally recommended for blast control. The first application, applied between boot and very early heading, has the main effect of reducing the number of blast spores being produced and reducing the probability of infection. The second application, applied between 50 and 90% heading, also reduces spore production but primarily protects the head from infection. Obviously, because fungicide applications are not 100% effective, the fewer spores landing on the rice heads, the fewer infections. An example would be if a rice head was challenged with 10 spores and a fungicide was 90% effective. Then, an infection would be likely. However, if a boot application reduced spore production by 90%, the head would only be challenged by one spore, and the second application would be 90% effective in protecting the heads.

Severe rice blast epidemics are erratic in Louisiana. Major out breaks have occurred when susceptible varieties become popular and make up a significant percentage of the acreage. Examples include Tebonnet, Newbonnet, and Bengal in the 1980s and 1990s, and most recently, CL151 and CL261 in 2012. All of these varieties started out high yielding and apparently disease free, but after they became popular, blast became severe and their acreage declined rapidly. Adding to the severity of these epidemics, rice from the previous growing season often overwinters in the gulf coast rice growing area allowing significant amounts of blast to overwinter. This allows the epidemic to start earlier and at a much higher level than normal.

Update on Rice Blast in Arkansas-2013

Wamishe, Y.A.

Rice blast has been an unpredictable fungal disease and remains difficult to forecast given the multiple races of the pathogen, host susceptibility, and environmental factors. Spores can infect rice both early and late in the season beyond heading. The fungus survives between crops on infected rice residue or seeds. Spores could also be carried by wind and transported long distances. Rice leaves, collars, nodes or panicles are susceptible to infection. Disease pressure can be mild or severe causing up to 100 percent yield loss in a susceptible variety under favorable environmental conditions of wet foliage and warm temperatures. Blast can be more severe in fields with tree lines, no to shallow flood, and high rate of nitrogen fertilizers. Resistance to blast may not be lasting depending on race dynamics of the fungus population. Leaf blast lesions may remain small or expand to coalesce resulting in a burn down of rice leaves. Number, size, and age of lesions may be used to indicate degree of sporulation and hence the probability of infection at later growth stages of rice. Both higher number and bigger lesion size favors the potential for more spore production. When severe leaf blast is left unchecked, the most damaging form of blast known as "neck blast" or "neck rot" can devastate the rice crop resulting in lower yields. In 2013, fields with a history of blast planted late with susceptible varieties showed more neck blast without showing noticeable symptoms of leaf blast earlier in the season. For fields that showed leaf blast earlier in the season, but were adequately flooded and treated with fungicides, the result was fewer or no neck blast lesions. In some fields, late blast infection was not noticed until harvest. Unexpected lower yields directed the suspicion to finding the cause. For 2013, blast was more of an issue in the central and north eastern rice production areas of Arkansas with leaf blast reported in Randolph; Poinsett, White, Lawrence, Woodruff, and Monroe counties. Neck blast was relatively severe in Independence, Greene, Jackson, Randolph, and White counties.

Potential Risk of Wheat Blast Occurrence in the U.S.

Cruz, C.D.

Wheat blast, caused by the *Triticum* pathotype (MoT) of *Magnaporthe oryzae* (Couch & Kohn), is a serious disease of wheat causing yield failures and significant economic losses during epidemic years in South America. In this study, two pathway models were constructed for estimating the probability of MoT entry and establishment into the U.S. via the importation of wheat grain from Brazil. The two models are similar in structure and complementary in function but differ by two parameters and in the levels of spatial resolution. The first pathway model, P_{BR-US}, was constructed to predict MoT entry from Brazil and establishment into any wheat production area in the U.S. That model identified significant risk for MoT establishment in some areas. With the threshold levels used, the models predicted that the climate was adequate for maintaining MoT populations in some areas of the U.S. However, disease outbreak threshold levels were not reached in most of the country. Since entry is prerequisite to establishment, spread, and outbreak, a higher level of resolution for the entry stage was applied in the second pathway model, P_{BR-NC}. This model was based on a ground transportation corridor developed to target areas at risk to MoT entry within southeast North Carolina. Vulnerability of this corridor to MoT establishment was assessed based upon the presence of a susceptible host in a disease-conducive environment. The models generated in this study should provide the foundation for more advanced models in the future. The corridor approach that was developed may offer a strategy for establishing a sentinel plot system or for executing a targeted surveillance system.

Implication of Co-Evolutionary Dynamics for Genetic Resistance to Rice Blast Fungus

Jia, Y.

Plant resistance (*R*) genes play important roles in fighting against pathogens. Over 100 *R* genes and some of their cognate pathogen effectors have been molecularly characterized. It was found that most *R* genes encode predicated receptor proteins with nucleotide binding sites (NBS) and leucine rich repeats (LRR). In contrast, the cognate pathogen effectors are random molecules without common motifs. Understanding the molecular dynamics of host-pathogen co-evolution has been a subject for intensive investigation worldwide. Blast disease of rice (*Oryza sativa*) caused by the fungus *Magnaporthe oryzae* is one of the most serious crop diseases. *O. sativa* has been grown as an important food for human consumption for thousands years, and can be found in most countries around the globe. Thus far, *O. sativa* has the following five subgroups: aus (AUS), indica (IND), temperate japonica (TEJ), tropical japonica (TRJ), and aromatic (ARO). In the present study, the deployed major blast *R* genes, *Pi-ta*, *Pi-b*, and *Pi-z* in 1,800 rice germplasms, collected from over 100 countries, from the National Small Grains Collection (NSGC) have been analyzed using DNA markers and pathogenicity assays. *Pi-ta* and *Pi-b* were mostly found in IND and TRJ, whereas *Pi-z* was found in all subgroups except for ARO. Twenty rice germplasms with two *R* genes were only identified in indica cultivars collected from countries in Southeast Asia, China, Africa, South America, South Pacific, Mideast, and Europe. This analysis revealed that one or two *R* genes have been critical for combating blast disease worldwide. This finding has significant implications for evolution and adaptation of rice blast fungus. New strategies for crop protection will be presented.

Rice Blast Management: Cultural Practices

Lee, F. N.

Arkansas rice growers manipulate cultural practices to induce rice blast field resistance and produce high rough rice yields when growing moderately susceptible cultivars, often during blast conducive environments. These cultural practices, especially irrigation and fertility, are included in standard rice production practices (visit http://www.uaex.edu/Other_Areas/publications/MP-192.asp). Flood depth and duration facilitates anatomical and physiological changes at the cellular level to confer field resistance in the plant and limits infection and growth of the rice blast fungus.

Rice Blast Pathology, Breeding, and Management of the Disease in Hybrids at RiceTec, Inc.

Correa-Victoria, F.J.

Rice blast disease caused by the fungus *Magnaporthe oryzae* (*Pyricularia oryzae*) is the most important rice production constraint in the world potentially causing up to 100% yield losses. Rice blast is again emerging and considered a major threat for rice production in the US. Many farmers reported blast outbreaks in Louisiana in 2012 suffering heavy yield losses and reduced grain quality in susceptible rice varieties. Leaf blast, as well as rotten neck blast, was common on many rice fields. Similarly, severe blast epidemics were present and economically important in the same year in other rice growing areas, including the states of Arkansas, Texas, and Mississippi. The fungus managed to survive the warm winter, and early reports of rice blast were again in the news in 2013. Farmers needed to apply fungicides two time on very susceptible rice varieties to control the disease. Given the recent blast outbreaks, resistance is the best option to manage the disease, and currently, rice hybrids have the best overall blast resistance. However, heavy loads of blast spores being produced on susceptible varieties may pose a threat to the present blast resistance as new mutations compatible with deployed resistance genes may develop. Historically, new blast-resistant varieties controlled by major single genes are typically overcome by the disease within one to three years due to pathogen adaptation, which result in new races. One strategy to improve the durability of blast resistance is to pyramid resistance genes. To do this, extensive studies on the genetic and phenotypic structure of blast pathogen populations, including composition, distribution and frequency of the avirulence genes that underlie pathotype/race variation, are needed. Detailed information on this pathogenic variation is allowing RiceTec to develop and implement a breeding strategy for increasing frequencies of relevant major resistance genes and gene combinations in its blast resistance breeding program. The resistance breeding program is supported on available public information released by U.S. universities on molecular markers tightly linked to blast resistance genes. We are characterizing our germplasm for the presence/absence of main blast resistance genes. Our aim is to implement a breeding strategy based on pathogenic characterization, marker assisted selection for the introgression of blast resistance gene combinations and continuous evaluation and selection of resistance in segregating breeding populations under high blast disease pressure.

Potential for Consumer Acceptance and Economics of Blast Control through Cisgenic Rice

Nalley, L.

Rice is a staple crop for more than 50% of the world's population and the United States is currently the world's fifth largest rice exporter. Approximately half of the U.S. rice production is exported. Unlike soybeans and corn, which are inputs for livestock and biofuels, rice is primarily a field-to-plate crop. Direct human consumption poses some unique challenges to rice breeding because major importers of U.S. rice (EU, Japan, Korea, etc.) will not accept genetically modified (GM) rice. To put this in perspective, in 2006, a Liberty Link (a transgenic GMO) rice variety called LLRICE601 had been found in "trace amounts" in samples of rice intended for sale in Louisiana. Prices of U.S. rice tumbled as Japan and South Korea quickly halted imports of long-grain rice, while the EU, a major market, imposed compulsory testing of imports GM rice. Bayer® (the maker of Liberty Link) agreed to pay U.S. rice farmers $750 million in damages to settle actions over the contamination of the nation's rice by Bayer's experimental and unapproved GM Liberty Link rice. Thus, it is clear that a majority of rice importers are against GMOs. However, would consumers accept transgenic GMOs (where a gene from one plant species is inserted into another plant species to obtain a desirable trait)? There has not been an in-depth study of consumer acceptance of cisgenic GMOs (taking a gene from the plant's wild species and inserting it in the same domestic species to obtain a desirable trait). Cisgenic breeding is considered a GMO but could be replicated in nature (over many generations of selective breeding), unlike a transgenic GMO. The European Union has not ruled on the sales of cisgenics and has a nebulous policy towards them: "similar hazards can be associated with cisgenic and conventionally bred plants, while novel hazards can be associated with intragenic and transgenic breeding" (EFSA 2012). This policy can be interpreted as essentially saying - cisgenics are less dangerous than transgenics and equally as dangerous as conventional breeding techniques.

This study surveyed 3,000 Europeans in Belgium, France, Spain, England, and Holland to estimate consumers' willingness-to-accept cisgenically bred rice. Using a hypothetical multiple price list evaluation, consumers were told to select either rice A or rice B under different information sets. Rice A was always labeled as "conventionally bred rice" and rice B had varying information associated with it. The information sets included (1 the definition of cisgenic breeding, (2 the environmental benefits of cisgenic breeding, and (3 the fact that cisgiencis are considered to be GMOs. From these information sets, we wanted to determine if consumers viewed cisgenics as identical to what is traditionally thought of as a GMO - transgenic breeding.

Not surprisingly, there were significant attitudinal differences across countries for both GMOs and cisgenics. France had the largest aversion to both types while England and Spain (Spain produces transgenic crops) had the least aversion. Across all countries, there was a monetary discount placed on cisgenic rice compared to conventionally bred rice. But, the majority of people in each country seemed to agree that cisgenics were acceptable for sale in their country if they were labeled as a GMO. If Europeans were to allow cisgenics into their market, this could open up large yield gains in the U.S. and abroad for rice producers by producing cisgenically bred rice. At the very least, this study informs EU policy makers that it appears that EU consumers view cisgenics as a different type of GMO.

Rice Blast Research: Improving Our Arsenal and Using It

McClung, A.M.

Rice blast disease is a constant threat to U.S. rice production, and there have been sporadic outbreaks of the disease for many decades. However, the U.S. southern rice growing area has been fortunate because the pathogen population has been relatively stable compared to other rice producing areas in the world. It has only been when susceptible varieties and the right environmental conditions have occurred that serious outbreaks have developed. This is in spite of the narrow U.S. rice gene pool that is essentially confined to tropical japonica germplasm and is derived from relatively few progenitor cultivars. Rice cultivars introduced to the U.S. before 1920 have been shown to be the source of the major blast resistance genes, Pi-ks, Pi-km, and Pi-z, that are still being effectively deployed today. Other broad spectrum blast resistance genes have been more recently introduced; Pi-ta2 in 1989 and Pi-b in 2004, both from indica sources. Since 2003, U.S. rice breeders have utilized genetic markers that are closely linked to major Pi-genes in their selection process. In addition, there have been on-going efforts to evaluate the USDA rice germplasm collection to identify different genetic sources possessing these known genes, as well as identify new Pi-genes through mapping efforts. It is critical for breeders to have these tools so that Pi-genes can be pyramided to provide durable resistance against existing and emerging races of blast.

Wheat blast disease recently emerged in South America and could become a threat to U.S. wheat production. Our understanding of wheat blast disease is comparable to that of rice blast disease some 50 years ago. The problem is serious because of the extensive acreage of wheat production, there are no known resistance genes, and control using fungicides is unreliable. Because of the on-going threat of blast disease in rice and new concerns regarding blast in wheat, a multi-state USDA/NIFA/AFRI grant entitled “Novel strategies for managing blast diseases on rice and wheat” was developed and provided the opportunity to host this symposium focused on rice blast management strategies and the potential impact of wheat blast.

Nine scientific presentations were made at the symposium with an overview of the research problems being addressed and the expected outcomes of the project being presented by Dr. Barbara Valent. Although rice Pi-genes are available and used by breeders, none of the commonly deployed Pi-genes provide resistance to all U.S. races of blast. Dr. Rick Cartwright presented an historical perspective regarding the sporadic but persistent nature of blast disease in the U.S. Drs. Don Groth and Yeshi Wamishe reported that recent outbreaks of rice blast in the U.S. have been attributed, in part, to the release of high yielding but susceptible varieties and mild winters allowing survival of the pathogen on crop residue. Dr. Fernando Correa-Victoria demonstrated the need for an aggressive breeding strategy to stack Pi-genes and that this can be facilitated through the use of linked molecular markers. Dr. Yulin Jia presented results of a survey of some 1,800 cultivars from the USDA rice core collection and found that Pi-ta and Pi-b genes were common to indica and tropical japonica germplasm whereas Pi-z was found in all but the aromatic subgroup of rice. This indicates that these genes have been globally important and, through genotyping and phenotyping efforts, novel genes can be found in genetic collections. The impact of flood depth and duration on rice blast disease development was presented by Dr. Fleet Lee and suggested that future efforts to decrease the amount of irrigation water used in rice production may have a negative effect on blast disease control. Dr. Cruz performed modeling studies to assess the likelihood of wheat blast proliferating in the southern U.S. where there is significant winter wheat acreage and climatic conditions that allow the organism to be sustained. One practical suggestion from the research was to establish sentinel plots that could be used to monitor evidence of the disease. Another approach that the project is addressing is the use of cisgenic technology to engineer new rice varieties with existing rice Pi-genes that would result in rapid pyramiding of resistance genes into new cultivars. Dr. Lanier Nalley presented results of a survey of acceptance of such technology performed with a group of European consumers known to be generally not in favor of transgenic technology. In summary, this symposium provided an overview of what has been learned about rice blast disease management, what are the existing knowledge gaps, how this knowledge can help direct research to control wheat blast, and how novel control strategies are being explored that will help protect these two major crops in U.S. production from losses due to blast disease.

Abstracts of Papers from the General Session
Moderator: Steve Linscombe

History of Rice in Louisiana

Linscombe, S.D.

Louisiana rice production was facilitated by several circumstances that developed in the late 1800s. These included (1) the completion of the railroad system from New Orleans westward through south Louisiana and Texas, (2) the availability of cheap land and abundant water in the prairies of southwest Louisiana, and (3) the development of steam-powered farm implements. The railroad was completed from New Orleans westward in about 1883. This facilitated the sale of the abundant prairie land in southwest Louisiana. Railroad agents came to the region from the grain-producing region in the American Midwest to develop and sell this land for agricultural production. The first prospective farmers came primarily from the Midwestern states of Iowa, Illinois and Kansas. Land could be purchased for as little as 30 cents per hectare (12 cents per acre) , and $14 down would initiate the sale of 65 hectares (160 acres). Grain farmers from the Midwest came in large numbers and brought with them their steam engines, steam tractors, mechanical harvesters, and knowledge and expertise in mechanized farming. They soon discovered that corn and wheat did not prosper in the coastal prairies but rice certainly did. Many farmers later came to the region directly from Europe, with a large portion from Germany. The wheat twine binder was successfully adapted to rice harvesting by Maurice Brien in 1884. Railroad shipping records indicate that one twine binder was shipped to Louisiana in 1884, 200 in 1887, and more than 1,000 in 1890. Steam tractors and threshers became common in the region, and in 1888, William Deering and Company began to manufacture a harvester designed especially for rice. It became evident, however, that the capital improvements and technology required for rice production greatly exceeded those required for grain production in the Midwest. Mr. Seaman A. Knapp left the presidency of Iowa State College to move to the region as a farm specialist. He promoted experimental farms, brought improved rice varieties and conducted a number of other activities that benefited the establishment and success of early rice production in the region. Mr. Knapp spent a great deal of his time educating producers on the newest technologies and varieties. He is given much credit for the establishment of the Cooperative Extension Service that now exists throughout the U.S. and is part of the LSU AgCenter in Louisiana.

It is estimated that by 1895, there were almost 121,400 hectares (300,000 acres) in rice production in the U.S., most of which was in Louisiana. Rice production also spread rapidly into southeast Texas during this period. By 1903, Louisiana had more than 151,757 hectares (375,000 acres)() and Texas had more than 93,078 hectares (230,000 acres)in production. Other important developments in Louisiana rice production during this period included establishment of large-scale canal and irrigation systems. Canal and land development companies built large canal systems that ran for many miles. These systems typically pumped water from bayous or rivers using large steam engine-driven pumps. The water was delivered to adjacent fields along the length of the canals and offered rice farmers a dependable supply of fresh water. The canal company in turn received a share of the crop in exchange for the irrigation water. During the early days of rice production in the region, most of the rice was shipped to the established milling industry in New Orleans. By the turn of the century, however, prairie rice farmers began building private and cooperative mills in the production area of southwest Louisiana. The first part of the 20th century also brought improved varieties. A number of new rice varieties were introduced from other countries, and several new varieties were introduced from Japan. Mr. Solomon Wright, a Midwesterner who relocated to Crowley, developed the Blue Rose variety that was the standard of the industry for many years. Also, in 1909, the Rice Experiment Station was established on a tract of land west of Crowley. The Rice Station came to be because of a cooperative endeavor between the Louisiana Agricultural Experiment Station, the U.S. Department of Agriculture and local rice farmers. The station was originally established with the primary mission of introducing and later developing improved rice varieties. This has remained an important objective, and through the years, other important research areas were added to the mission of the current LSU AgCenter Rice Research Station. The development of the rice industry was the foundation for the settlement and development of the coastal prairie region of Southwest Louisiana and remains an important economic engine for this region.

Chalky Grain and the U.S. Rice Industry

Oard, J.H.

The U.S. rice industry has historically enjoyed an international reputation for products based on high levels of grain quality, cooking quality, and grain appearance. These important attributes have received increased scrutiny in the past four years from researchers, millers, exporters, and international customers. The proportion of chalky grain in current U.S. varieties has been identified as an issue that impacts certain U.S. export markets. Multiple research studies have identified high night temperature and relative humidity during grain filling as major factors that contribute to chalky grain. Genetics also plays a role for some varieties that consistently produce high chalk levels over multiple years and locations. The USA Rice Federation has established the Rice Marketability and Competitiveness Task Force to evaluate various rice quality issues. In 2012, the Task Force examined 20 U.S. varieties across six locations in the southern U.S. that showed considerable variation for percent chalk. Ten commercial mills provided qualitative evaluation of the samples in the study for a number of quality characteristics including chalk. These analyses resulted in variable assessments of this trait. A challenge for the rice industry has been the establishment of a common definition of chalk from market, government, export, and customer perspectives. Other issues include common quantifiable grading standards and procedures for exporters and customers, identity preservation, premium pricing, producer incentives, and quality analysis before export. Central American customers for rough rice have recently expressed concerns for U.S. varieties in terms of percent chalk, grain shape, translucency, brightness, and cooking quality. To retain current export markets and to identify new customers, the U.S. rice industry will need to work together toward improved communication, cooperation, transparency and common standards to define and measure chalk. Public and private rice breeders in the United States are placing considerable efforts and resources toward developing new varieties with low chalk and high grain quality for both domestic and international markets.

Effect of Water Management on Rice Agronomics and Grain Arsenic Concentration – Preliminary Results of a Multi-State Effort

Harrell, D.L., Walker, T.W., Roberts, T.L., Greer, C., McCauley, G., and Stevens, G.

Arsenic (As) can be found naturally in soil and water in both the organic and inorganic forms. The inorganic form of arsenic is particularly worrisome because it is a human carcinogen and has been linked to lung, skin, and bladder cancer. The Food and Drug Administration (FDA) recently evaluated the As content in approximately 1,300 samples of rice and rice products. In September of 2013, the FDA released the results of this study to the public and they concluded that the levels of As in rice and rice products occur in very low amounts and do not pose any immediate or short-term health risk. This is great news to the rice consumers and the rice industry as a whole. However, there are still many more questions that need to be answered. For example, can altering rice water management practices reduce As grain content? Do certain rice varieties or hybrids take up and assimilate less As in the grain than others? What effect does altering water management have on rice grain yields, production inputs, and overall production costs? With these questions in mind, a multi-state trial was established in 2013. The objective of this study was to determine the influence of different water management practices on rice grain yield, milling yield, As concentration in the rice grain, and the economic impact of each production system.

Field trials were established in each of the major rice producing states, including Louisiana, Arkansas, California, Texas, Mississippi, and Missouri. Each trial consisted of six varieties/hybrids and four water management strategies. Rice varieties/hybrids evaluated included 'CL151,' 'Cheniere,' 'Jupiter,' 'Presidio,' 'CLXL729,' and 'CLXL745.' California rice varieties differed from the other trials and included 'M-205,' 'M-206,' 'M-202,' 'S-102,' 'L-206,' and 'CM-101.' The water management strategies included: 1) The traditional drill-seeded, delayed-flood management practice, where a continuous flood (CF) was applied after the rice reached the 3- to 4-leaf stage of development and left until 2 weeks before harvest; 2) Straighthead management (SH), where the rice was flooded for 10 days to 2 weeks followed by draining until the soil cracked. This was followed by re-flooding until draining for harvest; 3) Intermittent flooding (IF), where the initial flood was held for 2-3 weeks, the flood was then allowed to evaporate until mud was exposed, followed by re-flooding to a 2- to 4-inch depth; and 4) Semi-aerobic rice management (SA), where flushing was conducted bi-weekly but aerobic conditions are allowed to persist.

Rice yields were averaged across varieties within a water management treatment and were significantly ($P = 0.0056$; LSD = 559) affected by water management at the Louisiana location. Rice yields were 9,321, 8,422, 8,299, and 8,237 kg ha^{-1} for the CF, SH, IF, and SA treatments, respectively. In Missouri, mean yields were 9,082, 8,407, 7,313, and 6542 kg ha^{-1} for the CF, SH, IF, and SA water management systems, respectively. In Texas, mean rice yields were 2,248, 2,238, 2,208, and 1,205 kg ha^{-1} for the SH, CF, IF, and SA treatments, respectively. Yields in the Arkansas trial exhibited little to no yield loss from alternative irrigation management practices with mean rice yields being 11,080, 11,239, 10,920, and 10,539 kg ha^{-1} for the CF, SH, IF, and SA water management systems, respectively. In Mississippi, relative rice yields were 100, 98, 98, and 59% for the CF, SH, IF, and SA water management practices, respectively.

Managing Sheath Blight in the Age of Fungicide Resistance

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

For at least 15 years, application of strobilurin fungicides azoxystrobin and trifloxystrobin has been the major control method for sheath blight, the most important disease of rice in the southern United States, caused by the fungus *Rhizoctonia solani*. In 2010 and 2011, in an area near Mowata, Acadia Parish, Louisiana, sheath blight control with these fungicides was very poor, even after multiple applications. Several factors were examined, including sources of fungicides, application timing and methods, additives, water quality, and unusual weather patterns. None of this information could explain the consistently poor fungicide performance. Representatives from Syngenta isolated *R. solani* from samples of blighted rice and soybeans with aerial blight (same pathogen) collected from these fields and tested them at their Vero Beach, Florida, facility for sensitivity to azoxystrobin, the active ingredient in Quadris and one of two active ingredients in Quilt fungicides. Both fungicides are used extensively on rice and soybeans in Louisiana. The tests showed that these isolates were at least 10 times more tolerant of azoxystrobin than isolates collected both before QoI fungicides were commercially available and concurrently from nearby fields in which the fungicides remained effective. Azoxystrobin-resistant isolates were also resistant to trifloxystrobin, the active ingredient of Gem and one of two active ingredients of Stratego fungicides. Although several other fungicides, including propiconazole, flutolanil, and iprodione, are labeled for sheath blight control, they are not effective enough to help manage resistance to the strobilurin fungicides.

The consensus had been that fungicide resistance in *R. solani* would not develop or would be slow to develop because, traditionally, only one fungicide application was made per season. Also, *R. solani* reproduces asexually, and populations may therefore be less genetically diverse than those of a sexually reproducing pathogen. Unfortunately, because of increased fungicide use after the 2006 epidemic of narrow brown leaf spot (*Cercospora janseana*) on rice and the new threat of Asian soybean rust, *R. solani* populations were increasingly challenged by strobilurin fungicides. Resistance quickly developed and spread thereafter, causing rice farmers in this area to lose a major tool for sheath blight control. This means they must rely on partial host resistance and cultural management to control sheath blight and potentially aerial blight in soybeans. This will include use of less susceptible varieties, lower nitrogen and planting rates, and inoculum-reducing practices such as rotation, cultivation, and sanitation. Because sclerotia of *R. solani* are long-lived in soil, these cultural practices are not very effective for sheath blight management. However, several new options are available to rice farmers. These include a new soil test that accurately predicts nitrogen needs, thus avoiding excessive amounts; the culture of crawfish (*Procambarus clarkii*), which destroy crop debris; and a Section 18 application for fluxapyroxad (Sercadis). Even with these new options, farmers will have a difficult time controlling sheath blight with the loss of the strobilurin fungicides because 1) most rice varieties are susceptible to very susceptible to this disease, 2) soybean is a host for *R. solani* and is the major rotational crop for rice, and 3) effective inoculum-reducing practices are lacking. Development of Q_oI-resistant populations of *R. solani* in southern Louisiana has necessitated a complete change in the approach to management of sheath blight of rice in this region.

Indications are that the strobilurin-resistant *R. solani* continues to spread into new areas in south central Louisiana. Sercadis appears to be very effective against both the resistant and wild types of *R. solani* and should receive a full federal label in 2014. The major difficulty is attempting to control multiple diseases, including sheath blight, blast and *Cercospora,* in areas where the resistance is present. Multiple (2-3) modes of action need to be utilized since Sercadis does not have blast or *Cercospora* activity.

Rice Program Provisions in the 2014 Farm Bill

Salassi, M.E.

On February 7, 2014, a new farm bill, the Agricultural Act of 2014, was signed into law and became the standard for commodity farm income protection for the next five years. This new farm bill not only included changes in the distribution of federal funds between programs within the total bill but also included significant changes in the commodity specific income protection options available to crop producers. Funding of nutrition programs continued to comprise the majority of program funds, projected at $756.4 billion over a 10-year period representing 79.1% of total farm bill funds. Crop insurance programs were the second ranked funding category with projected spending at $89.8 billion over 10 years. Conservation and commodity programs were funded at $57.6 billion and $44.4 billion, respectively, over 10 years. Proportional funding changes within the farm bill resulted in an increase in funding for crop insurance programs and a decrease in funding for nutrition, conservation and commodity programs.

The new farm bill repealed the direct payment and counter-cyclical payment programs which existed in the prior 2008 farm bill. Replacing these commodity income support programs in the new bill were two options from which producers can choose participation. One program option is the Agricultural Risk Coverage (ARC) Program which bases commodity income support on historical revenue per acre values. The other program is the Price Loss Coverage (PLC) Program which is a commodity price based program using fixed reference prices as the basis for income support. Income support payments authorized under either of these two programs are decoupled from production, meaning that current year income support determination is not based on current plantings or production. Both programs will continue to use a percent of established crop base acres as the framework for farm-level payment determination. Under this new farm bill, producers have the option to reallocate base acres within a farm, not to exceed current total base acres. In addition, producers enrolled in the PLC Program will have the opportunity to update program yields. The reference price for all rice under the new farm bill is $0.3086 kg^{-1} ($14.00/cwt.). The PLC Program includes an adjustment factor of 1.15 to the rice reference price for California medium-grain rice. The marketing loan rate for all rice remains at $0.1433 kg^{-1} ($6.50/cwt.). Additional programs authorized under the new farm bill include the Supplemental Coverage Option (SCO), which provides coverage for crop insurance deductibles, and the Crop Margin Coverage (CMC) Program, which is designed as a crop insurance type of program related to crop market net returns over specified production cost items.

The Use of Insecticidal Seed Treatments in U.S. Rice

Stout, M.J.

The widespread adoption of neonicotinoid and anthranilic diamide seed treatments for management of the rice water weevil and other insect pests of rice in the southern United States is the most important development in rice insect management over the past two decades. This brief overview of the use of insecticidal seed treatments in rice includes a summary of the history of seed treatment use in rice and a discussion of the spectra of activity of different seed treatments against target pests, the costs and benefits of seed treatment use, and the compatibility of seed treatment use with other agronomic practices and with integrated pest management.

Altering Starch Functionality

King, J.M.

Starch provides diverse functions in food, and one challenge is to produce clean label starch to replace chemically modified starch. One way to do this is to determine if natural additives like amino acids and fatty acids added to rice starch can change starch functionality in terms of its pasting, thermal and other properties. Another way is by enzymatic treatment. This presentation will cover some of the results we have found in our studies using these treatments.

Rice Weed Management Continues to Evolve

Webster, E.P., Fish, J.C., and McKnight, B.M.

Weed management in rice continues to evolve, especially for Louisiana, and several experimental herbicides have been or are being evaluated in the state. Research was conducted at the Louisiana State University AgCenter Rice Research Station near Crowley, Louisiana, the Northeast Research Station near St. Joseph, Louisiana, and the Macon Ridge Research Station near Winnsboro, Louisiana. Other studies were conducted on producer fields located in south Louisiana.

Saflufenacil, sold under the trade name Sharpen, has been evaluated as a postemergence herbicide in rice. The herbicide is currently labeled as a preplant burndown herbicide in rice with a 14-day preplant interval. Saflufenacil has similar activity to carfentrazone and acifluorfin. It has excellent activity on hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], Texasweed [*Caperonia palustris* (L.) St. Hil.], and Indian jointvetch (*Aeschynomene indica* L.). Saflufenacil also has activity on rice flatsedge (*Cyperus iria* L.) and several grass species. Saflufenacil will be labeled at 25 to 50 g ai/ha, and adjuvant selection can impact activity. The most consistent adjuvant is methylated seed oil (MSO); however, when saflufenacil is applied at 50 g/ha plus MSO moderate to severe crop injury can occur. Two rice tolerance trials were conducted in 2013 to evaluate the impact of saflufenacil on Clearfield hybrid 'CLXL 745' and conventional hybrid 'XL 729.' Saflufenacil applied at 25 g/ha injured rice of 10 to 20%; however, at 50 g/ha, injury increased above 30%. This injury was transient, and by 2 to 3 weeks after treatment, injury dropped below 15%. Saflufenacil has potential for use in Louisiana production systems; however, this herbicide will need to be used with caution.

FMC received a full label in 2014 for a pre-package mixture of clomazone plus quinclorac, sold under the trade name for Obey. This mixture of clomazone plus quinclorac can be an effective herbicide when applied in mixture. Each herbicide when applied alone has certain weaknesses on certain grasses or broadleaf weeds; however, when applied together, each herbicide compliments the other and essentially broadens the spectrum of both herbicides. Isagro received a label for a pre-package mixture orthosulfamuron plus halosulfuron, sold under the trade name Strada Pro. The addition of halosulfuron broadens the activity of orthosulfamuron on *Cyperus* species. Isagro also recently received a label for a pre-package mixture of orthosulfamuron plus quinclorac, sold under the trade name Strada XT2. Orthosulfamuron plus quinclorac can be a useful herbicide under certain conditions and with a weed spectrum. The highest rate that can be applied is 500 g ai/A. Each one of these herbicides can be useful in Louisiana production systems. Results from this year indicate that the orthosulfamuron plus halosulfuron pre-package mix has an excellent fit in Louisiana rice production.

Benzobicyclon, a Gowan experimental herbicide, is currently being sold in Japan. This herbicide has soil activity but must be activated with establishment of a permanent flood within a few hours of application; however, this herbicide seems to be more consistent if a flood is present prior to application. This herbicide has excellent activity on ducksalad [*Heteranthera limosa* (Sw.) Willd.] and other aquatic weeds, and also has activity on annual sedges, grasses, and broadleaf weeds. Initial observations indicate activity on Amazon sprangletop [*Leptochloa panicoides* (J. Presl) Hitchc.]. Benzobicyclon has potential to be a herbicide that can be used on several thousand acres in Louisiana.

Abstracts of Papers on Breeding, Genetics, and Cytogenetics
Panel Chair: James Oard

U.S. Rice Breeding - 30 Years of Genetic Gains

Moldenhauer, K.A.K., McKenzie, K.S., Sha, X., Linscombe, S.D., Lyman, N.B., and Nalley, L.L.

Genetic yield gains in U.S. rice have been associated with improved traits like semidwarf habit, herbicide tolerance, disease resistance, specific cultivars, and F_1 hybrids. Yield advancement and rate of gain have varied by production region and time period. Yield advancement and genetic gain in U.S. rice production have been very dramatic since the 1980s, estimates from regional varietal testing range from 25 to 87 kg ha^{-1} y^{-1}. In the Southern U.S., this dramatic yield advance is continuing. Rice yield increases in California, although higher, have slowed, indicating a yield plateau may have been reached.

From 1981 to 2011, U.S. rice yields have increased 47% (2.5 t ha^{-1}) at an average of 86 kg ha^{-1} y^{-1}. Reilly and Fuglie in their paper on future yield growth in crops projected U.S. rice yields for 2011 to be approximately 8 and 11 t ha^{-1} for the linear and exponential growth rates, respectively. The average U.S. rice yield for 2009-2011 was 7.8 t ha^{-1}, which was close to the linear growth prediction but well below the exponential model. Their annual increment for rice yield with the linear prediction was 85 kg ha^{-1} y^{-1}, almost identical to the actual calculated value of 85.9 kg ha^{-1} y^{-1} for the U.S.

U.S. rice breeding programs have historically been public sector and grower supported efforts. Changes have occurred with the commercially available privately developed Clearfield technology and F_1 hybrid rice. Clearfield cultivars exclusive to the Southern U.S. provide non-transgenic herbicide tolerance for red rice control and have become very popular and successful. F_1 hybrids, many of which are Clearfield, account for about 25% of the acreage in the Southern U.S and have been successful.

Genetic gains have not been made through the adaption of transgenic rice because it is not commercially or politically acceptable in the U.S. or anywhere in the world to date. Genetic markers have received considerable emphasis in rice research and breeding becoming routine in many U.S. breeding programs. As rice yields increase, the question arises about maximum yield potential of rice. Grain yields of 16.5 t ha^{-}1 have been reported in replicated plot experiments in the U.S., but the relatively high yields produced in the U.S. make achieving yield increases more challenging as the maximum yield potential of rice is approached.

Breeding for High Quality Medium- and Long-Grain Rice for Arkansas and Mid-South

Sha, X., Beaty, B.A., and Bulloch, J.M.

The uncharacteristic low milling yields combined with high degree of chalky kernels and variable cooking quality observed during 2010-2011 served as a wakeup call to the U.S. rice industry, which historically is world renowned for its high quality rice. The extremely hot summers, changes in cultivar/hybrid, and the interaction between the two most likely contributed to the poor quality. Due to the fact that about 50% of U.S. rice is for export market and a large portion of domestic consumption goes to the processing industry, development of rice cultivar/hybrid that maintains its superior quality under diverse environmental conditions is critical for the U.S. rice industry to retain and expand its key markets, both domestic and international.

Rice quality is a general term which primarily includes milling quality, grain quality, cooking quality, and nutritional quality. Milling quality determines the whole kernel and broken kernel ratios of the milled rice. Grain quality or grain appearance is associated with size, shape or dimension, chalkiness/translucency, and grain uniformity. Chalkiness is related to the shape, size, and packing of amyloplasts - organelles responsible for the synthesis and storage of starch granules within the endosperm. Cooking quality is mainly associated with the amylose content and gelatinization temperature. The chain structure of amylopectin was also related to hardiness and stickiness of the rice after cooking. A series of enzymes including starch synthetases are involved in the biosynthesis of starch in rice grain. Most of these enzymes are represented by different isoforms and are encoded by multiple genes, leading to a highly complex biosynthesis and accumulation process.

Even though most predominant high-yielding cultivars or hybrids have an inferior quality, several current pureline cultivars showed the quality similar to that of the imported premium quality rice. By taking a balance approach, we should be able to develop new rice cultivars not only with improved grain and milling yields but also with the acceptable grain and cooking quality.

The University of Arkansas Hybrid Rice Breeding Program

Berger, G.L., Moldenhauer, K.A.K., Sha, X., Yan, Z.B., and Wilson Jr., C.E.

During the past 10 years, hybrid rice (*Oryza sativa*) production has increased from less than 1% of the total acreage in Arkansas in 2002 to more than 40% of the acreage in 2013. As this trend continues, the value of high-yielding rice hybrids continues to increase. A distinct advantage of hybrid cultivars over pure line cultivars is the ability to produce high yields in adverse soil and/or environmental conditions. State average rice yields between 2002 and 2013 have increased an average of 112 kg ha^{-1} y^{-1} (100 lbs/acre/year). Much of this increase is due to the adoption of hybrid rice, particularly on farms with a history of lower yields. The rice farmers of Arkansas, as represented by the Arkansas Rice Research and Promotion Board, have been very clear in their desire for University of Arkansas-developed hybrid rice cultivars. This desire led to the inception of the University of Arkansas hybrid rice breeding program.

Currently, the University of Arkansas hybrid rice breeding program is focused on the development of hybrids with typical long-grain quality adapted to the mid-South. Of utmost importance is development of male sterile lines and high yielding hybrids with high milling yields and improved grain quality. A major advantage of the University of Arkansas rice breeding program is that we have three sources of material that can be used for development of hybrids. By using male lines from Dr. Moldenhauer's program and Dr. Sha's program, and male lines developed in the hybrid program, we increase the chance of identifying superior hybrid combinations. Additionally, hybrids developed by the University of Arkansas bring many other advantages, not the least of which is an increase in yield potential over current conventional alternatives.

Development of male sterile lines (both 2- and 3-line) with typical long-grain quality is currently ongoing. Existing male sterile lines have the ability to produce hybrids with excellent yield potential but are inferior in quality to typical U.S. long-grain cultivars. Both traditional and marker-assisted selections are being used for identification of superior male sterile lines.

For the past three years experimental hybrids (both 2- and 3-line) have been tested in local and regional nurseries. During 2013, grain yields of experimental hybrids ranged from 6,204 kg ha^{-1} to 11,702 kg ha^{-1} (123 bu/ac to 232 bu/ac). The quality of these hybrid combinations is currently being assessed. Continuing work will focus on the identification of new combinations adapted to the mid-South.

Collaborative efforts are important to rice research and hybrid development. For years, the International Rice Research Institute, as well as many Asian countries, has worked on development of public hybrid rice breeding programs. Private industry has been engaged in hybrid breeding for many years throughout the world, including companies such as Rice Tec, Bayer, and Dupont. It has only been within the past five years that major University Experiment Stations in the Southern U.S. have invested resources in hybrid rice breeding.

Progress in Hybrid Rice Development and Production at the LSU AgCenter Rice Research Station

Li, W., Oard, J.H., Linscombe, S.D., Harrell, D.L., Sha, X., Groth, D.E., and Richard, J.E.

Hybrid rice is the commercial crop of F_1 seeds derived from two genetically different inbred parents. Due to heterosis, hybrid rice can produce ~ 15% yield advantage over the best inbred variety under similar conditions. By incorporating hybrid rice-related traits from Chinese germplasm into U.S. long-grain genotypes, our ultimate goals are to develop and identify male-sterile lines, restorer lines, and hybrid combinations adapted to southern U.S. environmental conditions.

According to a collaborative research agreement between the Louisiana State University Agricultural Center and Guangxi Academy of Agricultural Sciences in 2008, a number of advanced hybrid rice germplasm lines were introduced. Since then, with these source germplasm lines, we have achieved good progress in hybrid rice development and production at the Rice Research Station. A large number of testcrosses between Chinese male-sterile lines and Louisiana long grains have been made and evaluated under field conditions. Nearly 100 candidate hybrid combinations have been identified with 10-20% yield advantage over commercial checks and comparable milling yields, grain quality, maturity, and plant height. Several restorer and maintainer lines of Louisiana origin have been identified from field evaluation of approximately 2,700 lines. Four long-grain male-sterile CMS lines have been developed using Louisiana varieties. Approximately 300 male sterile PTGMS lines have been evaluated with some used to develop candidate hybrids with high yield potential, suitable maturity, no shattering, no lodging and low levels of chalk. Selected parental lines have been used for seed increase, additional test crosses, and small scale seed production. The medium-grain hybrid LAH10 has been evaluated four years in Louisiana and other U.S. rice growing states with no. 1 yield rankings in the 2012 URN trial across all-states and in the 2013 Louisiana URN.

Mining Genes in Breeder's Nurseries, Yield Trials, and Collections

Tabien, R.E. and Harper, C.L.

Gene mining aims to identify genes that contribute to the development of phenotype or trait. The trait of interest defines the screen to use such as herbicide for herbicide tolerance or low temperature for cold tolerance. Plant collections in gene banks are the traditional and main source of materials for screening to identify genotype with the trait or gene of interest. If diversity is not enough in the collection, variants can be created through induced mutation and hybridization. Crosses commonly done by breeders can expose valuable traits hidden in the genome. Many traits are present in the genome but not expressed until these are in the right genetic background or environment. Several reports indicated presence of resistance/tolerance in crosses of two susceptible parental.

The seed storage of the breeders can be like a small gene bank as breeder maintains collections of germplasm, elite breeding lines, and hundreds of populations, mostly remnants of previous plantings. Moreover, every season, thousands of lines are evaluated in breeding nurseries, and hundreds of near-uniform lines in the performance trials. These could be a good source of important traits but maybe overlooked as focusing narrowed down to releasing varieties.

Germplasm collection and breeding materials in Texas rice breeding program were initially evaluated for herbicide tolerance. Alleyways of nurseries and performance trials were sprayed with Roundup herbicide and the panicles of survivors were harvested for further evaluation. A separate field for screening composed of elite lines and germplasm collection from the program was also established to evaluate more entries in a given year. After several years of screening using the recommended rate for Liberty and Roundup herbicides, several genotypes survived Liberty but very few for Roundup. Re-evaluation of survivors showed consistent tolerance for Liberty but not for Roundup. The collections of Liberty-tolerant genotypes were further evaluated using 2x rate of Liberty and screened for germination and seedling cold tolerance. Later, drought and water submergence tolerance screenings were conducted on selected lines for possible tolerance to multiple abiotic stresses. Results indicated that breeding nurseries and elite lines in yield trials can be a source of important genotypes once a screen is imposed. Our best materials for herbicide tolerance were derived from alleyways survivors and these showed potential tolerance for other abiotic stresses. Screening of ratoon in yield trials for Liberty tolerance was recently conducted and survivors were noticed in all replications for some lines segregating for tolerance. Genotypes at breeders' disposal may have been used in natural screen like severe insect infestation, or disease epidemics to identify resistant plants but these can be mined for other new genes using appropriate screens.

Development of New Rice Lines Showing Broad Disease Resistance to Bacterial Panicle Blight and Sheath Blight

Karki, H.S., Shrestha, B.K., Groth, D.E., and Ham, J.H.

Progenies descended from the cross between Bengal (a medium-grain variety) and LM-1 (a mutant line derived from the long-grain variety, Lemont) were tested for their disease resistance to sheath blight and bacterial panicle blight, which are major disease problems in the rice production in the southeastern United States. Bengal is susceptible to both sheath blight and bacterial panicle blight, while LM-1 is partially resistant to both diseases. Several progeny lines showed high levels of partial disease resistance to sheath blight and/or bacterial panicle blight, suggesting that they are new useful breeding materials to improve disease resistance. Particularly, one of the selected lines, LB-33, showed superior phenotypic traits in terms of disease resistance and yield. In the field tests in 2012 and 2013, LB-33 exhibited higher levels of partial resistance to sheath blight and bacterial panicle blight than its partially resistant parent, LM-1. LB-33 also showed a higher yield potential than both of the parental lines. Other traits of LB-33 include taller plant height and larger panicle length compared to the parental lines. Cultivating LB-33 will increase the yield due to its high yield potential and disease resistance to sheath blight and bacterial panicle blight. In addition, this new rice line is an excellent material for the rice genetics study of disease resistance and the breeding of new disease-resistant varieties.

Calcium Application Decreases Straighthead and Increases Seed Set in Rice

Huang, B., Zhou, W., Xiong, H., Yan, Z., Yan, W., Li, Y., and Ntamatungiro, S.

Even though large efforts have been made to study straighthead disease for improving cultivar resistance since the early 1900s in the US, its causal factors are still not exactly known. Among those putative factors, calcium (Ca) received scientific attention in 1969 and has been studied since then. After reviewing the previous studies, we conducted this experiment in greenhouse conditions to address the relationship of straighthead with application of Ca into the soil.

US cultivar Cocodrie and three breeding lines, 8-18, 8-9, and 12-38, were used for this study. Cocodrie is known to be susceptible to straighthead so it has been widely used as susceptible check in studies for straighthead. However, the breeding lines 8-18, 8-9 and 12-38 are relatively resistant to straighthead. Three plants were grown in each pot (22 cm tall and 22 cm diameter) filled up with the silt loam soil collected from University of Arkansas at Pine Bluff farm where the straighthead naturally occurred. Four levels of Ca treatments, 0g Ca, 297g Ca (Calcium carbonate) at vegetative stage (V-Ca), 535g Ca at booting stage (B-Ca), and V-Ca plus B-Ca (VB-Ca), were applied to each of the varieties with three replications. Within each replication, the pots were completely and randomly placed. During the season, a variation of straighthead symptoms including sterile and deformed grains and panicles were observed among the Ca treatments and varieties. At maturity, five representative panicles were harvested from each pot to record seed set rate (%) for assessing straighthead, which is very resistant at more than 80% of seed set rate and very susceptible at 0% of seed set rate. Data were analyzed using SAS package.

ANOVA (Analysis of Variance) of the seed set rate showed that the variations due to varieties, Ca treatments and their interactions were all highly significant ($p<0.0001$). As expected, Cocodrie was mostly susceptible with an average seed set of 20.75%, while line 8-9 was mostly resistant with a seed set of 79.75%. The pair-wise differences of seed set among these four varieties were all significant at 5% of probability. VB-Ca resulted in the highest seed set of 70.50% which was significantly higher than V-Ca of 47.25% and B-Ca of 46.75%. The check with no Ca treatments had the lowest seed set of 37.25% which was significantly lower than any one of Ca treatments. For susceptible Cocodrie and 8-18 which checks had almost no seed set (1.00 and 8.90%), VB-Ca recovered Cocodrie to 52.16% and 8-18 to 61.76%. The seed set rate of 8-9 and 12-38 were 63.50 and 68.97% for checks, respectively, and VB-Ca treatments increased their seed set rate up to 89.96 and 74.28%, respectively. Therefore, our results suggest that application of Ca to soil, especially at both vegetative and booting stages, could largely reduce straighthead disease so that susceptible varieties could have quite high levels of seed set rate.

Rice Grain Element Concentration Predictions Based on Leaf Concentrations: Accelerating Improvement of Nutritional Quality

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The genetic improvement of rice grain element composition traditionally requires analyzing the grain element concentrations of large numbers of genotypes. The study evaluated if vegetative-leaf concentrations of elements could be used to predict grain concentrations of the elements. The study material included 39 rice genotypes selected based on their extreme grain element concentrations in previous studies examining the USDA core collection under flooded and unflooded field management. In addition, 'Lemont' was included as a U.S. check variety because it has often been used as a parent for mapping populations in ionomic studies. In this study, weekly plantings of the 40 genotypes provided a wide range of vegetative development at the single harvest, which occurred when the earliest genotypes of the earliest planting dates were near boot stage. The developmental stage of each plant was recorded based on the number of leaves exerted per main culm, and the tip (3 cm) of the uppermost fully exerted leaf was harvested for analysis of elemental concentrations (ionomic analysis). If all of the highly ranked genotypes based on grain element concentration are high with respect to leaf concentration at a particular developmental stage, then screening of vegetative-stage leaf concentrations of that element has potential for predicting high grain genotypes in diverse germplasm. Results indicate that vegetative-stage leaf concentrations have potential to be used for indicating differences among genotypes in grain concentrations of some elements. As a group, genotypes selected for high grain-cadmium, -cobalt, -molybdenum, and -strontium harvested from flooded field plots showed higher leaf-element concentrations as well. Also, as a group genotypes selected for high grain-cadmium, -molybdenum, -rubidium, and -sulfur from unflooded field plots showed higher leaf-element concentrations. No leaf-grain associations were obtained for copper or nickel concentrations. For a particular element, when the selected genotypes as a group showed excellent agreement between leaf and grain element concentrations, the use of vegetative-stage leaf element concentrations to accelerate the screening of diverse germplasm collections for grain concentration of the element appears plausible. We appreciate the support provided by NSF Grant DBI-0701119.

Genetic Enhancement of Nutritional Quality in Rice and Other Grain Cereals

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Cereals are the most important crops in the world for both human consumption and animal feed. Improving their nutritional values, such as high in protein content, will have significant implications from establishing healthy lifestyles to helping remediate malnutrition problems worldwide. Improving protein content in rice, for example, will help enhance its nutritional profile. Recent trends indicate that developing healthy lifestyles is an increasingly important goal for many. To help achieve this goal, nutrient profiling systems were developed to assist individuals in identifying and selecting foods based on their criteria and preferences to establish individualized healthy lifestyles. Rice with higher protein content will have a better status in the nutrient-profiling systems. Besides providing a source of carbohydrate, the grain is also a natural source of dietary fiber, vitamins, minerals, specific oils, and other disease-fighting phytocompounds. Even though cereal grains contain relatively little protein compared to legume seeds, they provide protein for the nutrition of humans and livestock that is about three times that of legumes. Most cereal seeds lack a few essential amino acids; therefore, they have imbalanced amino acid profiles. Lysine (Lys), threonine (Thr), Methionine (Met), and Tryptophan (Trp) are among the most critical and are a limiting factor in many grain crops for human nutrition. Advancements in nutrigenomics and nutrigenetics continue to improve public knowledge in a rapid phase on the importance of specific aspects of food nutrition for optimum fitness and health. An understanding of the molecular basis for human health and genetic predisposition to certain diseases through human genomes enable individuals to personalize their nutritional requirements. It is critically important, therefore, to improve the grain protein quality. Highly nutritious grain can be tailored to functional foods to meet the needs for both specific individuals and human populations as a whole. The objective of this presentation is to discuss genetic enhancement of protein content in rice grain and compare it with other cereals.

The grain-quality enhancement program at the Rice Research Station is working on improving protein content in rice using various approaches that are specifically targeted to functionally change two key enzymes, dihydro dipicolinate synthase (DHDPS) and aspartate kinase (AK). These are the key enzymes in the biosynthesis pathway of Lys and Thr. Promising protein-rice lines are being tested in advanced trials. In addition to the advanced lines, new protein lines are being developed from Louisiana varieties and germplasm lines. For example, 79 lines have been developed from the variety Cocodrie with a range of crude protein content between 10.5 and 14.5% and 183 lines from the variety Cypress having protein content ranging from 10.5 to 14.2%. Both multi-location commercial advance (CA) and preliminary yield (PY) trials used 1.42 x 4.88 m^2 plots with a seeding rate of 100 kg/ha in a randomized complete block design. Rice was grown under flooded conditions, received approximately 134 to 168 kg/ha of nitrogen, and harvested when the average grain moisture content is 160 to 180 g/kg. For CA trial, no fungicide was applied at any location so the levels of resistance to multiple diseases can be evaluated. Parameters collected from most field trials included grain yield, whole and total milling percentages, seedling vigor, maturity, plant height, and lodging resistance. Total crude protein content of both brown and milled rice were measured in house using the N Combustion Analyzer by applying a high temperature digestion of 0.2 grams of ground rice grains at 850° to 1200°C. In addition, Bradford's method, SDS-PAGE, and fluorescence spectrometer were used for verification. Amino acid profiling were conducted using 200 mg ground sample were sent to a commercial laboratory for amino acid analysis using reversed-phase HPLC with pre-column phenylisothiocyanate derivatization or with post-column, ninhydrin derivatization to analyze the 16 amino acids plus hydroxyproline and hydroxylysine, cyst(e)ine, and tryptophan.

The enhancement of both protein content and essential amino acid obtained in the rice grain will be compared to the protein improvement in other cereals that are developed from various approaches, including manipulation of seed protein bodies or fractions (such as the high lysine content of *o2* mutants and *o2* modifiers (*mo2*) in QPM (Quality Protein Maize) lines, deregulation of certain biosynthetic pathways to overproduce essential amino acids that are limiting, nitrogen relocation to the grain through the introduction of transgenes (such as the use of BHL8 recombinant protein or 2S *Bertholletia exalsa* albumin), and exploration of genetic variance (such as interspecific hybrids between adapted and wild species). High protein rice grain can provide the base for developing novel foods and fibers or nutrient-dense food products. Highly nutritious grain can also be tailored to functional foods to meet the needs for individuals with specific genetic traits.

Developing User-Friendly Tools to Facilitate Interpretation and Utilization of Genomic Data for Applications in Plant Breeding and Genetics

DeClerck, G., Branchini, D., Agosto-Perez, F., Singh, N., Wright, M., Mezey, J., and McCouch, S.

For the past several years, the Rice Diversity Project (ricediversity.org) has been developing SNP genotyping platforms (e.g. 1536, 44K) both for exploration of genetic diversity and to study subpopulation structure, which is best achieved through the use of large numbers of markers from a range of germplasm types. Of parallel importance has been the development of smaller-scale genotyping tools (e.g. 384 OPA assays) that can be utilized for quick, low-cost screening in rice breeding programs. We are currently preparing release of a higher quality and more versatile chip in each platform type. The advancement of these technologies is part of a larger effort of the Rice Diversity project to develop analysis and informatics pipelines and data access tools. In addition to several high-throughput phenotyping projects and subsequent genome-wide association (GWA) analysis, we are building query and visualization tools to help researchers access, mine, and interpret genotype, phenotype, and association data in the context of the rice genome. We have set up a local instance of the UCSC Genome Browser populated with the rice MSU RGAP7 genome annotation, along with all of our public SNP datasets. We have also developed a graphical data browser called "GWAS Viewer" that allows researchers to visualize and mine GWAS Manhattan plots. Development of other user-friendly web-based tools for allele, germplasm, and candidate gene mining are also underway. With our focus on next-generation sequencing and data-intensive phenotyping, the bioinformatics overhead on the project is fairly substantial. We have needed to implement data storage and management strategies to handle a variety of data domains: 1) a large volume of sequence and genotype data (~20 TB); 2) several terabytes of image and measurement data has been generated by several high-throughput phenotyping projects; 3) seed and tissue information management to facilitate tracking alleles to specific germplasm accessions; 4) bioinformatics analysis. An emerging focus is the development of an all-encompassing laboratory information management and accompanying central database that can aggregate all of this data and its associated meta-data and ontological context so that project researchers can gain maximal benefit from this extensive body of data as a whole.

Identification of Candidate Genes Associated with Heterosis in Rice

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Hybrid rice due to heterosis has played an important role for ensuring stable rice production in the USA and globally. Heterosis is a complex biological phenomenon in which the offspring show superior performance compared to their inbred parents. The heterosis can be positive or negative based on breeding objectives and parental traits. In the present study, massively parallel signature sequencing (MPSS) libraries were constructed from leaves, roots, and meristem tissues from the two parents, Nipponbare and 93-11, and their F_1 hybrid to identify differentially expressed genes. A total of 1-3 million signatures were obtained from the MPSS libraries. Using cluster analysis, commonly and specifically expressed genes in the parents and their F_1 hybrid were identified in all three tissues. The differentially expressed genes identified in F_1 hybrids were mapped onto yield related quantitative trait loci (QTL) regions using a linkage map constructed from 131 polymorphic Simple Sequence Repeat markers with 259 recombinant inbred lines derived from a cross between Nipponbare and 93-11. The average of each yield component from replicated field plot experiments from three years and two locations was used for QTL mapping. QTLs were identified for yield related traits including days to heading, plant height, plant type, tiller number, panicle length, number of primary branches per panicle, number of seeds per panicle, total kernel weight per panicle, 1000 grain weight, and total grain yield per plant. Thus far, 71 QTLs related to the previously mentioned yield traits were mapped; three of which were novel. Many highly expressed chromatin-related genes in F_1 hybrids encoding histone demethylases, histone deacetylases, argonaute-like proteins, and polycomb proteins were located in these yield QTL regions suggesting potential epigenetic regulation for rice yield. Additionally, a total of 336 highly expressed transcription factor (TF) genes belonging to 50 TF families were identified in the yield QTL intervals. Differentially expressed genes belonging to biochemical pathways, including carbohydrate metabolism, energy metabolism, and metabolism of cofactors and vitamins, were highly represented in leaves, roots, and meristem tissues, suggesting these may be related to hybrid vigor. This study represents a comprehensive analysis of transcriptomes of F_1 hybrids to identify the genes related to positive and negative heterosis of yield related traits in rice. Identification of these candidate genes provides the starting genomic materials to elucidate the molecular basis of heterosis in rice.

Effects of the Rice "Green Revolution" Gene *sd1* Beyond Plant Height

Gu, X.Y., Ye, H., Feng J., Mispan, M.S., and Beighley, D.

Plant height is a major adaptive/agronomic trait for wild/crop species. Despite years of research on plant height, little is known about its evolutionary relationship and regulatory mechanisms shared with the other adaptive traits. The previous research on weedy rice, identified two quantitative trait locos (QTL) clusters both associated with seed dormancy and plant height on the long arms of chromosomes 1 (*qSD1-2/qPH1*) and 7 (*qSD7-2/qPH7*), and the *qSD1-2/qPH1* cluster-containing region also encompasses QTL for seed longevity/aging, vegetative tissue-growth rate, flowering time, tiller numbers per plant, and seed numbers per panicle. This research focused on the *qSD1-2/qPH1* cluster to identify the QTL underlying gene(s) and developmental mechanisms regulating seed dormancy.

High-resolution mapping delimited *qSD1-2/qPH1* to a genomic region of a few predicted genes, including *semi-dwarf1* (*sd1*) encoding GA20 OXIDASE-2 for biosynthesis of the phytohormone gibberellin (GA). The mutant *qSD1-2/qPH1* allele from the *indica* cultivar reduced germination and stem elongation and the mutant effects were recovered by exogenous GA, suggesting that *sd1* could be a candidate gene for both seed dormancy and plant height. Mutant analysis using a *japonica* line, which contains a T-DNA insertion in the promoter region of a functional *GA20ox-2* allele, confirmed that *sd1*has pleiotropic effects on seed dormancy and plant height, and also revealed that the gene mutation lowered the seed setting rate in the isogenic background. DNA sequence and phylogenetic analyses revealed that the wild-type (functional) allele of the pleiotropic gene from weedy rice that promotes germination and plant height originated from wild rice (*O. rufipogon*), whereas the mutant allele that reduce germination and plant height is loss-of-functional and prevails in *indica* semidwarf cultivars. Genetic differentiation in both seed dormancy and plant height was not detectable between the functional *GA20ox-2* alleles from weedy and *japonica*-type cultivated rice.

Tissue-specific expression analyses using genetic, histological, and molecular approaches demonstrated that the GA biosynthesis gene is expressed in endosperm and regulates the velocity of seed development, with the mutant allele delaying the endosperm cellular development and maturation and consequently postponing acquisition of embryo desiccation tolerance and seed after-ripening.

This research established that plant height co-evolved with seed dormancy and some other adaptive traits in wild/weed populations and the co-evolution could be mediated by the pleiotropy of a gene involved in GA biosynthesis, such as the rice “Green Revolution” gene *sd1*. The enhanced seed dormancy conferred by the loss-of-function mutation in a GA biosynthesis gene suggests that the Green Revolution may have increased the resistance of cereal crops to pre-harvest sprouting.

Evolutionary and Developmental Mechanisms of Seed Dormancy Revealed by Map-Based Cloning of Genes underlying a Major Quantitative Trait Locus from Weedy Rice

Feng J., Ye, H., Srivastava, V., and Gu, X.Y.

Seed dormancy promotes the survival of flowering plants (angiosperms) in diverse environments by distributing germination over time. Domestication tended to reduce seed dormancy to promote rapid, uniformity germination, which also causes the problem of pre-harvest sprouting in cereal crops. The previous research developed weedy rice (*Oryza sativa*) as a model system to elucidate genetic, evolutionary, and developmental mechanisms that directly regulate the natural variation of seed dormancy in grass species. Of the 10 quantitative trait loci (QTL) identified for seed dormancy in the system, the *qSD12* locus displayed the largest effect on delaying germination. This research was devoted to clone and molecular characterize the major QTL for seed dormancy.

Initial fine-mapping delimited *qSD12* to a short (<80 Kb) genomic region of 11 predicted genes, including a tandem set of six transposon/retrotransposon loci flanked by bHLH domain-containing or hypothetical genes. Further high-resolution mapping identified 15 rare recombinants between the predicted genes. Marker-assisted progeny testing to determine seed dormancy genotypes for all these recombinants revealed three genes underlying the major QTL, designated *SD12a*, *SD12b,* and *SD12c*. Genomic and cDNA sequence analyses suggest that *SD12a* and *SD12c* encode predicted bHLH domain-containing transcription factors while *SD12b* encodes a hypothetical protein. Alleles that enhance seed dormancy at all these three loci are donated by the weedy line SS18-2 originated from Thailand. Haplotypic analysis for the QTL complex-containing region using 586 accessions of wild (77, *O. rufipogon*), weedy (73), and cultivated (436, mainly landraces) rice demonstrated that the SS18-2-like haplotype is not present in the tested genotypes, suggesting that the major QTL may have been differentiated before domestication and all or part of the three tightly linked seed dormancy genes may have been eliminated at the beginning of the domestication. Tissue-specific expression analyses using genetic and molecular biology approaches revealed that all these three genes are expressed in developing embryos to regulate the seed dormancy development. RNA-sequence analysis identified a pool of candidate genes (~465) differentially expressed in developing embryos from three isogenic lines; and the downstream genes mainly consist of those with predicted functions for responses to abiotic stimuli and late embryogenesis abundant proteins.

This is the first report that a major QTL for such a domestication-related trait as seed dormancy could be underlain by tightly linked genes regulating germination capability through the embryo tissue. Most likely, the *qSD12* QTL differentiated before rice domestication and the genes enhancing embryo dormancy are rare in available breeding germplasm. The genetic/genomic structure of the major QTL and its underlying genes identified from this research provide a unique model to explain evolutionary and developmental mechanisms of seed dormancy in grass species and candidate genes to manipulate germination capability in breeding programs of the rice crop.

Using GWAS to Identify SNPs Associated with Rice Seedling Cold Tolerance

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Cold tolerance at the seedling stage is important for stand establishment when rice (*Oryza sativa* L.) is planted in cold water or under the cool temperatures that occur early in the growing season in temperate regions or at high elevations in the tropics. In these regions, the average temperature for germination and seedling growth is 15 to 17°C while the optimum temperature at these stages ranges between 25 to 30°C. If seedling cold tolerance is improved, rice could be planted earlier in the growing season in these regions with reasonable germination and limited seedling injury, resulting in respectable stand establishment.

The Rice Diversity Panel 1 (RDP1) composed of 421 accessions represents the five major subpopulations of rice including *aus* (60 accessions), *indica* (95), and admixture of *Indica* (11) representing the *Indica* subspecies, and *aromatic* (Group V) (16), *tropical japonica* (106), *temperate japonica* (111), and admixture of *Japonica* (22) representing the *Japonica* subspecies. The objectives of this study were to 1) screen the RDP1 for seedling cold tolerance using the "ragdoll" method, 2) measure the coleoptile elongation of the *Japonica* RDP1 accessions under cold stress, and 3) conduct genome-wide association studies (GWAS) to identify SNP (single nucleotide polymorphism) markers associated with seedling cold tolerance.

To screen the RDP1 using the ragdoll method, 420 accessions and three control accessions representing high (Quilla 66304), intermediate (Lemont), and low (Zhe 733) cold tolerance were arranged in a randomized complete block design (RCBD) with three cold replications and two warm replications. To achieve this, 10 ragdolls (seven different accessions and three controls) containing 30 sterilized seeds of a given accession were randomly placed in a tray (or block) and wet with sterile deionized water. Three trays were assigned to the cold temperature treatment in an incubator set at 12°C for 35 days and the remaining two trays were assigned to the warm temperature treatment in an incubator set at 30°C for 5 days. After incubation, the seeds were placed into one of three categories based on coleoptile length: >5 mm long, <5 mm long, or no germination. The contaminated seed were noted and removed from the analyses. For this analysis the adjusted mean for cold tolerance was calculated as the ratio of the percentage of the seed with coleoptiles >5mm in the cold treatment divided by the percentage of the seed with coleoptile length >5 mm in the warm treatment. Similarly, the cold germination rate was adjusted for seed viability calculated as the percent cold germination (all seeds that had a coleoptile) divided by the percent seed viability (all seeds that germinated in the warm treatment). This screening revealed only 17.7% of the *Indica* accessions were highly cold tolerant, whereas 51.5% of the *Japonica* accessions, excluding the *aromatic* (Group V) accessions, were tolerant, with coleoptile lengths >5 mm.

GWA analysis was conducted using TASSEL software (www.maizegenetics.net/) with SNP genotypes based on 36,901 high quality SNPs, available from the web site: www.ricediversity.org. Among all the accessions tested, the higher cold tolerance revealed marker-trait associations on chr. (chromosomes) 1S (short arm) and 2S and improved cold germination associations on chr. 1S, 1L (long arm), 2L, and 9L. In *Indica*, marker-trait associations were found on chr. 2S, 8S, 9S, and 12S for the higher cold tolerance and on chr. 1S, 1L, 2S, 2L, 7L, 8L, and 11L for better cold germination. In *Japonica*, excluding *aromatic* (Group V), associations were identified on chr. 1L, 2L, 4L, and 12S for high cold tolerance and chr. 2L, 4L, 7L, 9L, 11L, and 12L for improved cold germination. Many of these associations were located in the region of previously reported QTLs for cold tolerance.

To further dissect the cold tolerance in the *Japonica* accessions which exhibited more tolerance overall, 235 accessions were germinated following the RCBD previously described. Changes to the method were: a) instead of preparing a ragdoll, 10 seeds were placed on germination paper, which was rolled to fit in a 50 ml centrifuge tube; b) tubes were placed upright in a test tube rack (block) instead of a tray, so the coleoptile would grow straighter, making it easier to measure; and c) six random accessions and the same three controls were included in each block. When the incubation time was completed, the rolled paper was removed from the tube and a digital image was taken of the 10 seed in the given block. The coleoptile length of each seed was measured digitally using ImageJ, an image processing program. The mean coleoptile length for each accession in the cold treatment was adjusted for germination using the signal to noise ratio. GWA mapping revealed marker-trait associations on chr. 1L and 2S. Additional GWAS will be conducted using the 700,000 SNP genotypes generated from the high density rice array.

Use of the Rice Diversity Panel 1 to Map Traits Important for Rice Improvement

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Agosto-Perez, F.J., DeClerck, G.A., Mezey, J.G., and McCouch, S.R.

The 'Rice Diversity Panel 1' (RDP1) is composed of 421 diverse *Oryza sativa* accessions from 79 countries, including *indica* (95 accessions) and *aus* (60), which belong to the *Indica* varietal group, and *tropical japonica* (106), *temperate japonica* (111), and *aromatic* (Group V) (16) which comprise the *Japonica* varietal group. Thirty-three accessions are classified as admixtures because they share <60% ancestry with any single group. This panel was previously genotyped with 36 SSR (simple sequence repeat) markers, an Illumina 1536-SNP OPA with 1,311 high-quality single nucleotide polymorphisms (SNPs), and an Affymetrix custom-designed genotyping array with 36,901 high quality SNP genotypes. Currently, the SNP genotypes from a second Affymetrix custom-designed array identified as HDRA (high density rice array) are being finalized that will result in about 470,000 high quality SNPs useful for genotyping the *O. sativa* accessions. It is estimated that the number of useful SNPs will range from approximately 143,000 SNPs for *temperate japonica* accessions to 359,000 SNPs for *indica* accessions. The 'Rice Diversity Panel 2' (RDP2) composed of an additional 1,411 accessions, developed at the International Rice Research Institute, is currently being introduced into the USA and genotyped with the HDRA.

The RDP1 was characterized for several agronomic, morphological, developmental, and physiological traits and has been used in genome-wide association studies (GWAS) conducted using the initial Affymetrix SNP array. Currently, these analyses are being re-evaluated using the HDRA genotypes to discover additional marker-trait associations. In addition, we recently evaluated the RDP1 for seedling cold tolerance by measuring coleoptile elongation using two different methods. The results of this study and the GWAS are described in the Shakiba et al. abstract.

Seed of all accessions is available from the Genetic Stocks-*Oryza* (GSOR) collection and all SNP genotypes can be downloaded from the web site (www.ricediversity.org); those from the HDRA will be available after publication. Digital images of the seed, with and without the hull, can be viewed in the Seed Photo Library (rice diversity.org), and an individual panicle of each accession, as well as, means of the phenotypic traits, and SSR marker data including those for blast and grain quality, can be downloaded from the GSOR website. These RDP1 resources will allow interested rice researchers to (a) conduct GWAS on a trait(s) of interest without the expense of genotyping, (b) verify seed identify, and (c) develop mapping populations to validate GWAS results for the trait(s) of interest.

The RDP1 was characterized for three grain quality traits: apparent amylose content (AC), gelatinization temperature as measured by alkali spreading value (ASV), and protein content. Canonical discriminant analysis (CDA) revealed AC was the quality trait most closely correlated with subpopulation structure, followed by ASV. These traits indicate that *temperate japonica* was the most distinct group, whereas *aus* and *indica* could not be differentiated, and the *aromatic* accessions were closest to *tropical japonica*. The CDA of these grain quality traits and the previously analyzed 18 agro-morphological traits, confirmed that although there is significant variability within each of the five rice subpopulations, they can be differentiated on the basis of numerous traits, including plant height, number of panicles per plant, panicle length, and seed shape, as well as on cooking and eating qualities.

To validate the results of GWAS, four bi-parental RIL mapping populations within *Japonica* were developed. Three of these populations are in the F_8 generation and the fourth in the F_6. 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-to-width ratio, and seed weight. The Estrela (*tropical japonica*)/NSFTV199 (*tropical japonica*) population was evaluated in the field during 2013 and will be evaluated a second year in 2014. This population will be genotyped, most likely, using GBS (genotyping-by-sequencing) technology. For additional information on these populations, refer to the Hancock et al. abstract.

Identification of QTLs that Enhance the Nutritional Value of Rice Grain and Limit Accumulation of Undesirable Elements Such as Arsenic

Pinson, S.R.M., Tarpley, L., Yan, W., Norton, G., Zhang, M., 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 grain/food products through traditional breeding. Since this approach does not require genetic engineering, it is acceptable to many consumers and is compatible with organic labeling. 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 or Cd. The first step toward targeted breeding is the identification of genes responsible for orchestrating concentrations of various elements in the rice grain.

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. Genetic loci were mapped among several progeny populations from biparental crosses as well as among two sets of diverse rice accessions (SNP Diversity Panel 1and the USDA MiniCore). To increase opportunity to detect and characterize grain-element QTLs, the study populations were grown under two contrasting field redox conditions, flooded (reduced soil chemistry) and unflooded (flush-irrigated to maintain aerated soil chemistry while preventing water stress). Soil redox is known to often alter element availability and was expected to affect grain element concentrations. Inductively coupled plasma – mass spectrometry (ICP-MS) was used to analyze the harvested brown rice for variation in accumulation of 16 elements, namely As, Ca, Cd, Co, Cu, Fe, K, Mg, Mn, Mo, Ni, P, Rb, S, Sr, and Zn. Correlations among the individual elements and between each element with grain shape, plant height, and time of heading were studied. When the elements were considered individually, more than 150 grain-element QTLs were identified. However, in agreement with known shared transporters and element networks, many of the QTLs were co-located or clustered into 40 chromosomal regions associated with grain concentration of more than one element. Grain shape, heading time, and plant height proved to have little direct influence on rice grain element concentrations. Numerous element x element patterns were found, including strong positive correlations between P, Mg, and K. The two elements most strongly affected by soil flooding were As and Cd, with grains produced in flooded fields containing 30x higher concentrations of As but 10x lower Cd than rice produced in aerated soils.

Fifty accessions exhibiting extreme concentrations of one or more grain elements were selected from among a set of 1,700 accessions to be used in further gene-mapping, agronomic, and physiological studies. Analysis of seed from F_2 progeny from some of these crosses reveal 1:2:1 or 3:1 segregation ratios, suggesting that, at least in some accessions and for some elements, single major genes affecting grain element concentrations can be found. Rice accessions in the *indica* ancestral lineage showed higher grain concentrations of most elements than other rice lineages, including arsenic, while *japonica* accessions showed higher average grain concentrations of Cd, Cu, Fe, Mo, and Zn. Principal component analysis identified six elements (P, K, Mg, As, Cu, and Fe) as key to explaining most of the variance among the 1,700 diverse rice accessions, with the same six elements proving significant regardless of ancestral lineage or flooding condition.

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 elements up from the soil. Variation in grain elemental concentrations was not strongly associated with plant height, heading time, or grain shape, suggesting that variation for these traits will not confound efforts to identify genes for other mechanisms, such as element transporters. Because rice can be grown under both flooded and unflooded field conditions, and metal transporter proteins and genes have been shown orthologous between species as diverse as Arabidopsis, rice, and yeast, knowledge of the genetic and environmental factors affecting the rice grain elemental concentrations (ionome) can have applications well beyond rice.

Identification of Genetic Loci Underlying the Kernel Fissure-Resistance Exhibited by 'Cypress' and 'Saber'

Pinson, S.R.M., Gibbons, J., and Jia, Y.

The economic value of broken rice is about half that of whole milled rice, so one goal of producers, millers, and rice breeders is to increase the ability of the rice kernel to remain unbroken during the dehusking and milling processes. One of the primary causes of rice breakage is fissuring, or cracking, of the rice before it 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 kernels to reabsorb moisture. Fissures may be caused by rain or dew in not-yet-harvested fields. A few rice varieties produce grain more resistant to fissuring than others, and breeders would like to incorporate these genes into improved rice varieties. Identifying breeding progeny containing the desired genes is difficult, however, for traits such as kernel fissuring that are highly sensitive to variable environmental effects. Identification of molecular gene-tags to support marker-aided breeding selections is especially beneficial for environmentally sensitive traits.

Marker-assisted selection (MAS) is based on the principle that when markers linked to a gene affecting a desired trait are selected, the physically linked trait is also in selected individuals. The present study took advantage of the fact that the reverse also holds true and was accomplished by selecting for fissure resistance (FisR) versus fissure susceptibility (FisS) among the progeny of two populations, then identifying molecular marker alleles that were present in different proportions between the FisR and FisS subgroups. We identified marker-gene linkages in two populations, because identification of the same genes in multiple populations and environments increases confidence in those genes and enhances our knowledge as to which genes will be most effective under a variety of genetic and field conditions, i.e., the genes most useful to breeders and the industry.

The first study population was a set of 300 F_2s from a cross between 'Cypress' (FisR) and 'LaGrue' (FisS). Cypress is also a semidwarf whereas LaGrue grows to a taller plant height. We expected to find segregation for plant height among the Cypress x LaGrue progeny, but what was not anticipated was that all of the most FisR F_2 and F_3 progeny were of semidwarf height, while the FisS progeny were generally tall in height, suggesting the presence of a FisR gene near the sd1 gene on chromosome 1. Linkage between Cypress' FisR and sd1 was confirmed by non-random distribution of several molecular markers along chromosome 1 among the FisR and FisS Cypress x LaGrue progeny. This raised the question of whether FisR was due to a different gene physically linked to the sd1 gene on chromosome 1, or if FisR was a secondary effect of the semidwarf gene itself, for example, caused by the distance between the grains on the plant and flood water during grain-fill. Non-random marker distribution among the Cypress x LaGrue progeny detected a FisR locus on chromosome 8 as well as on chromosome 1.

The second QTL mapping population was derived from a cross between the variety 'Cybonnet,, which inherited its hull-related FisR from Cypress, and 'Saber,' a variety which was previously shown to have a FisR mechanism that was not hull-related, and thus different from that in Cypress and Cybonnet. This population consisted of 280 recombinant inbred lines (CbSa-RILs), which, being pure-breeding, allowed us to use replication across years and locations to obtain better estimates of FisR of each of the progeny lines (two replications each for TX2007, AR2007, and TX2009). Furthermore, because Cybonnet and Saber are both semidwarf in height, study of this population allowed us to evaluate the FisR genes from Cypress in a genetic environment (population) where differences in plant height did not exist. The 280 CbSa-RILs were molecularly characterized using a SNP chip designed to identify polymorphisms between japonica genotypes. Of the 384 SNPs, 28 proved noninformative due to both parents being either null or heterozygous at that locus, 212 were polymorphic, and clustering among the 144 monomorphic SNPs suggested several genomic regions to be identical by descent between Cybonnet and Saber, which are known to share ancestors. The QTL regions previously identified on chromosomes 1 and 8 were further saturated with the addition of 20 SSR loci. QTL mapping among the 280 CbSa-RILs confirmed the existence of three FisR alleles originating from Cypress, two on chromosome 1, and one on chromosome 8. The fact that the CbSa-RILs did not segregate for plant height but again showed linkage between markers linked to sd1 and FisR clarified that a FisR gene is linked to but not allelic with the sd1 locus. The FisR QTLs contributed by Cybonnet (and originating from Cypress) were all of higher confidence (LOD score) and larger phenotypic effect than those originating from Saber, which mapped to chromosomes 5, 10, and 12. Grain shape QTLs were also located on these same chromosomes. However, shape does not appear to be a large driving factor of Saber's FisR in that the single largest QTL for grain shape, on chromosome 3, was not associated with FisR. The markers we identified as linked to the FisR genes from Cypress and Saber can be used by breeders to improve the incorporation and stacking of these FisR alleles into improved U.S. rice varieties via MAS.

Development and Preliminary Evaluation of Molecular Markers for Sheath Blight Resistance in Rice

Sanabria, Y., Groth, D., Linscombe, S.D., Galam, D., de Guzman, C., Esguerra, M., Camacho, R., and Oard, J.

Various strategies, such as QTL mapping, genomic selection and genotype by sequencing, have been proposed to identify molecular markers and superior individuals for plant improvement. An alternative strategy has recently exploited filtering of genomic data to identify variants associated with Mendelian disorders in humans. Based on success in recent human studies, the objective of our research is to identify nsSNPs and other variants associated with sheath blight (SB) resistance in rice using a modified genomic filtering approach for 13 elite rice lines. Genomic filtering was used to identify variants between contrasting phenotypes for SB resistance with subsequent evaluation in the SB2 doubled haploid segregating population and > 30 inbred lines. Crosses between SB resistant and susceptible varieties were carried out to generate 1,866 BC_1F_1 plants that were advanced to create 768 BC_2F_1 populations based on selected markers and whole plant phenotypes. A total of 58 selected lines containing different combinations of putative resistant SB alleles were used to develop > 400 doubled-haploid lines. Future research will focus on evaluation of our doubled-haploids and various inbred lines under different field and greenhouse environments.

Weedy Red Rice as a Model for Breeding and Genetic Studies

Subudhi, P.K., De Leon, T., Parco, A., Singh, P., Karan, R., and Cohn, M.

Red rice is a weedy form of rice characterized by high genetic flexibility and phenotypic plasticity. It is a dangerous annual weed closely related to cultivated rice and is prevalent in most rice growing states in the southern United States, Europe, and Central and South America where no wild or weedy relatives are prevalent in natural habitat. It poses significant constraints to rice productivity and losses from red rice in the United States have been estimated at 50 million dollars annually. Since red rice is a great reservoir of useful genes such as seedling vigor, cold tolerance, competitive ability, nitrogen use efficiency, improved root attributes with the added advantage of being well-adapted to southern US rice areas, systematic effort is needed to discover such valuable genes to boost rice productivity. Due to its free intercrossing with domesticated rice and availability of abundant genomic resources including annotated genome sequence, red rice was used as a model to facilitate genetic investigations. Our long-term goal is to increase the utility of red rice for rice improvement by exploring the molecular basis of a number of quantitative traits that are responsible for its weedy behavior as well as improved agronomic performance.

Two recombinant inbred line (RIL) populations were developed from crosses involving two rice cultivars (Bengal and Cypress) and a red rice accession PSRR-1. A set of chromosome segment substitution lines of PSRR-1 was developed in Bengal cultivar background. These mapping populations were evaluated in field condition and observations were recorded on seed dormancy, seed shattering, and days to heading.

Several quantitative loci for these traits were identified in RIL populations. Evaluation of these traits in the CSSL population resulted in validation of some QTLs and discovery of new QTLs. Four seed dormancy QTLs two seed shattering QTLs were consistent in both populations. Both QTL number and the magnitude of QTL effects were influenced by genetic background. The genetic architecture for seed dormancy in US red rice was distinct compared with the earlier reported weedy accessions. The variation in seed dormancy among the rice cultivars could be due to segregation of minor QTLs, which should be manipulated to improve preharvest sprouting tolerance. Although the major QTL on chromosome 4 overlapped with s*h4*, the presence of the non-shattering SNP allele in the weedy rice accession suggested involvement of a linked locus or an alternative molecular genetic mechanism. Natural hybridization of rice cultivars with the highly variable *O. rufipogon* present in different geographic regions might be responsible for the evolution of a wide range of phenotypic and genotypic variability seen in weedy rice populations worldwide. Analysis of the days to heading and photosensitivity revealed that day neutral nature of the weedy rice accession used in our study may be due to genetic interaction involving *Hd1* and some other unknown genes.

Compared with phenotypic evaluation, exploration at the genome level is more efficient and reliable to discover novel genes in wild and weed species. Understanding the genetic basis of hidden diversity underlying important agronomic traits using genomic tools and the developed genetic resources will facilitate exploitation of weedy rice in rice breeding programs.

Genetic Diversity and Evaluation of U.S. Southern Rice Genotypes for Salinity Tolerance

De Leon, T., Linscombe, S.D., Gregorio, G., and Subudhi, P.

To develop rice varieties with salinity tolerance, it is important to understand the salinity response and the genetic profile of the rice materials at hand. In this study, the specific objective is to assess the genetic diversity and salinity tolerance of the 30 U.S. Southern rice varieties along with twenty more rice genotypes with varying degree of salinity tolerance. Screening was conducted during seedling and reproductive stages. Morphological, physiological, and biochemical were measured during seedling screening. Panicle length, grain weight, and sterility were evaluated during reproductive stage. Salinity responses of known genotypes were validated indicating the reliability of our seedling screening. Results showed that chlorophyll reduction, shoot length reduction, ion leakage, and shoot sodium-potassium ratio are positively correlated to the visual salt injury scoring while shoot potassium concentration is negatively correlated. Cluster analysis using these six quantitative traits classified most of the U.S. varieties into susceptible group with six varieties placed to moderately tolerant group. Visual scoring, however, identified LAH 10 and R609 as moderately tolerant. In the reproductive screening at salinity level of 8.8 dSm^{-1}, panicle length, grain weight, and sterility were greatly affected by salinity stress. The U.S. varieties were less affected as compared to the rice genotypes with seedling salinity tolerance. The grain weights in the U.S. varieties were reduced by not more than 30%; sterility ranges from 10 to 60% while panicle length reduction ranges from 0-35%. Percent reduction in grain weight is positive and highly correlated to percent sterility. The salinity responses of the rice genotypes during seedling stage are not correlated with their reproductive responses. Since salinity is less damaging to rice plants during reproductive stage, it is better to develop salinity tolerance during seedling stage. Genetic diversity indicated a narrow variability among the U.S. varieties. Since Pokkali and Nona Bokra are photosensitive landraces; dwarf and day neutral rice cultivar Geumgangbyeo can be used for development of salt tolerant varieties in the rice breeding program.

Field Performance of Marker-Assisted and Introgression Rice Lines

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

Marker-assisted selection and introgression for a number of important traits in rice have resulted in the development of advanced breeding lines. The use of molecular markers to evaluate important traits, simple and complex quantitative traits, has grown exponentially in the last two decades following the advancement in various aspects of genomic technology. Marker-assisted selection (MAS) becomes a routine procedure in many breeding programs of major grain crops. Linkage Disequilibrium between DNA markers and qualitative trait loci (QTLs) provides a basic principle of MAS that marker alleles are not randomly associated with QTL alleles. Molecular markers and other genomic information provide a direct way of selecting trait-associated genes at the DNA levels prior to the trait expression at the phenotypic level, alleviating possible confounding environmental effects. MAS helps improve the efficiency of genetic selection and, therefore, improve the overall breeding program. Gene introgression and pyramiding are common uses of markers and considered as one of the most successful practical uses of markers for a number of major genes or QTLs in the breeding programs. Genome sequence maps of many grain crops are publicly available, and they are a critical resource for advancing MAS. User-friendly genome browsers greatly help access the available data and mine the genome information. Publicly available markers for a number of important traits were used and incorporated into MAS in the development of new breeding lines. Grain quality, nutritional value, disease resistance, adaptation to less favorable conditions, and grain aroma are specific traits that are incorporated through marker breeding to develop improved breeding lines. The objectives of this study include developing breeding lines through marker-assisted breeding and introgressing important traits, such as aroma from Basmati/Jasmine rice and generate progeny backcross lines carrying target traits, and evaluate promising lines in preliminary yield (PY) and the commercial advanced (CA).

Standard protocols previously developed in the lab were applied in molecular marker work, from DNA isolation and PCR reactions to marker identification. Both SSR and SNP markers were used in the process. Advanced lines developed from marker-assisted selections were placed in the CA trials in four testing locations, Evangeline, Vermilion, and Jeff Davis parishes and the Rice Research Station near Crowley. Each location represents a different environment to allow entries to be evaluated in different planting dates, soil types, climatic conditions, management systems, disease pressure, and other variables. No fungicides were used, but standard agronomic practices were applied in individual locations. Traits evaluated include grain yield, whole and total milling percentages, seedling vigor, maturity, plant height, and lodging resistance.

In addition to utilizing markers originated from the U.S. rice background, marker-assisted breeding can also be conducted to include introgression of important genes, such as drought tolerant, cold tolerant (at seedling stage), salt tolerant, aroma (Jasmine), grain weight, and panicle blight-resistant genes from outside the U.S. genetic pool into adapted Louisiana cultivars and breeding lines. The marker-assisted selections were focused on the early generations of F_2 and F_3 lines. Lines containing fixed allele for the target genes were grouped to facilitate cost and labor efficiency. For a single gene target, fixed target alleles can usually be obtained through screening of the F_2 or F_3 progeny lines. More elaborate crossing schemes were used for a multiple gene target. The schemes were developed to keep the volume and cost of marker screening at its minimum level. Once the target genes have been fixed, the progeny lines were advanced and subjected to regular breeding selections. The most viable/promising breeding lines were then selected. Lines with high amylose content were verified using SNP makers. Advanced lines possessing grain characteristics commonly found in long-grain cultivars were advanced to multi location trials. Some advanced line performed well in the multi locations trials with good whole and total milling quality and a total yield range of 11,783 to 12,934 kg ha^{-1} (10,513 to 11,540 lbs/ac) compared to cultivar check Cocodrie of 11,645 kg ha^{-1} (10,390 lbs/ac). Among lines with high amylose content that were evaluated in CA and PY tests, they varied substantially in grain appearance. This provides the opportunity to select for the best grain quality. Performance of a subset of these selected lines will be discussed.

Early Screening of Recombinant Inbred Lines for Fissure Resistance in Non-Semidwarf Rice

Sater, H., Moldenhauer, K., Pinson, S., Boyett, V., and Mason, E.

Rice (*Oryza sativa L.*) kernel fissuring poses a major problem for both rice farmers and millers. It results in the decreased value of processed rice because of the increase in the percent broken kernels associated with fissuring. This study employs the use of fine mapping to increase the genetic resolution of fissure resistance traits found in 'Cybonnet,' a tropical *japonica* cultivar, as well as the transfer of these traits to standard height rice plants. Early recombinant inbred lines (RILs) came from a cross between a conventional inbred line with low head rice yield, and fissure susceptibility with 'Cybonnet' which has empirically been determined to have both high head rice yield, as well as fissure resistance. Using putative QTLs identified in previous fissure resistance studies, three regions of the genome were selected for mapping using SSRs to identify recombination. Preliminary screening of individuals was conducted in the F_2 generation. Eleven individual plants were advanced to $F_{2:3}$ based on the following criteria: 1) the individual maintained at least one standard height allele from the inbred parental line 2) the individual possessed recombination in the genomic region identified by Pinson et al., 2013 labeled as *qFIS1-2* where a major fissure resistance QTL was detected. Screening in $F_{2:3}$ will identify targeted individuals which will then be phenotyped. The targeted individuals will be either homozygous for standard height or homozygous for semidwarfism and will possess homozygous recombinant version of the subsequent alleles from 'Cybonnet' in the region trailing *sd-1*. The phenotypic assay to confirm the magnitude of difference between genotypes will use the percent fissured grain from individual genotypes in order to be consistent with those performed by Pinson et al., 2012. Thus, this study aims to quantify the linkage disequilibrium between *sd-1* and *qFIS1-2* as well as the effect of fissure resistance traits, mainly *qFIS1-2,* in standard height rice plants.

Determining Nitrogen Requirements for Aromatic Line Selection in the University of Arkansas Rice Breeding Program

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

Rice imports into the United States have increased by 31% in the last 10 years. Approximately 80% of all imported rice came from Thailand and India in 2011-2012. International research on aromatic rice and nitrogen fertilizer indicates that genotype differences in nitrogen-use efficiency exist. Two international studies found excess nitrogen fertilizer had no effect on grain yield in native aromatic rice cultivars. Information regarding successful cultural practices of aromatic rice varieties is very limited for the southern United States growing regions, especially for Arkansas. The development of an aromatic rice breeding program in the University of Arkansas, Division of Agriculture made evaluating cultural practices essential for the selection of the best lines. 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 (6) nitrogen rates were applied to seven (7) aromatic rice varieties and one (1) non-aromatic rice variety. Agronomic and yield data were collected. Hulled and milled seed were tested for the analysis of 2-acetyl-1-pyrroline (2AP) concentration at the USDA-ARS Southern Regional Research Center, New Orleans, LA. Results of the yield trials showed mixed varietal response to increased nitrogen fertilizer. Some varieties increased in yield while others remained unchanged or decreased with increased nitrogen fertilization. Total rice percentages in the three-year study varied significantly across varieties.

Development and Performance of Blast Resistant Near-Isogenic Lines of Rice in M-206 Genetic Background

Andaya, V.C., Oster, J.J., Andaya, C.B., Jodari, F., Samonte, S.O.P.B., and McKenzie, K.S.

The Rice Experiment Station (RES) located in Biggs, California, initiated a project to develop near-isogenic rice lines (NILs) containing different resistance genes to rice blast (*Magnaporthe grisea*) in the genetic background of M-206, a temperate Japonica medium-grain variety. M-206, a commercial rice variety, is a popular and widely grown variety in the Sacramento Valley and is susceptible to rice blast. Ten blast resistance genes were used in the gene introgression, namely, *Pi1, Pi2, Pi9, Pi33, Pi40, Pib, Pikh, Pikm, Pita2,* and *Piz5*.

Gene introgression was performed using at least seven backcrosses to M-206 using biological screening initially, followed by marker-assisted backcrossing using PCR-based DNA markers. Supplemental blast screening was performed to verify presence of resistance genes in plants used for crossing. The NILs were advanced to homozygosity and given individual designation that specifies the cultivar used and the resistance gene introgressed (*e.g.* M-206+*Pi33*). The agronomic and yield performance of the NILs, M-206, and check varieties were evaluated in replicated field experiments at RES in 2013. Seven of the NILs were also included in select locations of the Statewide Yield Test in 2012 and 2013.

This poster describes the development of the NILs and their performance in comparison to M-206 in terms of a number of agronomic and grain traits. It will also report if there are negative or positive effects of individual blast resistance genes to these measured traits.

Use of Modified Augmented Design (Type II) for Field Testing of Experimental Hybrids

Berger, G.L., Lee, G.J., Beaty, B.A., and Sha, X.

Field testing of a large number of experimental rice (*Oryza sativa* L.) hybrids is necessary to determine the best heterotic combinations that possess excellent yield potential and grain quality. The choice of experimental design for early generation testing is sometimes limited by seed quantity and available space. Often, early generation testing relies on the use of unreplicated designs to test a large number of experimental hybrids which offer little in the way of accounting for experimental error due to field variability.

An alternative to an unreplicated design is the use of an augmented design. In an augmented design, experimental plots are unreplicated while checks are repeated. The goal of a modified augmented design (MAD) (type II) is to allow for testing of unreplicated experimental hybrids while estimating experimental error from replicated checks. The design proposed by Lin and Poushinsky (1989) is structured as a split plot with whole plot arranged in rows and columns. Each whole plot contains five subplots; a check cultivar is assigned to the center subplot in each whole plot. Check cultivars are also assigned to an arbitrary number of subplots which allows for estimation of subplot error.

A MAD (type II) was used to test experimental rice hybrids during 2013 at the Rice Research and Extension Center in Stuttgart, AR. RoyJ was assigned to the center subplot in each whole plot. Wells and Francis were assigned as check cultivars to subplots in three random whole plots to serve as subplot checks. Additionally, five restorer lines were also assigned to two random subplots each. In total, 87 experimental hybrids were tested in unreplicated subplots. Plots were planted on May 29. Seeding rates were 33.6 kg ha^{-1} (30 lbs/ac) for experimental hybrids and 67.2 kg ha^{-1} (60 lb/ac) for checks and restorer lines. Plots were managed using standard rice production practices for Arkansas. Measurements taken for each plot included stand counts, days to heading, plant height, lodging, grain yield, head rice, and total rice. Plots were harvested with a Wintersteiger plot combine fitted with a harvest master weigh system.

The Glimmix procedure in SAS 9.2 was used for analysis of data as described by Lin and Poushinsky (1989). Grain yield values for control plots of RoyJ varied from 9,180 kg ha^{-1} to 12,155 kg ha^{-1} (182 bu/ac to 241 bu/ac), while grain yields of experimental hybrids ranged from 4,186 kg ha^{-1} to 14,829 kg ha^{-1} (83 bu/ac to 294 bu/ac). Row, Column, and Row X Column effects were non-significant (P<0.05). Therefore, adjustment of grain yield for variability was not necessary. This suggests that the MAD (type II) design adequately accounted for field variation.

Molecular Characterization of Parental Lines and Hybrids in a Hybrid Rice Breeding Program

Boyett, V.A., Berger, G.L., Booth, V.L., and Thompson, V.I.

Development of hybrid rice cultivars has been a program at the University of Arkansas Rice Research and Extension Center (UARREC) for over three years. During this time, much effort has been devoted to the phenotypic and genotypic characterization of superior male-sterile (both 2- and 3-line) and restorer lines for use in hybrid development. Over the past three years, experimental hybrids have been developed and evaluated in local and regional nurseries.

In 2013, materials from the UARREC Hybrid Rice Breeding Program were characterized on a molecular level. The objective was to determine the genetic purity of the male-sterile and restorer lines, and allele tracking of the hybrid lines. Twelve male-sterile lines, 22 restorers, and 26 hybrids were analyzed in replicates of 10 with 23 molecular markers. Twelve of the markers were linked to agronomic traits of interest including cooking quality, disease resistance, leaf texture, and plant height. The remaining markers were selected for fingerprinting across the genome. A high-throughput embryo extraction method was used to obtain total genomic DNA from sterile line and hybrid seed. All molecular markers used were PCR-based microsatellite markers or allele-specific single nucleotide polymorphism (SNP) markers. Primers were pre-labeled with attached fluorophores. PCR products were resolved using capillary electrophoresis on an ABI 3730 DNA Analyzer.

The marker data indicated that 25% of the male-sterile lines and 91% of the restorer lines were genotypically pure and ready to use as parental material. Variability was observed for both target and random loci throughout the genome. Of the 12 male sterile lines, three were genotypically pure for target loci including amylose content, gel temp, and aroma. Other male sterile lines were segregating at low to high levels depending on the trait. In general, the restorers were less variable for both target and random loci. Hybridity was confirmed in all 26 experimental hybrid lines.

Development of *Japonica* Mapping Populations to Validate GWAS in the Rice Diversity Panel 1

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

In order to validate associations identified in the Rice Diversity Panel 1 (RDP1) between SNP markers and 34 phenotypic traits, four bi-parental recombinant inbred line (RIL) populations were developed from *Oryza sativa* L. ssp. *japonica* accessions that were phenotypically and genotypically diverse. Three of these populations were grown in the field in Stuttgart, Arkansas, to determine the range of phenotypic variation within each population.

Each population was represented by over 250 F_6 progeny lines grown in an unreplicated field study and data collected for 14 agronomically important traits. Two of the populations, Estrela (*tropical japonica*)/NSF-TV199 (*tropical japonica*) and Norin 20 (*temperate japonica*)/Fortuna (*tropical japonica*), were grown during summer 2012. The third population, L-202 (*tropical japonica*)/Trembese (*tropical japonica*), was grown during the summer 2013. Each population was evaluated using a completely randomized design with one to three parental rows randomly included in each range (tier) as a repeated check. Both parents and progeny lines were planted in rows about 2.2 m long with eight plants per row, 30.5 cm between plants within the row, and 30.5 cm between rows.

Phenotypic data for days to heading, plant type, and plant height were collected on each genotype in the field. One panicle was collected from a single, typical plant in each row to use for generation advancement and for additional phenotypic evaluation of the panicle. Panicles from 20% (50-60 lines) of the progeny from each population were randomly chosen for phenotyping. Data were collected on panicle length, panicle branching, awn presence, shattering tendency, number of seeds per panicle, weight of seeds per panicle, number of blank florets per panicle, seed length, and seed width. Additional phenotypic characteristics were derived from these values (total seeds/florets per panicle, panicle fertility, 100-seed weight, seed length-to-width ratio, seed volume, and seed surface area). Transgressive variation was most apparent where data were collected from every progeny line. However, the extreme range in variation noted in the parents for plant, panicle, and seed traits was reflected in the progeny, although data were taken from only 20% of the progeny.

The Trembese/L-202 parents were similar for days to heading, plant type, branches per panicle, 100-seed weight, and seed surface area; however, the progeny showed a wider range, suggesting transgressive variation. Long awns, a characteristic of Trembese, were present on many of the progeny seeds. Both the parents and progeny showed a wide range in plant height, panicle length, seeds per panicle, seed size, and seed volume.

The Estrela/NSFTV199 parents were extremely divergent for all traits evaluated except panicle length. Of note, Estrela has an open panicle with large seeds, whereas NSFTV199 has a compact panicle with clusters of small seeds. NSFTV199 has a more upright culm habit (tiller angle) whereas Estrela is more spreading with a wider tiller angle. Evaluation of the progeny lines in 2012 demonstrated a wide range in variation between the two types of plants, panicles traits, and seed characteristics, including panicle length, suggesting transgressive variation. This population was selected for a replicated field trial during the summer 2013 because it had limited lodging in 2012, all the progeny matured in the growing season, and it was phenotypically diverse. Phenotypic data are currently being collected on the panicle and seed traits, and we plan to evaluate the population for a second season in 2014.

The Norin 20/Fortuna parents were phenotypically diverse for all traits except panicle fertility and seed volume. This range in diversity was noted in the progeny with some transgressive variation, except for primary branch number per panicle and seed length. Fortuna seed had a tendency to shatter, and this was noted in about two-thirds of the progeny tested. Also, this population exhibited a tendency to lodge in the field. Unexpectedly, some of the progeny lines had purple leaves, purple stems, a deep purple hull color, and long awns. Close examination of seed from the Fortuna parent revealed a slight purple coloration at both ends of the seed where the awn and radicle are located, but no coloration was noted in the Norin 20 parent. Norin 20 has short awns, whereas Fortuna is awnless.

The populations have been advanced and F_8 progeny seed is being produced in the greenhouse to develop RILs for each of the three populations. Leaf tissue has been collected from each F_7 RIL progenitor plant for genotyping, most likely using genotype-by-sequencing (GBS) technology. Currently, F_6 is being produced from a fourth population, Kamenoo (*temperate japonica*)/Estrela (*tropical japonica*).

Response of Selected Rice Germplasm in Aerobic Production System

Harper, C.L. and Tabien, R.E.

Rice is largely grown in flooded fields. About 3,500 to 5,000 liters are needed to produce one kilogram of rice. With the scarcity of water and prevalence of drought year, alternative water saving management options and technologies are being developed and direct-seeded aerobic rice production system is one of them. The system is basically growing rice in well-drained, non-puddled, and non-saturated rice field similar to corn or sorghum production system. The irrigation water applied once in 5-7 days can result to about 60% water saving. Aerobic rice is being grown in large hectarage in Brazil and China and currently being adopted in the Southeast Asian countries like the Philippines and Bangladesh. Previous experiments of growing rice under aerobic conditions have shown great potential to save water but severe yield penalty has been the common concern. This could be resolved by developing a new type of rice that can produce high yields under aerobic conditions with high-production inputs.

Forty selected germplasm from cold and herbicide tolerance screenings were evaluated on non-flooded rice production system (aerobic) with drought stress in 2012, aimed to identify potential donors for aerobic rice development. However, only 24 entries were included in the second year test conducted in 2013. In both years, entries were planted in plots having six 6-meter rows spaced at 20 cm apart and arranged in randomized complete block design with two replications. Irrigation water was applied when some entries showed leaf rolling. Data on flowering and maturity date, plant height, grain yield and milling traits (percent total and milled rice) were gathered.

Results showed significant variation among 24 genotypes for most of the traits measured. Heading ranged from 78 to 117 days and plant height ranged from 39-109 cm. Main crop yield ranged from 2,349 kg ha^{-1} to 5,860 kg ha^{-1}. The percent total milled rice had a narrow range of 68-69% but percent whole grain (head rice) was wider, with a range of 36-57%. The genotype x year interaction was also significant, indicating that environment greatly affects performance of the genotype. Ranking on yearly grain yield showed that six entries were consistently among top 10 and four was always in top five high yielding entries. Nine entries had at least 55% head rice in two years but only one was among the top 10 high yielding genotypes. Correlations analysis among means showed that days to heading was negatively correlated with percent total milled rice (-0.50) while plant height was positively correlated with percent head rice (+0.52). Although not significant, early heading and maturing genotypes tend to have high grain and head rice yield. Yield and milling traits showed potential donors for aerobic production system with drought.

Fast-Throughput Screening Method for 2-Acetyl-1-Pyrroline (2AP) for Rice Flavor Breeding Trials

Hopfer, H., Jodari, F., Negre-Zakharov, F., and Ebeler, S.E.

Despite the US exporting large amounts of rice, the demand for aromatic rice varieties (e.g. Basmati) is mostly covered by rice brought into the US from countries such as India and Pakistan. Breeding aromatic rice varieties that could be grown in the US is of high importance to deliver US alternatives to imported aromatic rice. Aromatic rice varieties have typically higher amounts of one impact flavor compound – 2-acetyl-1-pyrroline (2AP). 2AP is formed in every rice variety, but only the aromatic varieties lack the enzyme that degrades 2AP; these varieties thus accumulate 2AP to an extent that is sensorially perceivable. Therefore, measuring the 2AP content in rice provides a good estimate for the aromatic properties of rice.

2AP has a very low aroma threshold, meaning that it is detectable in very small quantities (threshold in air is 0.02 ng/L). Additionally, 2AP is a known Maillard reaction product, generated when reducing sugars and amino acids are exposed to heat, such as in baked white bread or cooked rice. The measurement of 2AP in uncooked rice has therefore two major implications; first, the method needs to be sensitive, able to detect and quantify 2AP at and below the sensory threshold, and secondly, the method cannot introduce any heating of the sample to avoid 2AP generation due to Maillard reaction processes. Additionally, for the screening of breeding trials with only small sample quantities available, ideally the method should measure 2AP in single rice kernels.

In the past, gas chromatography (GC) with either a flame ionization detector (FID) or a mass spectrometry (MS) have been utilized for the determination of 2AP in rice, but all these methods used large quantities of rice and/or involved heating the samples to 80°C or higher. In this work, we developed a fast and sensitive screening method for the detection of 2AP in single rice kernels, using headspace solid phase microextraction with GC tandem mass spectrometry (HS-SPME-GC-MS/MS). The method development was focused on high throughput for the screening of aromatic rice breeding trials, resulting in a total analysis time of 15 min per sample.

2AP was quantified in raw rice kernels with a stable isotope ([$^{2}H_4$]-2-acetyl-1-pyrroline (d4-2AP)) as internal standard, overcoming the problems associated with the previously used 2,4,6-trimethyl-1-pyridine (TMP). A single rice kernel or 1 g of rice kernels was weighted into sample vials, spiked with the internal standard and measured in quadruplicates.

Calibrations were linear between the concentrations of 53 and 5,380 pg/g. The limit of detection (LOD) was 39 pg/g with a signal-to-noise ratio of 3:1.

Recovery and reproducibility were determined by spiking two different levels of known concentrations of 2AP into an aromatic rice variety (A-301). Recoveries were between 95 and 120% (average = 109% ± 9% (s.d.), n = 4) when samples were spiked with 5.42 ng/g 2AP and between 106 and 114% (average = 112% ± 5% (s.d.), n = 4) when spiked with 538 pg/g 2AP. Using the developed method, we screened 48 aromatic and non-aromatic, milled rice varieties from three harvest years for their 2AP content.

Straighthead and Grain Yield of Twelve Conventional and Twelve Hybrid Cultivars in a Silt Loam Field of Straighthead Natural Occurrences

Huang, B., Yan, Z., Yan, W., Berger, G.L., Deren, C.W., Zhou, W., Li, Y., and Ntamatungrio, S.

Straighthead disorder often results in grain yield dramatically reduced in rice. This disease is typically characterized by spikelet sterility, so that the panicles become blank and remain upright at maturity. Straighthead could occur every year with an increasing frequency recently in Arkansas where about 50% of the US rice is produced. The exact cause of straighthead is unknown, and the current water management practices to prevent straighthead dramatically increase productive cost to rice growers and waste water resources. Therefore, breading straighthead resistant varieties to control this disease using genetics is very important research area because saving productive cost could benefit the growers and saving water resources could benefit the environments.

Twelve conventional cultivars and 12 hybrid breeding lines were selected from our previous studies for evaluating the straighthead resistance in a natural silt loam field in the farm of UAPB (University of Arkansas at Pine Bluff) where the rice straighthead naturally and repeatedly occurred in the past years. The 24 accessions were planted at three dates, 10 days apart, and three replications at each date. The variations of grain yields, 1000-grain weight, panicals/plant, and grains/panical were all significant among the 24 accessions and three planting dates ($P<0.001$). However, seed set rates were not significantly different among the 24 accessions. The hybrid lines had higher yields for planting date 1 ($P=0.020$) and date 3 ($P=0.025$) than the conventional cultivars. The grain weight/plant and grains/panical of the hybrids were higher ($P=0.008$ and 0.006, respectively) than those of the conventional cultivars. Data are still under the collection at present, and complete results will be reported in the meeting.

Development and Performance of Blast Resistant Near-Isogenic Lines of Rice in M-206 Genetic Background

Andaya, V.C., Oster, J.J., Andaya, C.B., Jodari, F., Samonte, S.O.P.B., and McKenzie, K.S.

The Rice Experiment Station (RES) located in Biggs, California, initiated a project to develop near-isogenic rice lines (NILs) containing different resistance genes to rice blast (*Magnaporthe grisea*) in the genetic background of M-206, a temperate Japonica medium-grain variety. M-206, a commercial rice variety, is a popular and widely grown variety in the Sacramento Valley and is susceptible to rice blast. Ten blast resistance genes were used in the gene introgression, namely, *Pi1, Pi2, Pi9, Pi33, Pi40, Pib, Pikh, Pikm, Pita2,* and *Piz5*.

Gene introgression was performed using at least seven backcrosses to M-206 using biological screening initially, followed by marker-assisted backcrossing using PCR-based DNA markers. Supplemental blast screening was performed to verify presence of resistance genes in plants used for crossing. The NILs were advanced to homozygosity and given individual designation that specifies the cultivar used and the resistance gene introgressed (*e.g.* M-206+*Pi33*). The agronomic and yield performance of the NILs, M-206, and check varieties were evaluated in replicated field experiments at RES in 2013. Seven of the NILs were also included in select locations of the Statewide Yield Test in 2012 and 2013.

This poster describes the development of the NILs and their performance in comparison to M-206 in terms of a number of agronomic and grain traits. It will also report if there are negative or positive effects of individual blast resistance genes to these measured traits.

Elucidation of Molecular Dynamics of Invasive Species of Rice

Liu, Y**.**, Qi, X., Vigueira, C., Jia, M.H., Jia, Y., Gealy, D., Olsen, K., Caicedo, A., and Burgos, N.

Cultivated rice fields are aggressively invaded by weedy rice in the U.S. and worldwide. Weedy rice results in loss of yield and seed contamination. The molecular dynamics of the evolutionary adaptive traits of weedy rice are not fully understood. To understand the molecular basis and identify the important genes /quantitative trait loci (QTLs) which are associated with weedy traits, two recombinant inbred line (RIL) populations were made between two weedy rice ecotypes, a straw hull weedy rice type 1135-01 (RR9) and a black hull type 1996-9 (RR20), and a putative evolutionarily close relative, the Asian *indica* rice variety Dee Geo Woo Gen (DGWG). The populations derived from the cross of RR9 and DGWG and the cross of RR20 and DGWG consist of 185 and 234 individuals, respectively. Both F_5 RIL populations were genotyped using next generation Genotype by Sequencing (GBS) method. The phenotype of nine traits including emergence date, heading date, chlorophyll content, seed shattering, plant height, plant type, panicle type, panicle length, and awns of two F_6 and F_7 RILs populations were evaluated in replicated field plot experiments in the summers of 2012 and 2013. Seed traits of one RIL population from the cross of RR20 and DGWG, including bran color, grain length, grain width, and kernel weight, are being evaluted in the lab using 2312 Graincheck. Disease reactions of all individuals of both RIL populations to the common races of U.S. rice blast, *Magnaporthe oryzae*, field isolates, IB54, IE1(ZN13), IE1K (TM2), ID1 (ZN42), and IB33, were determined in a greenhouse. Seedling height and culm color of all the RILs from the two populations were also evaluated in the greenhouse. The genomic regions associated with agronomic traits and with resistance to rice blast disease are being established by associating phenotypic and genotypic data generated using GBS. The haplotypes harboring important candidate gene(s) within QTLs are being analyzed and the co-segregation of molecular markers are being identified for important traits. The genetic basis of beneficial traits for crop improvement, insights into the molecular dynamics of the evolution of invasive weedy biotypes, and the implications for weed management will be presented.

Yield Performance of Cultivars Released by the Rice Experiment Station

Samonte, S.O.P.B., McKenzie, K.S., Jodari, F., Oster, J.J., Andaya, C.B., and Andaya, V.C.

Rice productivity per unit area has been increasing over the years. This has been attributed to better management practices, such as for soil fertility, water, insect pests, diseases, and weeds, and also to improved rice cultivars. Rice grain yields in California are the highest in the United States, and these have increased from 5,348 kg/ha in 1960 to 9,352 kg/ha in 2011 based on USDA-ERS data published in 2012.

The primary mission of the California Cooperative Rice Research Foundation, Inc. (CCRRF), Rice Experiment Station (RES) in Biggs, CA, is to develop improved rice cultivars for all grain and market types and to sustain high and stable grain yield and quality with minimum environmental impact for the benefit of California rice growers. The objective of this study was to determine the grain yield increase rate due to semidwarf cultivars released by the RES from the 1970s to the 2000s.

In 2012, 25 semidwarf cultivars released by RES were planted in plots at two sites within the station. These included L-206, M-205, M-206, and S-102, which produced mean grain yields of 11,838, 11,931, 11,424, and 10,567 kg/ha, respectively, in Statewide Yield Trials at RES in 2012. Planting was done by wet-seeding in site 1 and drill-seeding in site 2. These plots served as sampling units for a preliminary study that compared rice cultivars released by RES for California. This study determined the changes in grain yield and yield- and quality-related traits of released cultivars. This poster, however, focused on the analyses of the grain yield trends of mostly conventional long-, medium-, and short-grain cultivars.

Grain yields differed significantly among cultivars, ranging from 9,062 kg/ha for Calrose-76 to 12,030 kg/ha for M-206. Cultivar releases have increased grain yields significantly. Grain yield increase rate due to cultivar releases was estimated at 60 kg/ha/year. This rate, however, is a preliminary estimate based on one year's data. To account for common genotype x environment interactions that occur in yield trials, a second year of experimentation needs to be conducted. Results from this study will not only be useful in analyzing past rice cultivars but will also be useful in planning and breeding cultivars for the future.

Weather Data, Main Crop Yield, and Milling Traits in Selected Genotypes

Tabien, R.E. and Harper, C.L.

Temperature at flowering and grain filling is critical in grain development as it affects grain yield and milling quality. Two grain yield components, the filled spikelet percentage and weight per grain are realized at these stages. High temperature above 30^{o}C is generally not favorable at ripening stage. It can cause spikelet sterility and shorten the duration of grain filling. The length of ripening period is negative correlated with daily mean temperature. Similarly, grain yield and mean temperature during the 30 days after heading were found negatively correlated. U.S. rice cultivars were shown to be more sensitive to high temperature than Asian rice. The upper daytime air temperature between 32 and 35^{o}C was found the threshold for grain yield for some U.S. rice cultivars.

High temperature can also affect grain quality. High temperatures at the early stage of grain filling increased the rice grain fissuring at maturity. The average daily maximum temperature during 10 days after heading was highly correlated with fissuring. High temperature during the final stages of grain filling may result to excessive chalkiness. Radiation and relative humidity (RH) are also important environmental factors affecting grain yield and quality and may interact with temperature. Temperature above 35^{o}C and radiation lower than 200 cal cm^{2} per day at flowering can cause 40-60% sterility. Similarly, high RH of 88% at same 35^{o}C increases sterility. RH of 85–90% at heading and 35^{o}C day and 30^{o}C night temperature can induce complete grain sterility. It was suggested that cultivars with a wider spread of pollination may provide advantage during adverse weather condition.

Mean weather data values for 7, 14, 21, and 30 days after 50% heading (DAH) of common entries in 3-year (2007-2009, 2010-2012) and six-year (2007-2012) URRN trials were estimated to determine their correlation with main crop yield, percent total, and whole milled rice. The 6-year daily air temperature (minimum, maximum, and average), relative humidity (minimum, maximum, and average), and solar radiation were obtained from iAIMS climatic data in Beaumont that were available online at https://beaumont.tamu.edu/ClimaticData/. The first set of data (2007-2009) had 39 common entries while the second set (2010-2012) had 56 common entries. The third set (six 6-year data set) had a dozen genotypes. At 7 DAH, consistent highly significant positive correlation was noted between solar radiation and average daily air temperature, and grain yield and milling traits, while relative humidity (min., max., and average) was negative correlated with percentage total and whole milled rice in both 39 and 56 data set. The minimum daily temperature was also found negativity correlated with yield and milling traits. In 14 DAH, yield and milling traits were positive correlated with solar radiation but negatively correlated with minimum relative humidity and average relative humidity. Both percent total and whole milled rice was positively correlated with maximum daily air temperature but negatively correlated with maximum relative humidity. Correlation results for minimum and average daily temperature were not consistent in the two data sets. At 21 and 30 DAH, the same correlations at 14 DAH were obtained except the correlation of maximum daily air temperature was not consistent at 30 DAH. The small data set followed the trend observed in the big sets, particularly the effect of solar radiation and relative humidity (minimum and average). These results indicate the importance of solar radiation and relative humidity during the reproductive stage in obtaining higher grain yield and better milling qualities in current U.S. elite breeding lines, and the significant effect of maximum daily air temperature on percent total and whole milled rice on the same group of genotypes.

Screening and Performance Evaluation of Selected Genotypes to High Rates of Liberty Herbicide

Tabien, R.E. and Harper, C.L.

Development of new varieties with resistance to herbicide will greatly impact the future of rice cultivation. The current popularity of Clearfield technology suggests the importance of this technology in the highly mechanized rice production prevailing in U.S. Limiting the number of herbicide to use by the farmers can reduce production costs and minimize impacts of herbicide on water quality and the environment. Selected germplasm identified in the large scale screening and performance trials using the recommended rate of Liberty herbicide were evaluated for tolerance to 2x rate of recommended rate for Liberty herbicide. Nine genotypes with the lowest yield reduction using 1x rate (1.97 kg/ha) of Liberty herbicide and Rondo, a check variety were evaluated in sprayed and not sprayed plots for two years to determine yield performance in 2x rate (3.94 kg/ha) of Liberty herbicide. Test entries were direct-seeded in six 6-meter long rows spaced at 20 cm apart. Plots were arranged in randomized complete block design with four replications. Fertilizer rate of 224-56-0 kg/ha NP K was used. All phosphorus was applied before planting while nitrogen was split three-way: at planting, flooding, and maximum tillering. For sprayed plots, high rate of herbicide was applied 30 days after emergence. Heading date, maturity date, plant height, grain yield, percent total, and whole (head) milled rice were gathered both in sprayed and unsprayed plots.

Two-year mean data showed that spraying Liberty herbicide delayed heading and maturity of all entries, but the delay was much shorter (5-9 days) in herbicide-tolerant (HT) lines than Rondo, the check variety (20-23 days). Plant height was not great reduced in HT lines (6 cm) compared to the check (13 cm). The yearly yield reduction among HT lines was much higher in the second year, ranging from 38-65% compared to 6%-41% range during the first year. Similarly, the check had a different response, with 68 and 41% reduction for year 2 and 1, respectively. Grain yield reduction across years showed lower yield reduction on HT lines (36%) than the check (54%). Two HT lines (sister lines) had significantly lower grain yield reduction than the check variety (25 vs. 54%). It was observed that one HT line was consistently top yielder in both sprayed and not sprayed plot. It was comparable in grain yield to the check in not sprayed plot but significantly higher than the check in the sprayed plot. This line, however, had a mean yield reduction of 41% comparable to Rondo. All entries except one HT line had comparable % total milled rice in both sprayed and unsprayed plots. Similarly, except for one HT, all lines were comparable to the check in % whole grain in unsprayed plots. However, six HT lines were significantly better in % whole rice in sprayed plots than the check. Results indicate potential tolerant parents with higher yield and good milling in 2x rate of Liberty herbicide.

A Genetic Approach to Producing Rice Using Less Irrigation Water

Teaster, N.D., Henry, C.G., Anders, M.M. and McClung, A.M.

Research has shown that conventional rice production using the permanent flooded system can also result in high methane emissions, increased grain arsenic accumulation, and extensive demand on irrigation resources. Although rice is a staple grain for feeding half the world, there has been increasing interest in developing sustainable rice production systems that have less negative impact on the environment. Producing rice using aerobic culture or intermittent flooding practices has been adopted in various parts of the world and to a limited extent in the USA as a means of reducing irrigation costs. This study was initiated to identify genomic-trait relationships for plant characteristics that are important for rice production using intermittent flood culture. A chromosome segment substitution line (CSSL) population derived from a backcrossing TeQing, an indica cultivar from China, into the recurrent parent, Lemont, a japonica cultivar from the USA, was used. The population was previously genotyped using 178 Simple Sequence Repeat (SSR) markers and possesses one marker every 0.5 cM, on average. The genetic materials consisted of 117 introgression lines, the two parents, and 32 cultivars that serve as parentals for several other mapping populations. The study was conducted in Stuttgart, AR, during 2013 and included two irrigation methods, permanent and intermittent flood, and four replications. Each genotype was represented by about seven hill plots per replication and two representative plants were selected for phenotyping. Traits to be measured include days to heading, plant height, plant type, tiller number, panicle length, number of panicles, number of seeds per panicle, total kernel weight per panicle, 1000-grain weight, and total grain yield per plant. Soil moisture was mapped to track water stress levels in the intermittently flooded plots. Rainfall and other weather conditions were recorded on site to determine their effect on soil moisture and water stress. Initial analysis of population plant growth data by treatment revealed significant differences on average for intermittent flooding relative to permanent flooding; decreased plant height, increased days to heading, but no change in plant type. Additional results for other agronomic traits will be presented as well as plans for quantitative trait loci analysis (QTL). This study will generate phenotypic information which will be used to associate traits to genetic markers for the selection of cultivars with increased crop value while utilizing reduced water consumption.

Genome-Wide Association Mapping for Multiple Traits Using an Indica MAGIC Rice Population

Redoña, E., Bandillo, N., Gregorio, G., Raghavan, C., Singh, R.K., Thomson, M., and Leung, H.

Multiparent advanced generation intercross (MAGIC) populations offer the opportunity to conduct both linkage and association analyses to dissect the genetic basis of important quantitative traits. At IRRI, we have developed four types of MAGIC populations through several rounds of intercrossing among founder cultivars belonging to the *indica* and *japonica* ecotypes. We used a 96-line subset from an early generation (S1) MAGIC population derived from eight *indica* founders, referred to as '*Indica* MAGIC,' to determine the potential of recombined multiple genomes for coarse mapping QTLs underlying several traits via association analysis. Phenotypic evaluations conducted under controlled and field conditions yielded plants with tolerance to salinity and submergence. Disease screening revealed transmission of blast resistance from the founders to a majority of the progenies. Phylogenetic analysis revealed substantial genetic diversity among the *indica* founder lines. Cladogram analysis of the MAGIC lines and eight *indica* founder lines showed negligible population structure making the MAGIC Indica subset suitable for association analysis. Genome-wide association mapping using single nucleotide polymorphic (SNP) markers detected known genes/QTLs such as the *sub1* for submergence tolerance, *qBR9.1* for blast disease resistance, and *Saltol* for salinity tolerance in the population. Moreover, several novel QTLs for these same traits were detected. The S1 generation of MAGIC Indica could be effectively utilized for association mapping of multiple traits. Recombinant inbred lines combining all traits in new genetic backgrounds would be highly valuable for breeding new rice varieties.

GWAS Viewer: A Genome-Wide Association Study (GWAS) Visualization Tool Developed by the Rice Diversity Project

Branchini, D., DeClerck, G., Agosto-Perez, F., and McCouch, S.

The Rice Diversity Project (ricediversity.org) has developed a genome-wide association study (GWAS) visualization tool called "GWAS Viewer." This user-driven web-application is a high level, graphical data browser that allows researchers to view GWAS "Manhattan" plots in order to examine statistical significance data produced by association analysis between Rice Diversity genotype and phenotype data sets. The GWAS Viewer is dynamic and flexible – the user is provided with several options for refining or customizing the plots and can "draw" up to six plots at one time. Once the plots are rendered, an array of features are available including MSU/RGAP7 gene annotation display, click-thru to the Rice Diversity genome browser, synchronized zooming, filtering by chromosome, and a range of image exporting options. A user can also add their own candidate genes of interest to a plot by uploading a tab-delimited file containing LOC_IDs and location or by entering a list of LOC_ID. By clicking on a particular –log10 transformed p-value data point, a popup box with information about the data point and the associated SNP including the SNP ID, chromosome, genome position, -log10 p-value, and a hyperlink to the genome browser - zoomed in on that particular region of the genome. Clicking on a candidate gene feature will produce a similar popup box with annotation information and a link to the gene region in the genome browser. By hovering over a plot, a "ruler" appears that is synchronized across all plots for easy comparison of a region of interest. Finally, a user can choose to export a single plot as a png, jpg, pdf or svg (vector) image or export multiple plots as a pdf file.

Mapping Genetic Control of Cereal Grain Micronutrient Density in a Diverse Rice Germplasm Collection

Kandianis, C.B., Yan, W., and Grusak, M.A.

The phenotype of seed mineral accumulation is derived from the integration of multiple physiological processes including mineral acquisition, transport, remobilization, and storage. It follows, therefore, that this complex phenotype would be regulated by a genetic network encoding key steps in these biological processes. Existing genetic mapping studies conducted in cereals have found relatively few loci to be associated with variation in grain mineral accumulation. These results could indicate that (1) most genes involved with seed mineral accumulation individually exhibit very small effects on the phenotype, leading to poor detection with existing genetic mapping methods or (2) only genes with rate limiting effects on mineral accumulation truly influence the phenotype, thereby leading to the detection of fewer genes.

To adequately address an investigation of the genetic controls on mineral accumulation in rice grain, we considered a selection of grain mineral phenotypes which could provide insight to the factors regulating movement of minerals from vegetative to reproductive tissues. These phenotypes include: whole grain mineral concentration at harvest; proportion of mineral allocated to bran relative to endosperm in mature grains (mineral partitioning); and rate and duration of mineral accumulation in developing rice grains. Phenotypes were measured on field-grown and greenhouse-grown material from the USDA MiniCore Collection, a geographically diverse and genotypically rich germplasm resource comprised of several *Oryza* species which has been used as the base population for various genetic mapping studies. To maximize the genetic resolution of our mapping studies, we utilized Genotyping by Sequencing (GBS) methodology for SNP marker discovery and identified over 70,000 polymorphisms segregating in this population at a minor allele frequency (MAF) greater than 0.05. Genome-wide association studies (GWAS) considering population structure and kinship (Q + K) in mixed linear models were conducted to identify quantitative trait loci (QTL) significantly associated with variation in the selected mineral phenotypes.

Focusing on two essential dietary micronutrients, we found whole grain iron (Fe) and zinc (Zn) concentrations and mineral partitioning to be quantitative and controlled by multiple loci of variable effect size. Several whole grain mineral concentration and content QTL were found to co-localize with variation in seed biomass, suggesting that the regulation of source-sink dynamics contributing to seed growth could be of similar importance in controlling the dynamics of micronutrient accumulation in grains during seed fill. Mineral accumulation dynamics revealed a wide range of mineral and/or biomass accumulation rates and duration across tested MiniCore varieties, and GWAS analyses performed on a subset of the population suggested a heritable basis for these traits. We report the results of GWAS across these mineral phenotypes and discuss implications of the dependence of seed mineral density on the yield component of seed biomass.

Abstracts of Papers on Plant Protection
Panel Chair: Michael Stout

A Landscape-Level Management Program for Stem Borer Pests of Bioenergy and Conventional Cropping Systems in the U.S. Gulf Coast

Wilson, L.T., Yang, Y., Wang, J., Beuzelin, J.M., Wilson, B.E., Medley, J.C., Hoy, J.W., VanWeelden, M.T., White, W.H., Way, M.O., Showler, A.T., and Reagan, T.E.

The research presented herein focuses on the development of a landscape-level management program for the sugarcane borer and the Mexican rice borer, which are pests of a wide range of conventional and cellulosic gramineous crops and a number of weedy grass species along parts of the U.S. Gulf Coast. Both stem borers can cause major yield loss to rice and sugarcane if not properly managed. Conventional stem borer management occurs at a field-level, largely without considering how stem borer abundance in nearby fields impacts crop injury and pest control. Management is made even more complicated by alternate weedy plant host in field borders and nearby pasture-land serving as infestation sources throughout most of the growing season and as bridging hosts during winter months. Stem borer management will increase in complexity if a cellulosic bioenergy industry becomes a component of the U.S. Gulf Coast agricultural landscape due to the majority of potential bioenergy crops also being stem borer hosts. In this paper, preliminary results are presented addressing the putative impact of habitat management and spatial proximity of different stem borer host crops on regional stem borer abundance and economic impact.

Optimizing Use of Insecticides in Rice Pest Management to Enhance Sustainability

Godfrey, L.D., Goding, K., and Espino, L.A.

The goal of this research was to refine and advance IPM schemes for key rice invertebrate pests [particularly rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel] while maximizing protection of the environmental aspects of the rice agroecosystem and enhancing the cost effectiveness of management efforts in rice. Insecticide use in California rice has been on an upward trend the last few years primarily due to increased tadpole shrimp problems and perceived more favorable cost:benefit relationships for insecticide use. These types of increases typically “catch the eye” of regulatory officials in California.

Management - Studies were conducted on management of RWW, several aspects of the insect’s biology that could provide valuable information to assist with control efforts, and rice cultivar response to RWW injury. For the management efforts, work was done in aluminum ring plots (10.7 sq. ft.), small field plots (~600 and 1750 sq. ft.), and greenhouse studies to evaluate experimental insecticides versus registered standards for RWW control. Twenty-seven treatments (a total of nine different active ingredients) were evaluated in ring plots with six “new” products evaluated. The results and comparisons from ring plots are useful for evaluating efficacy but clearly the conditions are “artificial.” In summary, the pyrethroids still have good activity on RWW. Laboratory bioassays with lambda-cyhalothrin were conducted in 2013, and the RWW susceptibility was compared with similar studies/values developed in 1999, the initial date of registration. The susceptibility has not declined significantly over the ~13-year use period. Warrior® II showed very good flexibility in field studies with good results via a preflood application, as well as a conventional 3-leaf stage application. Mustang® was very effective with the 3-leaf application. The newest pyrethroid product, Declare®, appears to be as active as the other two materials and worked well preflood and at the 3-leaf stage. Dimilin® was not highly active on RWW and appears to have largely fallen out of the rice market. Belay® was evaluated preflood, at the 3-leaf stage (three rates), and at the 5- to 6=leaf stage as a rescue treatment. The 3-leaf stage applications produced good results (90%+ control) for RWW larval control and very good yield results. Belay is not applicable for use preflood and the 5- to 6-leaf “rescue” application produced a moderate level of RWW control. Belay is registered in California rice for the 2014 use-season. Coragen® was applied preflood with two rates in the ring study and three rates in the open plot study (follow-up studies in open field plots with natural infestations are needed to fully evaluate products). Results from the ring study were very

positive, whereas those from the open plot study were less conclusive. In 2011, Coragen results in open plot studies were very good on an extremely heavy RWW infestation, but results from 2012 and 2013 have been more erratic. This product provides the best RWW control with a preflood application.

Cultivar Response – Although resistance to invertebrate pests does not exist in commercial rice cultivars, rice varieties do differ in subtle (or in some cases more noticeable) ways including yield potential, response to nutrients, disease susceptibility, days to maturity, growth patterns, leaf shape and orientation, optimal seeding rate, vigor, etc. Some of these characteristics can affect insect pest infestations and damage. We have been evaluating the response of commonly-grown California rice cultivars to RWW in terms of 1) severity of infestation by adults, 2) RWW larval populations, and 3) yield loss upon infestation. This was done in controlled studies in ring plots with four varieties and in open field plots with 12 California rice cultivars, under treated and untreated conditions. The open field plot approach is preferred but the infestation severity is extremely unpredictable. Finally, two varieties that appear to respond differently to RWW from the small field plot studies were intensively studied in a field study with various RWW infestation regimes and four different seeding rates.

New IPM Strategies for Rice Water Weevil (*Lissorhoptrus oryzophilus* Kuschel) in California Rice Agriculture

Aghaee, M. and Godfrey, L.D.

Statement of rationale: The purpose of this study was to determine how flooding rice fields in winter leads to a decline in the number of larvae of rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) in the following spring. We focused on methane production in soil and silicon and arsenic content in the rice plant as possible sources of mortality for the weevil larvae. We also tested the efficacy of *Bacillus thuringiensis* subspecies galleriae (BTG) against weevil larvae.

Winter Flooding - Methods: This experiment was carried out in a lathehouse on the UC Davis campus. Each bin (0.3 x 0.5 x 0.2 m) was filled with a 10-cm depth of rice paddy soil. We had four treatments with eight replications: 4-month long flood, straw, combination (straw and flood), and a control (no flood and no straw). After the simulated 4-month long winter flood, all bins were dried for 2 weeks and then flooded to a depth of 10 cm. Rice variety M-202 was planted in each bin at a rate of 168 kg/ha. Four parthenogenetic rice water weevils were placed in small cages in each bin in late June. A rhizon gas sampler was placed in each bin for the collection of soil porewater to measure methane production. Bins were sampled twice for weevil larvae 4 weeks following infestation in July. Gas samples were taken five times between June and July. In August, 1 gram of rice leaf material was collected from each bin and sent to the UC Davis Analytical laboratory for analysis of arsenic and silicon content with plant tissues.

Winter Flooding - Results: There were significant differences between the control and the flood, straw, and combination treatments (Tukey HSD, $p < 0.05$). The methane production in the straw treatment was significantly higher than in the flood and combination treatment (Tukey HSD, $p < 0.05$). There were no significant differences in the amount of plant arsenic and silicon among treatments (Tukey HSD, $p > 0.05$). Methane production in soil did not follow weevil mortality trends across treatments. The flood treatments show the same trend as previous field studies on weevil suppression by winter flooding, but lack of weed control may have affected data collection. The interaction of the straw and flood effect was significant but it is unclear what effect it is having on the weevils because there were no differences in weevil mortality across the straw, flood, and combination treatments.

Efficacy of Bacillus thuringiensis serovar galleriae - Methods: We tested granular and foliar formulations of Bt. galleriae provided by Phyllom LLC on rice water weevil larvae at varying rates in addition to Warrior (lambda-cyhalothrin) and Azadirachtin as positive controls. The experiment was in a randomized complete block design with 14 treatments in five blocks. Each product was applied preflood and post-flood to determine the best timing of application for the product. Five rice plants were grown in 15x12 cm pots with paddy soil. Each pot was enclosed in a 61 x 10 cm^2 cylindrical mylar plastic cage to prevent weevils from escaping. Pots were infested at the 2- to 3-leaf stage. Post-flood applications were applied 3 days after weevil infestation. Weevils were subsequently removed 24 hours after post-flood applications. Pots were destructively sampled for weevil larvae 10 days after weevil removal.

Efficacy of Bacillus thuringiensis serovar galleriae - Results: The preflood granular Btg formulation at a rate of 19.4 g/m^2 had the best efficacy out of all the formulations and rates of the Btg products (Tukey HSD, $p < 0.05$). It did not work as well as the Warrior in 2013 (Tukey HSD, $p > 0.05$), which contrasts with results from 2012 where the Warrior and the preflood granular Btg had similar efficacy (Tukey HSD, $p < 0.05$). Based on these results, the preflood application of the granular Btg product may suffice for a grower considering organic production.

Efficacy of Seed Treatments for Control of Rice Water Weevil in Arkansas

Thrash, B.C., Lorenz, G.M., Taillon, N.M., Plummer, W.A., Chaney, H.M., Everett M., Clarkson, D.C., and Orellana, L.R.

The rice water weevil (RWW), *Lissorhoptrus oryzophilus* is one of the most destructive pests of rice in the Mid-South. Large block trials evaluating the efficacy of seed treatments to control RWW were conducted from 2008 to 2013. Trials were located in rice producing counties in Arkansas at 31 different locations. Each location consisted of a fungicide-only untreated check, one (2008), two (2009-2010), or three (2011-2013) insecticidal seed treatments; Dermacor X-100, Cruiser, and/or Nipsit Inside. Plant heights and stand counts were taken at least once for all trials. RWW densities were evaluated by taking 10, 10.16 cm diameter, 7.62 cm deep core samples per plot. Each sample was washed over a 40-mesh sieve and larvae were floated in a salt water solution. Yields were taken at 25 of the 31 locations and adjusted for moisture. Results indicated seed treatments reduce RWW numbers and increase yields.

Efficacy of Insecticide Seed Treatment Combinations for Control of Rice Water Weevil

Clarkson, D.L., Lorenz G.M., Taillon, N.M., Plummer W.A., Thrash, B.C., Everett, M.E., Orellana, L.R., and Chaney, H.M.

The efficacy of insecticide seed treatments IST for control of rice water weevil (RWW) has been well documented in Arkansas. However, we have occasionally seen differences in the insecticide seed treatments depending on other pests such as Grape Colaspis and true armyworm. Occasionally, particularly in extreme environmental conditions, we have also documented increased vigor associated with ISTs. In an effort to determine if there was value to combining seed treatments, we conducted two trials to determine if there were any additive or synergistic impact on the efficacy of various rate combinations of Dermacor X-100 and Cruiser Maxx against RWW. Data collected included stand counts, plant heights, and vigor ratings. RWW counts were made in each trial by taking three soil cores per plot at 21 days post flood. Plots were harvested and yield taken with a plot combine. Data was analyzed using JMP 11 and means separated using Fischer's Least Significant Difference (LSD) method ($p=0.10$). No differences were observed for stand counts, plant heights, or vigor ratings. RWW numbers were lower with the use of a low rate of Dermacor X-100 (2.5 oz/cwt) combined with any rate of Cruiser Maxx (7 or 3.5 oz/cwt). All rates of Cruiser Maxx (7, 5, and 3.5 oz/cwt) combined with a high rate of Dermacor X-100 (5 oz/cwt) did not separate from the untreated check.

Efficacy of Selected Insecticides for Control of Rice Stink Bug, *Oebalus pugnax*, in Arkansas 2011-2013

Plummer, W.A., Lorenz, G.M., Taillon, N.M., Chaney, H.M., Everett, M.E., Thrash, B.C., Clarkson, D.L., and Orellana Jimenez, L.R.

The rice stink bug, *Oebalus pugnax*, is one of the most destructive insect pests of rice production in the mid-south. Rice stink bugs feed on developing kernels resulting in yield loss. Infection by pathogens transmitted during feeding into the kernel cause discoloration which the rice industry categories as "pecky rice." This pest feeds on a large variety of wild hosts. For the purpose of this presentation, we will discuss trials conducted in grower fields from 2011-2013 to evaluate the impact of select foliar insecticides for control of rice stink bug.

The sites for these trials were located in Lonoke County (2011 and 2012) and Faulkner County (2013), Arkansas. The plot size was 3.8 m (12.5 ft) by 7.6 m (25 ft). A randomized complete block design was used and was replicated four times. The sample size was 10 sweeps per plot with a 38.1 cm (15 in.) diameter sweep net. Data were processed using Agriculture Research Manager, Version 8, AOV, and Duncan's New Multiple Range Test.
In 2011, assessments were taken 6 days after treatment (DAT) 1 and 7 and 10 DAT 2. Results showed no treatments reduced insect populations below threshold after the first application. However, all treatments except Declare .1124

l/ha (1.54 oz/acre), Mustang Max .1935 l/ha (2.65 oz/acre), and Karate Z .1315 l/ha (1.8 oz/acre) had fewer stink bugs compared to the untreated check (UTC). At 7 and 10 DAT 2, all treatments reduced rice sting bug numbers below threshold. In 2012, Endigo ZC .3654 l/ha (5 oz/acre), Endigo ZCX .3654 l/ha (5 oz/acre), Karate Z .2603 l/ha (2.56 oz/acre), Centric .2494 kg/ha (3.5 oz wt/acre), and Tenchu .6304 kg/ha (9 oz/acre) were evaluated. At 4 and 7 DAT 1, all treatments had fewer stink bugs than the UTC, although Tenchu did not reduce numbers below threshold. At 3 DAT 2 all treatments reduced stink bugs below threshold. In 2013, only one application was needed to reduce numbers below threshold. At 5 DAT 1, Centric .2494 kg/ha (3.5 oz wt/acre) reduced stink bug numbers better than all treatments except Endigo ZCX .4384 l/ha (6 oz/acre). In these trials, new insecticides not currently labeled were compared to recommended standard insecticides. Results indicate that new insecticides may have potential value for control of stink bugs in rice.

Efficacy of Foliar Insecticides at Different Timings for Control of Rice Water Weevil in Arkansas Rice

Chaney Jr., H.M., Lorenz, G.M., Taillon, N.M., Plummer, W.A., Everett, M., Thrash, B.C., Clarkson, D.L., and Orellana Jimenez, L.R.

Around 90% of rice acres in Arkansas are affected by rice water weevil (RWW). RWW adults emerge from overwintering in the spring when rice fields are being flooded. The adults feed on the leaves of rice causing white, linear feeding scars parallel to the leaf veins. Adult scarring may be heavy but does not usually result in yield loss. The damaging stage in rice is the larval stage which feeds on the roots causing stunting, color change, delayed maturity and subsequent yield loss if field populations are high. High infestations of RWW is dependent on several factors: availability of overwintering sites, overwintering survival, sequence of flooding rice fields in area, method of planting, and stand density. Currently, the recommended control for RWW is an insecticide seed treatment (IST). However, if an IST is not used, water management and foliar insecticides are the only options for control.

The purpose of this study is to compare foliar applications at different timings to include Karate Z and Belay at timings of 3 and 7 days after flood (DAF). Foliar treatments were compared to NipSit Inside IST. All treatments had the same fungicide seed treatment. Foliar applications were made with a backpack sprayer at 93.5 liters per hectare. Soil core samples were taken at 14, 20, and 29 DAF to assess RWW larval numbers.

At 14 and 20 DAF, all treatments had fewer larvae than the UTC except for Karate applied at 7 DAF. At 20 DAF, all treatments had a lower number of larvae present than the UTC. NipSit Inside IST had the fewest larvae followed by Belay applied at 7 DAF and Karate at 7 DAF. At 29 DAF, Karate applied at 3 DAF and Belay applied at 7 DAF had more larvae than the UTC. NipSit Inside IST had the fewest larvae at 29 DAF. Similar to previous studies, this study shows the increased control associated with insecticide seed treatments compared to foliar insecticide applications for RWW control.

A Historical Look at Selected Rice Insecticide Seed Treatments for Control of Rice Water Weevil from 2007 to 2013 - Where Are We Now?

Taillon, N.M., Lorenz, G.M., Plummer, W.A., Chaney Jr., H.M., Thrash, B.C., Clarkson, D.L., Orellana Jimenez, L.R., Everett, M.E., and Flynn, S.

In 2005, with the loss of Icon (fipronil) seed treatment, due to a voluntary withdrawal of the label by the company, rice growers had very few options for control of the rice water weevil (RWW), *Lissorhopterus oryzae.* a major insect pest of rice. This pest has the potential to substantially reduce plant stand and subsequent yield in any given year. Experiments and demonstrations have been conducted from 2007 to 2013 on numerous growers' fields across the state, as well as the Pine Tree Experiment Station, Colt, AR, and the Rice Research and Extension Center, Stuttgart, AR, to evaluate the efficacy of select insecticide seed treatments for control of (RWW). These trials consisted of small plot replicated experiments and large plot demonstration trials, and the comments on these seed treatments herein are based on these observations. In these trials, we have used seeding rates ranging from 22.5 to 135 kg/hectare. We have observed these seed treatments on conventional, Clearfield, and hybrid types of rice. The selection of locations was based on fields with a history of problems with RWW. However, we did not experience insect problems in every field.

Throughout the testing of these seed treatments, we have seen a general trend to improve stand count and vigor in many fields with the use of seed treatments. Seed treatments have increased stand counts in many trials as much as 10-20% above the untreated check. We have also documented increased plant height in some fields. The amount of vigor seen may be dependent on many factors, including pest pressure, environmental conditions, and seed quality. Many times we have observed under stressful conditions the seed treatment helped to moderate or buffer stress.

Root core samples (10.2 cm diameter) were collected at 3-5 weeks post flood and transported to the laboratory. Samples were washed through a ¼-inch screen into a 40-mesh sieve to collect RWW larvae. The sieves were placed in a 5% salt water solution, and the numbers of larvae that floated to the surface were counted. At the end of the season, plots were harvested and yields were measured and converted to bushels per hectare. Both Dermacor and Cruiser have continued to provide good control of RWW. Seed treatments provide good control when moderate populations of RWW are present on roots. When higher populations occur (>20 larvae per core), NipsIt Inside, Dermacor, and Cruiser each provide control. Each of the seed treatments provides significant benefits in terms of yield. Over the 5-year period, Dermacor provided a 17.3 bu/hectare yield increase, Cruiser provided a 14.8 bu/hectare yield increase, and NipsIt Inside provided a 14.8 bu/hectare increase. Based on the yield results, Dermacor, Cruiser, and NipsIt provided a 75, 73, and 81% probability of a net return, respectively. Based on these results, insecticidal seed treatments are recommended for RWW control in Arkansas.

Compatibility of Chlorantraniliprole Seed Treatments with Flood Depth and Plant Resistance for the Management of Rice Water Weevil

Lanka, S.K. and Stout, M.J.

Heavy reliance on insecticidal seed treatments for rice water weevil management is a particular concern because this pest has a history of developing resistance to insecticides. Prior research has shown potential for non-chemical strategies such as plant resistance and shallow flooding of rice fields in reducing rice water weevil larval densities. Demonstrating the compatibility of non-chemical and chemical management tactics is essential for designing sustainable integrated management programs. In experiments reported here, three tactics for weevil management—shallow flood depth, plant resistance, and seed treatments with chlorantraniliprole were evaluated for integrated use.

Experiments were conducted in the summers of 2009 and 2011 at the Louisiana State University Agricultural Center Rice Research Station, Crowley, Acadia Parish, LA. The experimental design in both years was a split-plot with three replications. In each year, the experimental area was divided into six leveed areas. The six leveed areas were divided into three blocks, with one leveed area in each block assigned to a "shallow flood" (5-cm flood) treatment and one to a "deep flood" (12.5-cm flood) treatment. Flooding depth was thus the main-plot factor in the split-plot design. Nine subplots in each main plot comprised factorial combinations of three varieties and three rates of insecticidal seed treatment. The three cultivars used in each of the two experiments represented cultivars with varying levels of resistance to rice water weevil. In both years, 'Jefferson' was included as the resistant cultivar and 'Cocodrie' as the susceptible cultivar. As the third cultivar, CL131 in 2009 and Neptune in 2011 were used. Neptune is a medium-grain cultivar and all others are long-grain cultivars. Seeds of each variety were treated with chlorantraniliprole to attain treatment rates of 0, 10, and 25 µg AI/seed (commercial rate) in 2009. The treatment rates used in 2011 were 0, 5, and 50 µg AI/seed. Densities of rice water weevil immatures (larvae and pupae) in subplots were determined by larval core sampling at 21, 28, and 37 d after permanent flood (2009); 19 and 26 d after permanent flood (2011). Rice was harvested by using harvester cum thresher and yields were recorded. Mean larval densities were analyzed as a repeated-measure split plot by analysis of variance (ANOVA) using general linearized mixed model using PROC GLIMMIX in SAS. The impact of weevil feeding on grain yield was assessed using ANOVA after adjustment of grain yields from plots to 12% moisture.

The present study demonstrated the potential utility and compatibility of these two alternative tactics with use of a seed treatment insecticide. No substantial antagonisms were found among these three tactics; the statistical interactions that were found arose from the strong and persistent effects of chlorantranilprole on larval densities rather than incompatibility of tactics. In both years, significant interactions between chlorantraniliprole seed treatment and flood depth resulted from the presence of a significant effect of flood depth on larval densities in plots not treated with insecticides but the absence of such an effect in chlorantraniliprole-treated plots, in which larval densities were very low regardless of flood depth. Similarly, the significant interactions involving time in both the

2009 and 2011 experiments reflected the tendency of larval densities to change over time (sampling date) in plots not treated with insecticide. Thus, use of shallow flooding or resistant varieties did not antagonize or compromise the effects of chlorantraniliprole seed treatment, although the use of chlorantraniliprole tended to mask the effects of the other two tactics.

Real Time PCR – Tool for Detection and Quantification of *Cercospora janseana* in Three Varieties Treated with Fungicide at Different Growth Stages of the Crop

Kaur, K., Chanda, A., Hollier, C., and Chen, Z.Y.

Narrow brown leaf spot of rice (NBLS) is an economically important disease of rice caused by fungal pathogen *Cercospora janseana.* It is commonly found in Louisiana, Texas, Mississippi, and Arkansas. In favorable climatic conditions, this disease can cause more than 40% yield loss. Narrow brown leaf spot was not a serious problem in previous decades, but since last decade, it is one of the economically important diseases of rice. Scientific literature has very limited information about the biology of the pathogen. *C. janseana* is one of the fungal species which is difficult to sporulate in artificial conditions. The Crop Loss Assessment Laboratory of Department of Plant Pathology & Crop Physiology in collaboration with Rice Research Station, Crowley, LA, has initiated studies to understand the biology of the pathogen and the integrated management of NBLS. Various studies have been conducted in field, greenhouse, and laboratory to understand host pathogen interactions. Studies have been conducted to understand the role of varietal susceptibility levels, fungicide timing, weather parameters, and planting time in disease development. In the laboratory, suitable media for its growth and sporulation has been developed.

In the field, its symptoms are deceptive with other rice diseases in early stages of the symptom development. A study was designed to detect *C. janseana* in asymptomatic and symptomatic leaves in early stages of disease development using real time PCR technique. For detection of *C. janseana*, DNA was extracted from the pure culture of *C. janseana*. Conventional PCR was performed with universal fungal primers followed by gel electrophoresis to find the size of the PCR product. After PCR product purification and sequence analysis, sequences were aligned and blast with NCBI database. Blast search showed the highest similarity with partial cds region of polyketide synthase gene of *Spherulina oryzae* (teleomorph of *C. janseana*). Specific primers and probe for real time PCR were designed based on that region. Field study was conducted to quantify *C. janseana* in three planting times, three varieties with different susceptibility levels, three fungicide treatments and control using real time PCR. Three varieties: Presidio (resistant), CL152 (moderately resistant), and CL131 (very susceptible) were planted in three different planting times: Mid-March, Mid-April, and Mid-May. Fungicide applications of Tilt (propiconazole @ 6 fl. oz per acre) were applied at panicle initiation, early boot, or late boot stage of rice crop. To quantify the inoculum build up over time in treated and control varietal plots at three different planting times, samples were collected before the fungicide application and after the fungicide application at each growth stage in all the three varieties in three planting times. Results showed significant variations in level of inoculum among the varieties, planting times and fungicide treatments.

Effect of Nitrogen Rate, Source, and Varietal Susceptibility Levels on the Development of Narrow Brown Leaf Spot of Rice

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

Narrow brown leaf spot is one of the major rice diseases. It is caused by a fungal pathogen *Cercospora janseana.* Symptoms include narrow brown cylindrical spots with dark margins and greyish centers on the leaf lamina and a net-like pattern on the leaf sheath. The pathogen overwinters on weeds as alternative hosts and in residues of crops in the field. It is an airborne pathogen and can also be transported by splashing water and plant-to-plant by leaf rubbing. It affects the rice crop at various crop growth stages, i.e. panicle initiation, boot stage, and heading stage. This disease was not economically important in past few decades but after the severe disease outbreak in 2006, its incidence and severity increased year by year. In optimum conditions, this disease can cause more than 40% yield loss. It is commonly found in Louisiana, Texas, Mississippi, and Arkansas. Very limited information is available in literature about the biology of the pathogen and disease development and its management. Studies have been done by the Crop Loss Assessment Laboratory of Department of Plant Pathology & Crop Physiology in collaboration with Rice Agronomy laboratory, Rice Research Station, Crowley, LA, to understand the biology of the pathogen and the integrated management of narrow brown leaf spot. Studies about the critical roles of varietal susceptibility levels, effective fungicide timing, planting time, and weather factors like temperature and dew period have been done. Many studies done on other hosts and pathogens have shown that nitrogen rate and source have a significant effect on the disease development. A study was conducted to study the effect of nitrogen rate, source, and variety susceptibility level on the development of narrow brown leaf spot. Three different nitrogen rates (0, 50, and 100 kg ha^{-1}/0, 45, and 90 pounds per acre) in the form of urea, ammonium sulphate, or a blend of urea and ammonium sulphate were applied to two varieties CL151 (moderately susceptible) and CL111 (susceptible). Another study was conducted to study the effect of nitrogen rates on different varieties. Three different nitrogen rates (0, 100, and 168 kg ha^{-1}/0, 90, and 150 pounds per acre) were applied to different varieties. Disease severity and incidences on lower middle and flag leaves were noted weekly using disease rating scale 0 to 9. Results showed that disease severity was less in CL151 (moderately susceptible) as compared to CL111 (susceptible). A higher nitrogen rate reduced the disease severity in flag leaves. A blend of urea and ammonium sulphate reduced disease as compared to urea or ammonium sulphate. A significantly higher disease severity was seen when urea was used as source as compared to ammonium sulphate.

New Blast Race in California and Breeding Response

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After the release of M208 (Piz gene), a new blast race was found capable of infecting it. Since then, additional blast genes have been backcrossed into an M206 background and four gene pyramids assembled with the aid of molecular markers.

Infected M208 nodes and collars were collected by the author and Timothy Blank of California Crop Improvement Association between 2009 and 2012. Frequency of infected plants ranged from 0.005 to 0.02 percent and did not increase during the sampling period. Single spore isolates were made from each tissue sample. Rice tissue samples were also analyzed with DNA markers and identity confirmed as M208.

Spore suspensions of single spore isolates were inoculated onto the traditional International Differential set and also onto a new set of monogenic lines produced by the IRRI-Japan Collaborative Research Project. The original IG1 race found in California for the first time in 1996 was verified, and a new race, IB1, was identified as well. On the original International Differential Set, the IG1 race could only infect California varieties with the Piks or no genes, but the IB1 race could overcome many genes, including Piz and Pik. Pot2 analysis carried out at UC Riverside showed the races to be closely related.

In 2005, materials developed by the IRRI-Japan Collaborative Research Project were obtained. Genes effective against the IG1 race were selected for an immediate backcross program. Seven backcrosses were made onto M206 using traditional biological screening and also molecular markers. Isolines of each gene were produced. Agronomic characteristics of these lines are very similar to M206 and yielded more than M208. Four genes were pyramided using markers (Pi40, Pikh, Pi33, and Pita2). Agronomic testing of these materials is in progress.

In summary, a new blast race (IB1) was recently found in California on M208 (Piz resistance gene). This race does not appear to be increasing in frequency, and so it may not be as fit as the original IG1 race. DNA tests indicate the races are closely related. Major resistance genes have been pyramided into an M206 background as a response to this new race and are now being tested for agronomic characteristics.

Multistate Evaluation of Brassica Cover Crop, Biocontrol Agent, and Fungicide for Integrated Management of Sheath Blight of Rice

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Sheath blight, caused by *Rhizoctonia solani*, is the most important disease limiting rice production in the southern rice-producing states. The fungus survives between crops as sclerotia and mycelium in infected plant debris. The sclerotia and infected plant debris serve as primary inoculum. Infection starts when sclerotia and infected plant debris float to the water surface after rice fields are flooded and come into contact with the sheaths of plants. Currently, rice growers heavily rely on fungicides for control of this disease. However, excessive use of fungicides can cause negative impact on the environment and lead to the potential development of fungicide resistance. The objective of this study was to develop an integrated management approach using brassica cover crop, plant growth-promoting rhizobacteria (PGPR), and fungicide for control of sheath blight. Brassica plants (*Brassica* spp.) contain glucosinolates. Once incorporated into soil, they are able to produce the gaseous isothiocynates that are toxic to *R. solani* and many other soilborne pathogens. Through this biofumigation process, brassica crops have the potential of suppressing sheath blight by reducing primary inoculum in soil.

Experiments were conducted in *R. solani*-infested field plots in Texas, Arkansas, and Mississippi in 2012 and 2013 to evaluate the efficacy of brassica cover crop, PGPR, and azoxystrobin (Quadris, Syngenta) for the control of sheath blight. This trial was conducted as a split plot design with four replications. Main plots consisted of two cover crop treatments: 1) brassica 'Caliente 199' and 2) fallow (no cover crop). Subplots were five treatments: 1) *Bacillus subtilis* PGPR strain MBI600, 2) combination of PGPR strain MBI600 with Quadris (azoxystrobin) at 329 ml ha^{-1} (4.5 fl oz/A), 3) Quadris at 329 ml ha^{-1} (4.5 fl oz/A), 4) Quadris at 658 ml ha^{-1} (9 fl oz/A), and 5) non-treated control. The brassica crop was planted in the fall or early spring and incorporated into soil before winterkill or in the late spring, respectively. For PGPR treatments, seeds of the rice cultivar 'Cocodrie' or 'Presidio' were treated with MBI600 prior to seeding. At the boot stage, plots were sprayed with MBI600 and/or azoxystrobin. Sheath blight severity was assessed near maturity. Plots were harvested using a plot combine and grain yield determined.

In Texas and Arkansas, sheath blight severity was lower in plots seeded to brassica cover crop than in plots left fallow in 2012 and 2013. However, the brassica cover crop treatment did not significantly increase grain yield compared to the fallow treatment. Similarly, PGPR alone reduced disease severity but did not increase yield. Combinations of brassica cover crop with Quadris at 329 ml ha^{-1} (4.5 fl oz/A), PGPR with Quadris at 329 ml ha^{-1} (4.5 fl oz/A), or all three treatments resulted in a consistent and significant improvement in disease reduction and yield increase compared with the non-treated control. These combinations achieved similar efficacy as did Quadris applied at the full rate of 658 ml ha^{-1} (9 fl oz/A). In Mississippi, PGPR applied alone or in combination of Quadris at 329 ml ha^{-1} (4.5 fl oz/A) was effective in increasing yield on Cocodrie but not Presidio. Results of this study indicate that combined use of brassica cover crop and/or PGPR with a rate-reduced fungicide can offer new management options for sheath blight while reducing the use of fungicide in rice. This research was financially supported by the USDA/NIFA SRIPM Grant (2010-34103-21156).

Differential Activity of Chlorantraniliprole and Thiamethoxam Rice Seed Treatments on Life Stages of Rice Water Weevil

Lanka, S.K. and Stout, M.J.

Insecticidal seed treatments with chlorantraniliprole (CAP) and thiamethoxam (TMX) are used for the management of rice water weevil, *Lissorhoptrus oryzophilus* Kuschel (Coleoptera: Curculionidae) in the United States. Because both insecticides are systemic, and all life stages of rice water weevil interact with rice plants, multiple life stages of this pest could be affected by these seed treatments. The rational use of these insecticides in weevil management requires identifying the target life stages of *L.oryzophilus* and understanding relative persistence and potencies of both chemicals. To study the activity of CAP and TMX on *L. oryzophilus*, a series of greenhouse and laboratory experiments were conducted on rice plants treated as seeds with different rates of CAP and TMX.

Adult feeding assays on foliage from treated plants (6- to 7-leaf stage) revealed divergent effects: TMX but not CAP affected adult mortality and foliar consumption. The relationship between dose and mortality for TMX was also determined by combining estimates of leaf biomass consumed by weevils with foliar insecticide residues estimated by LC/MS/MS. Adult exposure to treated plants (6- to 7-leaf stage) led to reduced egg numbers and first instar emergence. The low egg numbers by adults on CAP-treated plants was confirmed as a sub-lethal effect: survival was not impacted on foliage from CAP-treated plants but the number of eggs laid by adults was reduced when adults exposed to foliage from CAP-treated plants were released on untreated plants. Sub-lethal effects of TMX on weevils that survived feeding exposure were manifested in reduced egg numbers.

Finally, the differential activities of CAP and TMX on *L. oryzophilus* life stages (including late instar) were investigated by infesting treated plants with adults in the greenhouse. Insecticidal activities on different life stages were related to the patterns of insecticide distribution in leaves, shoot and roots. For chlorantraniliprole, the greatest reduction occurred in late instars feeding on roots, whereas for thiamethoxam, reduction was largely due to reduced adult survival and egg-laying. High aboveground concentrations of thiamethoxam and high below ground concentrations of chlorantraniliprole in rice plants were consistent with these differential activities. Such patterns of activity could have implications for managing populations of *L. oryzophilus* in the field.

Update of Insecticidal Rice Seed and Foliar Treatment Research in Texas

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Insecticidal seed treatments are becoming increasingly popular for Texas rice farmers. Currently, three insecticidal seed treatments can be used by Texas rice farmers who have readily adopted this technology. However, some farmers continue to rely on foliar insecticidal treatments which are effective against selected insects when applied at the proper time. For the past 2 years, we investigated rates and timings of the above pesticides to help develop integrated pest management programs for rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel, and stalk borers, primarily Mexican rice borer, *Eoreuma loftini* (Dyar).

Experiments were conducted in 2012 and 2013 at the Texas A&M AgriLife Research and Extension Center at Beaumont. Experimental design was a randomized complete block with four replications. Plot size was 5.5 m (18 ft) by 1.22 m (4 ft). Seeding rate varied by variety: hybrids, 22.4 kg/ha (20 lb/ac); CL162, 56 kg/ha (50 lb/ac); and Presidio 89.7 kg/ha (80 lb/ac). Recommended agronomic practices were employed. Foliar treatments were applied with a backpack spray rig. The flood was applied to plots about 3 weeks after rice emergence through soil. Approximately 2, 3, and 4 weeks after flood, plots were sampled for RWW by taking five cores per plot and washing them to obtain immature RWW. Each core was 10 cm (4 inches) in diameter by 10 cm (4 inches) deep. When rice was in the milk stage, the middle four rows of each plot were inspected for whiteheads, which is a good indicator of stalk borer damage. At maturity, plots were harvested with a small plot combine. Yields were converted to 12% moisture, and all data were analyzed by ANOVA and means separated by LSD.

Reduced rates of Dermacor X-100---2.61 ml/kg seed (4 fl oz/cwt seed) and 3.26 ml/kg seed (5 fl oz/cwt seed)---applied to hybrid seed effectively controlled RWW. CruiserMaxx Rice at the recommended rate provided less control than the Dermacor X-100 treatments. Both rates of Dermacor X-100 gave excellent control of stalk borers as evidenced by low densities of whiteheads. For CL162, the average yield increase for the seed treatments (Dermacor X-100 and CruiserMaxx Rice) was more than 897 kg/ha (800 lb/ac) compared to the untreated. For the hybrid, the average yield increase for the seed treatments was more than 1,233 kg/ha (1,100 lb/ac) compared to the untreated.

Belay 2.13SC at 329 ml/ha (4.5 fl oz/ac) applied immediately before and 7 days after flood provided excellent control of RWW. An application at 14 days after flood was not effective. Belay 2.13SC applied 7 days after flood performed better than Karate Z applied at 146 ml/ha (2 fl oz/ac) at this time.

Development of Integrated Pest Management for Sugarcane Borer *Diatraea saccharalis*, (Lepidoptera: Crambidae) in Louisiana Rice

Sidhu, J.K. and Stout, M.J.

Rice is grown over an area of approximately 500,000 acres in Louisiana. The lepidopteran stem borer complex attacking rice in the southern U.S. includes stalk borer *Chilo plejadellus* Zincken, sugarcane borer (SCB) *Diatraea saccharalis* (F.), and Mexican rice borer, *Eoreuma loftini* Dyar. With the increasing impact of stem borers in Louisiana, an urgent need exists to develop strategies for management that include host plant resistance, cultural practices, and chemical control. Currently, no IPM program is in place for stem borers in Louisiana rice and research has been initiated to develop an IPM program for these pests.

The first objective of this research was focused on host plant resistance. Studies were conducted to characterize variation in resistance among commonly grown cultivars in Louisiana. For this objective, oviposition preference and larval performance of sugarcane borer on commonly grown rice cultivars in Louisiana were investigated. The oviposition preference study was conducted in a greenhouse on the campus of Louisiana State University. Eight widely grown rice cultivars, representing 75% of the acreage in Louisiana, were used. Results from this study revealed significant differences among cultivars for oviposition preference. Overall females of *D. saccharalis* preferred ovipositing on the upper sides of the leaves of rice plants. When tillering and boot stages were compared, boot stage was more susceptible for oviposition by sugarcane borer females. Greenhouse and lab experiments were conducted to assess the performance of sugarcane borer on different rice cultivars. In these studies, three different measures of performance were used; boring success of larvae, relative growth rates of larvae, and time until entry into the stems. Results from these studies revealed significant differences among varieties for these measures of performance. Results also revealed a strong correlation between performance and preference. Different measures of performance were also positively correlated.

Another objective was to investigate the effect of silicon soil amendments on performance of sugarcane borer, *D. saccharalis,* on two rice cultivars, Cocodrie and XL723. A significant increase in silicon content of rice plants supplemented with calcium silicate was observed compared to the control plants. Soil Si amendment led to lower relative growth rates and reduced boring success of sugarcane borer larvae on plants treated with silicon than on control plants. Effects of soil Si amendments appeared to be more pronounced in a susceptible cultivar, Cocodrie compared to a moderately resistant cultivar, XL723.

Studies were conducted to evaluate the efficacy of Dermacor seed treatment against sugarcane borer. Dermacor seed treatment was the most effective among different insecticides used in a field study and significantly increased larval mortality in lab and greenhouse experiments.

These studies will help facilitate scouting for sugarcane borer in the field and improvement in insecticide timing. Potential exists for current use of these (moderately resistant) cultivars in IPM programs and as sources of resistance in breeding programs for stem borer resistance. Soil Si amendment has the potential to fit into the IPM program for stem borers as it is feasible, environment friendly, and compatible with other control tactics. Dermacor seed treatments could also be incorporated into IPM for stem borers.

Does an Increase in Invertebrate Biodiversity in Rice Fields Affect Rice Water Weevil (*Lissorhoptrus oryzophilus)* Populations?

Mercer, N, and Stout, M.J.

Rice IPM in the U.S. is done mainly with the use of pesticides, plant resistance, and cultural practices but lacks a biological control component. Asia, however, has had success with using natural enemies to control rice pests through varying methods. Here, we investigate one of the methods, whether it is possible to increase the diversity of invertebrates in a rice field and if this increase can negatively affect rice water weevil (*Lissorhoptrus oryzophilus*) populations in Southern Louisiana. Of the 16 plots, half were randomly assigned as treatment plots and the other half were left as controls. The treatment consisted of two applications of composted manure. All plots were flooded before planting and kept flooded throughout the experiment. No pesticides were used in either treatments or controls. Plots were sampled for invertebrate fauna by coring, aquatic netting, trapping, and with floating pitfall traps. There was no significant difference between control or treatment plots for either abundance or diversity. *L.oryzophilus* larvae numbers did not significantly differ between control and treatment either. The current experiment failed to increase the biodiversity and control *L.oryzophilus*, further testing is needed to see if the treatment had the desired effect on the community or had a potentially negative effect.

Do Arbuscular Mycorrhizal Fungi (AMF) Interactions Change the Resistance of Rice Plants to Pests?

Bernaola, L., Schneider, R., and Stout, M.J.

Plants face numerous hardships from both aboveground and below-ground stressors, and they defend themselves against harmful insects and microorganisms in many ways. Feeding by herbivores can change the physiology of plants at a systemic scale and as a consequence herbivores can trigger a cascade of interactions that extend beyond the initial attacker. Many of these responses are manifested in changes in primary and secondary metabolism in the plant. Arbuscular mycorrhizal fungi (AMF) are symbiotic associations in many plant roots thought to play a central role in plant nutrition, growth, and fitness. My current research involves the interactions of rice with AMF and two insect pests in Louisiana: rice water weevil (RWW) and fall armyworm (FAW) as well as a soilborne pathogen, sheath blight. We hypothesize that the interaction of AMF with rice roots changes the resistance of rice to pests. Our aims are: to investigate the effects of AMF colonization on performance and preference of herbivores, fall armyworm (FAW) and rice water weevil (RWW); and whether this symbiosis has an impact on resistance to infection by the rice sheath blight. Field and greenhouse studies indicated that both performance and preference of insects on rice was enhanced when plants were colonized by AMF. In the field, inoculating rice plants with mycorrhizae resulted in higher numbers of RWW larvae on roots of plants. In the greenhouse, weight gains and relative growth rates of FAW larvae were higher on rice plants treated with mycorrhizae. In pathogen inoculation, lesion lengths and the susceptibility to the fungus were higher in rice plants colonized by AMF. Nutritional analysis on root and shoot tissues indicated no significant difference in the concentration of nutrients in mycorrhizae-colonized plants. We conclude that AMF colonization influences processes in the root system of rice plants making them more susceptible to insect and pathogen attack. Understating interactions among above- and below-ground organisms may help in developing novel methods for managing insect pests of rice.

New Threshold for Rice Stink Bug in Mississippi

Awuni, G., Gore, J., Musser, F., and Cook, D.

The rice stink bug, *Oebalus pugnax* (F.), is the most important late season insect pest of rice in Mississippi. It can cause severe yield losses in some years, but the biggest concern from growers is the decrease in grain quality. Rice stink bug feeding during the early grain development stages typically results in blank kernels leading to direct yield losses. During the later stages of grain development, rice stink bug feeding causes discolored or deformed kernels often referred to as "pecky" rice. In most years, nearly every hectare of rice is infested with rice stink bug at some level. As a result, growers typically average 1 to 2 applications for this pest every year.

The current threshold for rice stink bug in Mississippi is dynamic and changes during grain development. The current threshold states that rice stink bug should be treated when there is an average of five stink bugs per 10 sweeps during the first two weeks of heading, and 10 stink bugs per 10 sweeps after that point. This threshold is based on expected yield losses and grain injury at different stages of development. However, there have been numerous questions from growers and consultants about the validity of this threshold. To address this, research was initiated in during the 2010 season in two different caging experiments. In the first experiment, sleeve cages were used to cage either one or two rice stink bug adults on an individual rice panicle. In the second experiment, rice stink bug adults were caged over multiple rice plants in a 2.6 m^2 area. The densities included 11 or 22 adults per m^2. A non-infested control was included in each experiment. Additionally, rice stink bugs were caged at three timings that included bloom, milk, and soft dough. At the end of the season, all rice was harvested and threshed by hand and dried to 12% moisture. Harvested grain was classified as blank, damaged, or clean. The number of kernels in each panicle was counted and weighed to determine grain weight and percent damage.

In the sleeve cage experiment where one stink bug was infested per panicle, yield reductions averaged 37.5, 19.4, and 22.6% at bloom, milk, and soft dough stages, respectively. Where two stink bugs were infested per panicle, yield losses averaged 46.9, 25.8, and 25.8%, at each of those stages, respectively. The percentage of damaged kernels were higher at the milk stage than at the bloom stage. There was no difference in the percentage of damaged kernels at the milk and soft dough stages. The percentage of blank kernels were significantly higher at the bloom and milk stages than at the soft dough stage. In the large cage experiment where the infestation density was 11 adults per m^2, yield losses averaged 9.1, 12.1, and 5.7% at bloom, milk, and soft dough, respectively. Where the infestation density was 22 adults per m^2, yield losses averaged 17.6, 21.0, and 14.0% at those stages, respectively. The highest level of damage was observed for infestations at the milk stage, followed by soft dough, and the lowest damage was at bloom. The percentage of blank kernels was higher at bloom than at milk and soft dough.

Based on these results, the current action threshold may need to be refined. In particular, the timings of when those thresholds change needs to be refined. These results suggest that rice needs to be intensively managed for rice stink bug through the soft dough stage. This is based on both yield losses and damage in the current experiment. As a result, the new threshold for rice stink bug on rice in Mississippi will now read: "Treatments should be made when you find an average of five stink bugs in 10 sweeps from panicle emergence through soft dough. After that point, treatments should be made when you find an average of 10 stink bugs in 10 sweeps." Additional adjustments will likely be made to the actual threshold in the future. From the large cage experiment, we estimated that 11 stink bugs per m^2 is equivalent to approximately 3 stink bugs per 10 sweeps and 22 stink bugs is equivalent to approximately 6 stink bugs per 10 sweeps. At these densities, significant yield losses were observed even at the soft dough stage. In conclusion, the threshold for rice stink bug in Mississippi will likely be reduced to 3 or fewer stink bugs per 10 sweeps.

Impact of Water Management and Agronomic Practices on the Performance of Insecticidal Seed Treatment in Mississippi Rice

Adams, A., Gore, J., Musser, F., Cook, D., Walker, T., and Awuni, G.

Two field trials were conducted to determine the impact of water management on the efficacy of insecticide seed treatments against rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, in rice at the Delta Research and Extension Center during 2011 and 2012. The performance of thiamethoxam, chlorantraniliprole, and clothianidin was evaluated when the permanent flood was established at different timings (6 and 8 weeks after planting) and the effect of flush number (0, 1, or 2) on seed treatment performance was evaluated. Seed treatment efficacy was not impacted by delayed flooding, but two flushes reduced efficacy of some seed treatments.

Efficacy of Rice Insecticide Seed Treatments at Selected Nitrogen Rates for Control of the Rice Water Weevil

Everett, M.E., Lorenz, G.M., Slaton, N.A., Hardke, J.T., Clarkson, D.L., Flynn, S., Thrash, B.C., and Orellana, L.R.

Insecticide seed treatments have become the preferred method of control for the most injurious pest of rice, the rice water weevil. The benefits associated with insecticide seed treatments are well documented, but there have been instances where these treatments have not performed as expected and significant rice water weevil damage has occurred to the rice despite the treatment. Rice plants are highly dependent on the uptake of adequate nitrogen (N) for vigorous growth and the production of high yields in most fields. For this reason, N might contribute to the variability in insecticide seed treatment performance. Seven trials were conducted at the Pine Tree Research Station in St. Francis County, AR, and the Rice Research & Extension Center in Arkansas County, AR, to examine rice growth and insect population responses to different insecticide seed treatments and N rate combinations. Insecticide seed treatments included clothianidin (NipsIt INSIDE 5FS) at 1.2 g/kg seed, thiamethoxam (CruiserMaxx Rice 5FS) at 4.4 g/kg seed, and a non-treated (fungicide only) control. All seed received the same fungicide treatment which included 0.23 g/kg seed Apron, 0.029 g/kg seed Maxim, and 0.62 g/kg seed Dynasty. Nitrogen was applied at 0, 50, 100, 150, and 200 kg urea-N/ha. Averaged across all trials, NipsIt INSIDE and CruiserMaxx insecticide seed treatments resulted in significantly greater initial (135 to 136 plants/m^2) and final (171 to 173 plants/m^2) stand density than the no insecticide control [125 (initial) and 165 (final) plants/m^2). Three weeks after establishing the permanent flood, rice water weevil larvae number among the three seed treatments regressed across N rates at each of the seven sites varied considerably (~5 to 20 larvae/3 cores). Despite the variability, within each site, rice water weevil larvae populations increased positively and followed either a linear or nonlinear (e.g., quadratically) pattern as preflood-N rate increased. When the increase was quadratic, larvae numbers were lowest for the no N control and tended to peak near the greatest preflood-N rate. Among the seed treatments, rice water weevil larvae populations were numerically and sometimes statistically greatest in rice that had no insecticide seed treatment, and larvae populations were generally similar in rice that was treated with NipsIt INSIDE or CruiserMaxx. Grain yield was measured at five of the seven sites and the three seed treatments exhibited the same general grain yield trend within each site. Grain yield increased positively and linearly or nonlinearly (e.g., quadratically) as preflood-N rate increased with the defined curves within each site being parallel among the three seed treatments but having numerically and sometimes statistically different intercepts. The intercept values were statistically different at three of five sites and showed that the intercept for rice with no insecticide was equal to or lower than that of rice receiving either NipsIt INSIDE or CruiserMaxx, which were always similar. The results indicate that rice yields were, on average, 500 kg/ha greater when an insecticide seed treatment was used. Analysis of rice plant N concentration for determining total N uptake for the 2013 sites is not yet complete, but results from two 2012 sites indicated that N uptake at early heading was not affected by insecticide seed treatment. If this result for aboveground N uptake remains true for the 2013 sites, the increased yield from applying insecticide seed treatments is apparently not from enhanced soil- or fertilizer-N uptake but from some other benefit imparted by the insecticide seed treatments.

Blast: The Numbers Game

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

Management of blast is a numbers game based on the number of initial infections, susceptibility, and popularity of a variety. The key two players in this game are the number of spores challenging the rice plant and the effectiveness of the fungicide being used to protect the plant. The earlier and higher the initial infection levels result in more blast infections. The more susceptible a plant is, the more lesions it has, and the more spores it produces. Also, as the popularity of a variety increases, the acreage increases, and the number of compatible spores in the area increases. The time period between initial infection to new spore production can be as little as five to seven days, allowing for rapid buildup of disease. As spore numbers increase, the probability of an infection increases because more spores have a greater chance to land on a susceptible plant.

The race of the fungus also plays a part because an incompatible spore will not cause an infection on a resistant rice plant. Of course, if the environment is favorable (i.e. the field is drained), more disease is possible. If the environment is unfavorable (i.e. very dry or very hot), the epidemic will not develop no matter how favorable the host pathogen relationship is. In the crop's favor, lesion production decreases as tissues mature, becoming resistant to infection. If a susceptible host is planted, a compatible blast race infects the crop early, and if the environment is favorable, an epidemic will develop very rapidly and can destroy a crop.

No blast fungicide is 100% effective. Fungicide efficacy is controlled by how active the fungicide is against the pathogen, timing of the fungicide, and coverage. Rice fungicides range from no blast activity to being very active against the blast fungus. It is very important to know that most rice fungicides have no curative activity against blast. This means that they are preventative and must be applied before infection to have activity. Once an infection occurs, it cannot be eliminated by a fungicide application. Fungicide timing, therefore, is critical to blast control because we are trying to protect the emerging head from neck and panicle infections. Applying a fungicide before head emergence provides little if any protection, and applying after emergence allows infections to occur. Rice heads become resistant to infection and potential damage decreases as they age. Therefore, applications after heading are unnecessary. Unfortunately, fungicide applications do not cover all of the head tissues allowing some infections. Poor fungicide distribution, wind, rain, uniformity of heading, and canopy thickness reduce fungicide coverage.

The fewer potential blast infections, the higher the probability a blast fungicide can control blast. This is the reason two fungicide applications are normally recommended for blast control. The first application, applied between boot and very early heading, has the main effect of reducing the number of blast spores being produced and reducing the probability of infection. The second application, applied between 50 and 90% heading, also reduces spore production but primarily protects the head from infection. Obviously, because fungicide applications are not 100% effective, the fewer spores landing on the rice heads, the fewer infections. An example would be if a rice head was challenged with 10 spores and a fungicide was 90% effective. Then, an infection would be likely. However, if a boot application reduced spore production by 90%, the head would only be challenged by one spore, and the second application would be 90% effective in protecting the heads.

In 2012 and 2013, a blast management trail was conducted at the Rice Research Station using host resistance and fungicides. Five varieties were used ranging from very susceptible (VS) to resistant (R). Fungicide applications were applied at heading or at boot and heading. An unsprayed check was included. All inoculum was from natural sources, and the field was managed to promote blast development (i. e. planted late, drained at tillering, and fertilized with high nitrogen rates). Percent heads infected with blast, yield, and whole grain milling were recorded for each variety-fungicide combination.

The very susceptible variety, CL261, had 37% head infection in the unsprayed check and only yielded 4,397 lb/A. Due to the high disease pressure, it required two fungicide applications to reduce the percent blasted heads and restore yields to near the varietal potential. With susceptible to moderately resistant varieties, it only required a single application to reduce the percent blasted heads and restore yields. The resistant variety did not require a fungicide application to control blast. The slight yield increase was probably due to control of secondary diseases present. This shows why two applications are sometimes necessary under heavy disease pressure, and sometimes a single application is sufficient. It also shows that blast fungicide applications are not 100% effective. That is why two applications are recommended for very susceptible and susceptible varieties.

Sercadis® Fungicide for Management of Sheath Blight (*Rhizoctonia solani*) in Rice

Rhodes, A.R., Guice, J.B., Reeves, B.R.S., and Bardinelli, T.R.

Fluxapyroxad is a new fungicide in the chemical class carboxamide for control of *Rhizoctonia solani* in rice. Fluxapyroxad will be marketed by BASF as Sercadis fungicide. The federal registration for Sercadis is expected for 2014. Sercadis should be applied between panicle differentiation and late boot stage when environmental conditions favor disease development at a rate of 0.44 to 0.497 l/ha.

Sercadis provides a new mode of action for rice growers to combat sheath blight, including QOI-resistant sheath blight. Sercadis fungicide will be a tool in the resistance management strategy for sheath blight control. Best use recommendations of proper rate and proper carrier volume for coverage are also critical resistance management strategies for rice growers. A field study was conducted to evaluate three aerial application volumes for efficacy of controlling *Rhizoctonia solani* with Sercadis. Results indicate that the 10-gallon per acre application volume provided better plant coverage and disease control than the 3- or 5-gallon per acre application volumes.

A laboratory study was conducted to evaluate the systemicity of Sercadis in the rice plant. Rice plants were inoculated with *Rhizoctonia solani* under high humidity. Evaluations at 10 days after treatment found that *Rhizoctonia solani* severity level was less than 1 (scale of 0-9) as compared to other fungicides that were at levels of 2 or higher. Fluxapyroxad has unique movement and binding properties which provide systemic control of *Rhizoctonia solani* in rice. Fluxapyroxad has acropetal translocation and migrates towards the tips of the leaves and pervades the entire cross-section of the leaf. Due to its excellent systemic distribution, fluxapyroxad also protects those parts of the leaf that were not reached during spraying.

Development of a Pathology Toolbox for Genetics and Breeding for Resistance to Rice Sheath Blight Disease

Jia, Y.

Accurate evaluation of the host response of rice plants to sheath blight disease, *Rhizoctonia solani*, is important for genetic studies and breeding for improved resistance. In the present study, a method to evaluate the response of a recombinant inbred mapping population, consisting of 574 F_{10} individuals derived from a cross of susceptible cultivar Lemont with a moderately resistant cultivar Jasmine 85, and an easy to use method for mass production of *R. solani* for field study were developed.

For evaluation of the mapping population individuals to *R. solani*, rice seeds were sown into a 96-cell tray (1 seedling/cell) and grown to the 3- to 4-leaf stage for pathogen inoculation. *R. solani* was grown on PDA media. A single agar plug containing mycelia was attached to each individual sheath immediately above the soil. Inoculated plants were placed in plastic containers and covered with a lid to maintain humidity and kept in a greenhouse at 24-30°C. Disease lesions were measured using a ruler approximately 3-5 days after inoculation. The average of the disease lesions from three replicate plants was used as the disease rating for each line of the mapping population. This method reduces time and greenhouse space needed for phenotyping as compared to previously developed methods.

For mass production of *R. solani* inoculant for field evaluations, fungal mycelia from PDA plates were used to inoculate a sterile mixture of corn and rye in a plastic container and covered with a lid. The inoculated mixture was maintained under regular white florescent light at room temperature (21-25°C) for approximately 2 weeks until the appearance of white sclerotia. The fungal mixture was then air dried at room temperature with a fan for 1 week and then pulverized. Detached leaf inoculations were performed to verify pathogenicity of *R. solani*. Leaf tissue from Lemont, on moist filter paper in covered Petri dishes, were inoculated with agar plugs with mycelia, from recently produced inoculant, and kept at room temperature. Disease lesions were observed 3 days after inoculation and pathogenicity of *R. solani* was verified. This method is fast, inexpensive, and can be easily implemented in any laboratory.

In summary, a simple and easy to use method for evaluation of host response and mass production of *R. solani* were developed. It was anticipated that these methods will accelerate genetic studies and breeding efforts for improved sheath blight resistance.

Effects of Excessive Nitrogen Fertilizer on Rice Diseases with Emphasis to Bacterial Panicle Blight

Wamishe, Y.A., Belmar, S.B., Kelsey, C.D., Gebremariam, T.A., and McCarty, D.L.

Nitrogen fertilizers have been praised for increasing yield potential of modern rice varieties. On the other hand, they have been blamed for increasing diseases in the North American rice production system. In 2012 and 2013 crop seasons, field experiments were carried out at the Rice Research and Extension Center near Stuttgart, Arkansas, to test for changes in the incidence of bacterial panicle blight (BPB) at two rates of nitrogen. In 2012, seeding rate and nitrogen fertilizer effects on BPB disease incidence and severity were tested using a split plot design. *Burkholderia glumae*-inoculated seeds of Bengal and Jupiter were planted at a recommended seeding rate [99 kg/ha (88 lb/acre)] and a high seeding rate [197 kg/ha (176 lb/acre)] on April 27. Two pre-flood nitrogen rates were investigated: the NST*R recommended rate 168 kg N/ha (150 lb N/acre) and a rate of 202 kg N /ha (180 lb N/acre). When data were analyzed, seeding rate and fertility showed no treatment effects on disease incidence. This lack of detectable differences may be due to the low levels of BPB in early planted plots (April) compared to higher disease pressure found on late planted plots (late May) of other experiments. The experiment was repeated in 2013 with modifications: separation of fertility and seeding rate treatments, increased differences between fertility levels with 168 (150) and 247 kg N /ha (220 lb N/acre) and planting late (May 29) using a completely randomized experimental design. Although the environment seemed unfavorable for disease development with wet and cool season, statistical analysis showed significant effect of nitrogen to increase BPB disease incidence for both varieties. Mean disease incidence at 247 kg

N/ha (220 lb N/acre) was 1.6 times higher than at 168 kg N/ha (150 lb N/acre). Mean disease incidence in Bengal was 2.75 times higher than in Jupiter. The two fertility levels showed no significant differences in yield or milling quality. The experiment will be repeated in 2014.

Status of the Azoxystrobin (QoI) Resistance of *Rhizoctonia solani* Isolates from Rice in Louisiana

Olaya, G., Edlebeck, K., Buitrago, C., Sierotzki, H., Zaunbrecher, J., and Tally, A.

In 2011, *Rhizoctonia solani* AG-1 IA isolates resistant to QoI fungicides were detected in rice fields located in Acadia Parish, Louisiana. Resistance monitoring programs in rice and soybean fields have been conducted in Louisiana in 2011, 2012, and 2013 for the QoI fungicide azoxystrobin. A total of 457 isolates were collected in 2011 from 23 fields located near the problem area and their sensitivity was determined using a Perennial ryegrass (*Lolium perenne*) bioassay. In eight fields, no resistant isolates were detected. In 15 fields, the frequency of resistant isolates varied from 7 to 100%, indicating that there is still an azoxystrobin dose response. In 2012, 237 isolates were collected from 12 fields. Isolates from only one field were all sensitive to azoxystrobin. Resistant isolates were detected in the remaining 11 fields, and the frequency of resistant isolates ranged from 39 to 100%. In 2011 and 2012, resistant isolates were detected in fields located less than 40 km away from the first detection field. In both years, isolates collected from fields located more than 41 km away from the first detection site were all sensitive to azoxystrobin. In both years, isolates collected from fields located more than 41 km away from the first detection site were all sensitive to azoxystrobin. *R. solani* isolates were also collected in 2013 and their sensitivity to azoxystrobin is being determined. Results of these resistance monitoring studies are helping in the recommendation of the best managing practices to control *R. solani* on rice in Louisiana. The sequencing of the cytochrome *b* gene revealed that QoI-resistant isolates had phenylalanine to leucine substitutions at codon 129 in the cytochrome b gene (F129L mutation).

Blackbird Research for Rice Crop Protection at the National Wildlife Research Center

Werner, S.J., Eisemann, J.D., O'Hare, J.R., and Linz, G.M.

Blackbirds can damage newly-planted and ripening rice in the mid-South. In 2001, USDA Wildlife Services' researchers estimated that blackbird-caused economic losses to the U.S. rice industry were $21.5 million. These losses in 2011 were estimated as $23.1 million based upon the value of the rice crop in Arkansas, California, Louisiana, Mississippi, Missouri, and Texas. Since 1949, National Wildlife Research Center (NWRC) researchers have investigated the efficacy of more than 300 chemical compounds as non-lethal and lethal management techniques, including DRC-1339 avicide (a.i. *3-chloro-p-toluidine* hydrochloride) and clay-coated seed treatments, registered agricultural pesticides, and naturally-occurring chemical repellents for the management of blackbird damage to rice production. NWRC's research regarding blackbird impacts to rice production is presently focused to develop application strategies for non-lethal chemical repellents and provide data necessary for the registration of effective wildlife damage management techniques. As a result of NWRC's research collaboration, Arkion Life Sciences received approval to market AV-1011 blackbird repellent (a.i. 9, 10-anthraquinone) as a preplant rice seed treatment in Louisiana and Missouri in 2009. For the 2014 growing season, a FIFRA Section 18 Emergency Exemption is pending for the use of AV-1011 on water-seeded and drilled rice in Louisiana. Pending funding and an Experimental Use Permit, NWRC is prepared to conduct additional field efficacy testing to evaluate anthraquinone and other chemical repellents in a large-scale field setting, and advance product registration. In supplement to field research, recent NWRC feeding experiments in captivity have provided data necessary to develop a novel application strategy that exploits blackbirds' use of ultraviolet visual cues for the application of chemical repellents and the protection of agricultural crops.

Broadcast application of DRC-1339 avicide, developed by the NWRC in the 1960s, has proven to be an important tool for protecting rice from bird depredation. Past collaborative efforts among NWRC scientists and registration staff and the Louisiana rice industry have resulted in studies that allowed modifications to product labels (e.g. reduced plant-back intervals) and made this tool even more valuable. Currently, the U.S. Environmental Protection Agency (EPA) is reviewing DRC-1339 registrations and the supporting data. The EPA has determined that existing environmental fate and aquatic toxicity data are not adequate to support current uses, particularly broadcast applications. Through negotiations with EPA, Wildlife Services has reduced the total cost of new data requirements by nearly $1 million and developed a plan for further cost reductions. USDA's Wildlife Services program will continue to provide Federal leadership and expertise for the management of blackbird impacts to U.S. rice production.

The Past, Present, and Future of Using DRC-1339 to Protect Rice from Blackbirds

Eisemann, J.D., O'Hare, J.R., Stephens, S.S., Darrow, P.A., and Jones, J.W.

In response to a growing need to control birds in a variety of agricultural programs, Wildlife Services National Wildlife Research Center developed an avicide in the 1960s which is now commonly known as DRC-1339. Since then, DRC-1339 has been registered to control birds through the US Environmental Protection Agency for dozens of agricultural, natural resources, human health, and personal property damage situations. The USDA Animal Plant and Health Inspection Service now maintains registrations for five nationally available products and more than two dozen state approved products available to meet locally important needs. Broadcast applications of DRC-1339-treated brown rice have proven to be an important tool for protecting rice from bird depredation. Past collaborative efforts among NWRC scientists and registration staff, and the Louisiana rice industry have resulted in studies that allowed significant modifications to product labels (e.g. reduced plant-back intervals) which make this this tool even more valuable for controlling birds. As required by the Federal Insecticide, Fungicide, and Rodenticide Act, the U.S. Environmental Protection Agency (EPA) is currently reviewing DRC-1339 registrations and the data necessary to support continued product registrations. This review includes conducting new risk assessments for the protection of human health and the environment. EPA is also revising mitigation of risks to threatened and endangered species. As a result of this review, the EPA has determined that existing environmental fate and aquatic toxicity data are not adequate to support current uses, particularly broadcast applications. Wildlife Services has begun the process of negotiating modifications to existing label language and planning for meeting new data requirements. Through negotiations with EPA, Wildlife Services has reduced the total cost of new data requirements by nearly $1 million but approximately $800,000 is still required to maintain all current DRC-1339 registrations. This presentation will provide information on the developmental history of DRC-1339 in response to stakeholder needs and the plan for meeting current data requirements. USDA's Wildlife Services program will continue to provide Federal leadership and expertise for the management of blackbird impacts to U.S. rice production.

Abstracts of Posters on Plant Protection
Panel Chair: Michael Stout

Disease Reactions of IRRI Near-Isogenic Rice to U.S. Isolates of *Magnaporthe oryzae*

Feng, C., Rotich, F., Jia, Y., and Correll, J.

Rice blast, caused by *Magnaporthe oryzae*, is a destructive disease of rice. The use of resistant cultivars is the most effective way to manage this disease. However, to be effective, it is necessary to know how the isolates of the pathogen within a population respond to specific resistance genes. Two sets of near-isogenic lines (NILs), each containing a target resistant gene, in either a Japonica cultivar (Lijiangxintuanheigu -LTH) or an Indica cultivar (CO39) background, have been developed by IRRI. Twelve U.S. reference isolates were tested on 31 LTH NILs and 20 CO39 NILs containing 25 targeted resistance genes. NILs containing genes Pia and Pi3(t) were susceptible to all reference isolates tested whereas NILs containing Pi9(t) or Pi12(t) were resistant to all isolates. Lines containing genes Pib, Pi11(t), and Pita-2 were resistant to nine or 10 isolates. Four loci provided resistance to reference isolate 49D (race IB-49) or IB33 (race IB-33), 7 loci were resistant to isolate TM2 (race k), and 14, 16, and 17 loci were resistant to isolate IB-54, isolate #24 (race IG-1), and isolate ID-13, respectively. Pi19(t) and Piks were only resistant to one isolate. PiI, Pikh, and Pikp were resistant to two isolates, and five loci, including Pi1, Pi7(t), Pik, Pika, Pikm, were resistant to three isolates. Thus, the five loci (Pi9(t), Pi12(t), Pib, Pi11(t), and Pita-2) were the most effective resistance genes to the panel of reference isolates evaluated and could be exploited to improve resistant to rice blast disease in the United States.

Tadpole Shrimp Studies

Espino, L.A.

The tadpole shrimp (*Triops longicaudatus*) is a crustacean pest of seedling rice in California. Eggs are in the soil and hatch after fields are flooded. After rice is seeded, tadpole shrimp may feed on germinating seeds or small seedlings, preventing germination and dislodging plants. Additionally, their activity muddies the water, preventing light penetration and reducing plant growth. Once plants emerge through the water, they are not susceptible to tadpole shrimp injury.

The objectives of these studies were to determine developmental time and distribution pattern of the tadpole shrimp. To determine developmental time, soil from infested fields was flooded and emerged tadpole shrimp were reared in small pans in the greenhouse. Tadpole shrimp were sampled daily, their carapace measured, and the proportion of individuals with eggs recorded. To determine degree days from flooding, a lower developmental threshold of 14^{o}C was obtained from the literature. Water temperature was recorded hourly throughout the sampling period. The greenhouse study was replicated two times. To determine the distribution pattern, two commercial fields were sampled. In each field, one 3 ha basin was selected for sampling in a grid pattern. Tadpole shrimp were counted in three, 0.2 m^2 rings in each of 12 sampling points. Sampling was initiated at flooding and ended 35 days later.

Maximum carapace size was reached at about 800 DD after flooding. Carapace growth had a significant relationship with DD (size in mm = 0.1035 * ln (DD) - 0.3372, r^2 = 0.8). Eggs were first found in the egg sacs when carapace reached 6 mm. The proportion of tadpole shrimp with eggs in their egg sacs followed a significant inverse relationship with DD, however, the fit was not very good (Proportion of tadpole shrimp with eggs = 0.9589 – 114.2525/DD, r^2 = 0.4).

Tadpole shrimp were present throughout the sampled basins. Average number of tadpole shrimp per sampling point per basin were 1.74 and 0.5. In both basins, the number of tadpole shrimp in the 12 sampling points were not significantly different. At the densities sampled, the variance was lower than the mean, indicating a uniform spatial pattern.

Effects of Timing and Rate of Fungicide Application on Narrow Brown Leaf Spot of Rice in Main and Ratoon Crops

Liu, G., Zhou, X.G., and Vawter, J.

Narrow brown leaf spot (NBLS), caused by *Cercospora janseana*, is one of the most important rice diseases in Texas. This disease tends to be more severe in ratoon crop than in main crop. Narrow brown leaf spot is also more severe at late plantings of rice. Currently, fungicide application is one of the most important management tools to reduce the damage caused by NBLS. However, information is limited on the optimum timing and rate of fungicide application for control of NBLS in main and ratoon crops. The present paper reports the determination of the optimum timing and rate of propiconazole applied to maximize NBLS control and grain yield for both main and ratoon crops in Texas.

Field experiments were conducted in a randomized complete block design with four replications at Eagle Lake, Texas, during 2010-2012. Rice cultivar Presidio was drill seeded at 90 kg ha^{-1} (80 lb/A). Narrow brown leaf spot developed from natural infestation. Fungicide treatments, resulting from the combinations of two application times and three rates of fungicide PropiMax (propiconazole) on the main and ratoon crops, were evaluated. A single application of PropiMax was made at 0, 365, and 731 ml ha^{-1} (0, 5, and 10 fl oz/A) at the boot or heading stage of the main crop and/or at the boot stage of the ratoon crop. Narrow brown leaf spot severity was assessed close to rice maturity. Rice plots were harvested using a plot combine and grain yield was determined. After harvesting of rice, the plots were managed for second (ratoon) crop according to local recommendations. Narrow brown leaf spot severity was assessed close to rice maturity. The ratoon crop was harvested for grain yield.

In the main crop, all application time and rate treatments of PropiMax significantly reduced NBLS severity. Single application at either rice growth stage or at either rate equally reduced NBLS severity compared to the untreated control. However, all fungicide application time and rate treatments did not affect main crop yield. In the ratoon crop, a single application of PropiMax at 10 fl oz/A made on the main crop resulted in a significant increase in yield. Ratoon crop plots that received an additional fungicide application at either rate had less NBLS severity compared to the plots that did not. However, they did not significantly increase ratoon crop yield. In general, all fungicide application treatments could increase combined main and ratoon rice yield by 4.4 to 9.4% at 576 to 1,212 kg ha^{-1} (514 to 1,081 lb/A). These results demonstrate that a fungicide applied between boot and heading is equally effective for control of NBLS in the main crop. Under the moderate levels of disease pressure, a single application of the fungicide made between boot and heading in main crop will be adequate in reducing the damage caused by NBLS in main and ratoon crops since an additional application of the fungicide on ratoon crop did not significantly increase rice yield.

Modeling Spatial Spread of Bacterial Panicle Blight of Rice from a Source of Inoculum

Zhou, X.G.

Bacterial panicle blight, caused primarily by *Burkholderia glumae*, can cause significant losses in yield and quality of rice. Infected seeds are the primary source of inoculum for the development of the disease. The extent of damage caused by the disease largely depends on the secondary dissemination of the bacterium via rain splash and panicle contact in a cropping season. However, spatial aspect of epidemics of the disease is poorly understood. The objective of this research was to determine the spread of rice bacterial panicle blight from an introduced source of inoculum in field plots.

Rice plots of each 2.4 by 2.4 m were established in 2010 and 2011 in Texas. Two rice varieties, Cocodrie and XL723 (susceptible and moderately resistant to bacterial panicle blight, respectively), were randomly planted into plots with four replications. At the heading stage, plots were infested by placing potted panicles with symptoms of the disease at the center of each plot to establish a point source of inoculum. Diseased panicles were produced by artificially inoculating with *B. glumae* in the greenhouse. Starting 2 weeks after initial introduction of diseased panicles, disease severity on panicles was rated at the straight-line sections of 0, 5, 10, 15, 20, 25, 30, 35, and 40 cm from the original inoculum source in each of the four cardinal directions using the 0-9 scale, where 0 = no symptoms, and 9 = 81-100% panicle area discolored or dead.

Three weeks after the introduction of inoculum, disease symptoms developed on the panicles surrounding the point source of inoculum. Disease severity was greater at the distances close to the inoculum source. In general, disease severity declined with distance from the inoculum source on either variety in each year. However, disease severity on XL723 was significantly lower at each distance than disease severity on Cocodrie. Disease on XL723 also was limited within 15 cm from the inoculum source while disease on Cocodrie was able to spread as far as 40 cm. An exponential model was used to quantify the effects of distance and variety resistance on disease severity. At all assessment times, there was a significant ($P \leq 0.05$) decline in disease severity with increasing distance from the inoculum source. Variety resistance significantly affected the steepness of the disease gradient (k) as well as the overall level (a) of disease severity. The estimated values of k and a were 0.06 and 9.0, and 0.11 and 2.7 for Cocodrie and XL723, respectively. Results of this study indicate that the secondary dissemination of rice bacterial panicle blight was limited and variety resistance played an important role in limiting the spatial spread of the disease.

Role of Seeding Rate, Tillage Practices and Varietal Susceptibility Levels on Development of Narrow Brown Leaf Spot of Rice

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

Narrow brown leaf spot of rice (NBLS) is caused by the fungal pathogen, *Cercospora janseana (Passalora janseana).* It is an emerging pathogen of rice, commonly found in Arkansas, Mississippi, Louisiana, and Texas. It affects the photosynthetically active area of leaves and sheaths and which subsequently affects the yield. It can cause more than 40% yield loss in conducive conditions. Various plant parts (leaves, sheaths, internodes, glumes, and seed coat) are affected by the disease. Narrow brown leaf spot was not an economically important disease in the last few decades, but more recently, its severity and incidences are and expressed as severe outbreaks. Very limited information is available in scientific literature about pathogen biology, nutritional requirements, and factors that trigger the disease development. Crop Loss Assessment Laboratory, Department of Plant Pathology & Crop Physiology, LSU, in collaboration with Rice Pathology and Rice Agronomy Laboratories at the Rice Research Station, has been working to understand the mechanism of disease development and its management. To study the development of NBLS in conventional and stale seedbed tillage systems, in different seeding rates and in varieties of susceptibility levels, a field experiment was conducted at the Rice Research Station, Crowley in 2011-12. Varieties rated as moderately susceptible (CL151), susceptible (CL111), and very susceptible (CL131) were seeded at nine different seeding rates (5-45 seeds/square feet) in conventional seedbed and stale seedbed systems. Experimental design is randomized block with four replications. Observations were taken weekly on lower, middle, and flag leaves. A 0-9 rating scale was used to rate the plots, with 0 = no disease and 9 = more than 75% of leaf area covered by symptoms. Results showed significantly higher disease incidence in stale seed-bed compared to conventional seed-bed system. Disease incidence and severity were found higher in the very susceptible variety (CL131) as compared to the moderately susceptible variety (CL151). Disease incidence increases with increase in seeding rate in the very susceptible variety (CL131) in the stale bed, and disease incidence is significantly higher as compared to moderately susceptible variety (CL151) in the stale bed at lower seeding rate. Slower progression of disease in conventional seedbed as compared to stale seedbed. Disease incidence and severity are lower in moderately susceptible variety (CL151) as compared to the very susceptible variety (CL131).

Fungal Endophyte Seed Treatment Reduces Rice Seedling Diseases

Zhou, X.G. and Redman, R.S.

Early planting is critical to optimizing rice main and ratoon crop yields. However, early plantings often experience early season cold injury, resulting in poor seed germination and seedling growth. Early plantings under cool and wet soil conditions are also vulnerable to seed rot and seedling diseases caused by various fungal pathogens. These diseases cause irregular and thin stands and weakened plants. Development of a new fungal symbiotic seed treatment technology that can enhance rice seedling cold tolerance and reduce seedling diseases is desirable towards minimizing cold weather-related damage to rice production. In growth chamber studies, we found that rice seeds (Presidio and XL723) treated with strains A, B, and C of fungal endophytic plant symbionts were able to induce cold tolerance at 41 and 50°F. The objective of this study was to evaluate the effectiveness of seed treatment with these endophyte strains for induced cold tolerance and seedling disease management under field conditions.

A field trial was conducted as a split plot design at Beaumont, Texas, in 2012. Whole plots consisted of three rice varieties, Cocodrie, Presidio, and M206. Subplots were four seed treatments: 1) untreated control, 2) fungal endophyte strain A, 3) fungal endophyte strain B, and 4) fungal endophyte strain C. In 2013, a similar trial was conducted at two locations, Beaumont and Eagle Lake, Texas. Whole plots of this trial consisted of three rice varieties, Cocodrie, Presidio, and CL151. Subplots were five seed treatments: 1) untreated control, 2) fungicide mix containing Apron (mefenoxam) at 8.813 g (a.i.)/100 kg seed (0.141 oz (a.i.)/100 lb seed), Maxim (fludioxonil) at 1.375 g (a.i.)/100 kg seed (0.022 oz (a.i.)/100 lb seed), and Dynasty (azoxystrobin) at 6.938 g (a.i.)/100 kg seed (0.111 oz (a.i.)/100 lb seed), 3) fungal endophyte strain A, 4) fungal endophyte strain B, and 5) fungal endophyte strain C. Each treatment was replicated three times in the Beaumont trials and four times in the Eagle lake trial. These trials were conducted in the fields that had been cropped to rice for many years and naturally infested with the seedling disease pathogens including *Pythium* spp., *Rhizoctonia solani,* and *Fusarium* spp. Prior to planting in mid-March, seeds were treated with fungal endophyte strains A, B, or C at 100 spores/seed and air dried. Cold injury, stand, and leaf chlorophyll content were assessed at 3 to 5 weeks after planting. Plots were harvested using a plot combine and grain yield was determined.

There were no significant interactions between variety and seed treatment in each trial. Seedlings from seeds treated with any of the fungal endophyte strains showed a lower level of cold injury compared to the seedlings from untreated control seeds in the two trials in 2013. Seed treatments with strains A or B significantly increased stand in each trial. Seed treatments with any of the fungal endophyte strains numerically increased yield by 1% (67 kg/ha or 60 lb/A) to 11% (650 kg/ha or 580 lb/A) although they were not statistically different. Fungicide seed treatment increased stand but did not significantly improve yield. In addition, seed treatment with strain A consistently improved chlorophyll content over three trials. The results of this study indicate that seed treatment with fungal endophytic plant symbionts induced seedling cold tolerance and reduced seedling diseases. Fungal endophytic plant symbiont seed treatment may provide a new tool to manage rice seedling diseases.

Effect of Silicon Soil Amendment on Performance of Sugarcane Borer, *Diatraea saccharalis*, (Lepidoptera:Crambidae) on Rice in Louisiana

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 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 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 sugarcane borer 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 as compared to the untreated plants. Silica contents were higher in the treated plants as compared to 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.

Recent Outbreaks of Rice Blast in Texas

Zhou, X.G.

Rice is an important agricultural commodity in Texas. Rice blast, caused by *Magnaporthe oryzae*, is one of the most devastating diseases in rice worldwide. The pathogen causes leaf blast, node blast, collar blast, neck blast, and panicle blast. Neck blast and panicle blast directly affect grain development and cause more yield and quality losses than leaf blast. Release of many resistant cultivars has limited the epidemics of rice blast. Outbreaks of blast have not occurred in Texas since the late 1990s. However, sever outbreaks of rice blast took place in Texas in 2012 and 2013. The objectives of this presentation were to provide a historical review of rice blast and an update on the recent outbreaks of the disease in Texas.

Prior to 1950s, blast did not cause substantial yield and quality losses of rice. However, with the increased usage of nitrogen fertilizer following the World War II, blast became a major disease in rice. Increase in severity of the disease also coincided with the change in virulence of *M. oryzae* over time. The dominant races of *M. oryzae* in Texas have changed to IC-17, IB-19 and IE-1 from IG-1 during the 1960s through 1970s. Continued efforts in improving varietal resistance using major resistance genes including *Pi-b*, *Pi-kh(m)/s, Pi-z,* and *Pi-ta* and in employing proper irrigation and other cultural management practices have contributed to the successful control of this disease. Since late 1990s, rice blast has not been a major disease causing significant yield losses in Texas; outbreaks of the disease has not been seen for more than 10 years.

However, recent outbreaks of rice blast occurred in two consecutive years in Texas. In 2012, severe outbreaks of leaf blast took place on the cultivar CL261 in several commercial fields located in Jefferson County, Texas. The disease attacked more than 400 acres of rice fields, causing significant yield loss. In 2013, severe outbreaks of neck blast and panicle blast occurred in approximately 20 acres of commercial fields at different locations of Jefferson County, Texas. The disease was so severe that diseased (white) panicles covered all affected areas. In addition, leaf blast, collar blast, neck blast, and panicle blast also outbroke in both main and ratoon crops in research plots at the Beaumont Center in 2012 and 2013. Affected cultivars and breeding lines in the research plots included CL261, Rex, RU1103172, and RU1103178. Races of *M. oryzae* causing these outbreaks of rice blast are under investigation. The Texas Rice Belt provides a warm, humid climate favorable for the infection and reproduction of *M. oryzae*. Current agronomic practices including dense stands and excessive use of nitrogen fertilizer increase the likelihood of disease development. Blast poses a threat to Texas rice production.

Residues of Thiamethoxam and Chlorantraniliprole in Rice Grains

Teló, G.M., Senseman, S.A., Marchesan, E., Jones, T., Camargo, E.R., and McCauley, G.

The use of insecticides in irrigated rice has been intensified in the recent years due to greater incidence of pests at the economic injury level. In many cases, occurrence of pests causing crop injury had forced producers to apply pesticides near to harvesting time. Therefore, the use of pesticides is characterized as an essential management practice to ensure agricultural yield and food quality. Due to the increasing observation of pesticide applications directly on the organ of the plant that is used for consumption and associated with the fact that rice does not receive intensive industrial processing, the analysis of residues of insecticides on the grain becomes essential, as a way to ensure food safety and quality food. In general, the residues can persist until the harvest stage, resulting in the contamination of the rice grain. Therefore, it is necessary to study pesticide residues in rice grains to provide basic information for the use of thiamethoxam and chlorantraniliprole in pest management strategies in rice fields and to protect public health. The objective of this study was to analyze residues of these insecticides in hull, bran, and polished rice grain.

The first phase of the experiment was conducted during the summer period of 2012 at the David R. Wintermann Rice Research Station at Texas A&M University near Eagle Lake, TX. The rice was seeded in May 5, 2012, using the cultivar Presidio, with seeding rate of 90 kg ha^{-1}. The insecticide applications were done at 5, 15, 25, and 35 days after flowering (35, 25, 15, and 5 days before the rice harvest, respectively) using the recommended rate of thiamethoxam (30 g a.i. ha^{-1}) plus chlorantraniliprole (30 g a.i. ha^{-1}). Besides, a two-fold rate was used in the study (thiamethoxam at 60 g a.i. ha^{-1} plus chlorantraniliprole at 30 g a.i. ha^{-1}). In two treatments, a sequential application using the recommended rate was conducted at 5 and 25 days after flowering and at 5, 25, and 35 days after flowering. For quantification of residues in grains, rice plants were harvested when the average moisture content in the grains reached 22%. Rice harvest was performed 40 days after plant flowering, totalizing an area of 4.76 m^2 (4.0 x 0.95 m) in each plot. Subsequently, samples were cleaned and dried with forced air ventilation at $35^{\pm}2$°C until reaching an average moisture content of 13%. After that, the samples were stored at -20°C. Insecticide residues were quantified using different fractions of rice samples: 1) rice hull, removed from the rice processing carried out in a rice testing machine; 2) rice bran; and 3) polished grain, obtained with the polishing process in a rice processing machine. The second stage of the study was conducted in the laboratory of the Department of Soil and Crop Sciences at Texas A&M University. Prior to chromatographic analysis, the samples were subjected to the extraction process using an Accelerated Solvent Extraction (ASE), and afterwards, the samples were analyzed using Ultra Performance Liquid Chromatography (UHPLC).

Residues of thiamethoxam and chlorantraniliprole were quantified in rice hull. On average, residues of chlorantraniliprole were quantified in concentrations greater than thiamethoxam in rice hulls. Both insecticides were quantified independent of the application timing and rate in rice bran. The highest concentrations were observed for chlorantraniliprole, similar to the results observed in rice hull. With respect to the analysis conducted in polished grain, residues of insecticides were not quantified for the applications using the recommended rate performed at 5 days after flowering. For thiamethoxam, residues were not detected for applications conducted at 5 and 15 days after flowering; however, for all the other treatments, residues were detected for chlorantraniliprole with the highest values were quantified for applications with double the recommended rate. In conclusion, residues of thiamethoxam and chlorantraniliprole applied in rice were detected in hull, bran, and polished rice. Insecticide concentrations were higher in hull and in rice bran demonstrating the importance of evaluating the destination of pesticides and its residues from the field to the final food or feed.

Promises and Challenges of Genomics for Rice Pathology

Jia, Y., Lin, M., and Bianco, T.

Publically available genome sequences of *Magnaporthe oryzae*, *Rhizoctonia solani*, and *Oryza sativa* are being used to study host-pathogen interactions. Comparative genomic analyses on natural alleles of major resistance (*R*) genes and the corresponding avirulence (*AVR*) genes have provided new clues for a better understanding of the co-evolutionary dynamics of critical host and pathogen genes that are involved in host resistance and susceptibility. For the past two years, the molecular rice pathology program of the USDA Agricultural Research Service has been focusing on the following areas: 1) analysis of evolutionary dynamics of three major blast *R* genes, *Pi-ta*, *Pi-t*, and *Pi-d2*; 2) fine mapping of a major sheath blight resistant QTL on chromosome 9; 3) development of user friendly DNA markers for breeders to use via a marker-assisted breeding approach and useful genetic stocks and germplasm with two or more major blast *R* genes; 4) analysis of the resistant roles of major and minor *R* genes in selected germplasm and mapping populations; and 5) analysis of the genetic identity and expression changes of field isolates of *M. oryzae* and *R. solani* to predict stability of deployed resistance. A wide range of molecular techniques involved in DNA sequencing and analysis using Vector NTI, MEGA, and CLC Genomics; protein-protein interactions using two-hybrid systems; and gene expression using DNA microarray, Massively Parallel Signature Sequencing (MPSS), RNAseq, and real time (RT) PCR are being used interchangeably for achieving planned objectives. Recent accomplishments and challenges of the application of genomic information for rice pathology and crop protection will be presented.

Integrated Sensor System for Rice Growth Status Monitoring Based on UGS

Wang, P., Lan, Y., Luo, X., Zhou, Z., Zhou, X., Dou, F., and Hoffmann, W.C.

Considering precision agriculture practice, it is essential to acquire multi-source information simultaneously. The use of a number of sensing techniques working in combination could provide a better characterization of the crop canopy. Also, there are few studies about monitoring crop conditions using UGVS, especially for rice monitoring. The objective of this study was to develop a UGV-based multi sensors system and test the feasibility of this system for monitoring rice conditions. It will provide a good tool for monitoring and managing crop conditions in precision agriculture applications

The UGS, which included a GreenSeeker R100 system, a FieldSpec® Handheld portable spectroradiometer, and an infrared temperature sensor was mounted on the UGV. Each of these instruments is described in detail in the following sections. The system was designed to quickly measure real-time crop conditions including NDVI, spectral reflectance, and canopy temperature in rice growth season simultaneously. The UGS was a light-weight and height/width-adjustable platform with the capabilities of auto-control, four-wheel drive, wireless data communication, and 3D rotary connector rotation. The width can be adapted to the planting ridge spacing from 1 m to 2.2 m, and the height of the equipment install platform is adjustable from 0.5 m to 2 m. The travel speed is set to 3 km/h to ensure stability of measurement data. The load capacity is more than 100 kg. The front frame and rear frame were connected by the 3D rotate connector. The 3D rotate coupler is the main part of the platform to fulfill the turn and adjust the front frame and rear frame when the four wheels are in the uneven ground. It has a network camera, the video image in front of the platform can be sent to the control computer, and the operator could control its moving status by computer control software. It also can be set to the automatic control mode. The embedded image process software will determine the crop and soil edge, and adjust the moving direction dynamically. The third control mode is GPS control mode, before the experiment, the GPS position information for the desired track needs to be input into the control system. After the start button is pushed, it will move according to the preset GPS information.

The Normalized Difference Vegetative Index (NDVI), which is measured by the GreenSeeker R100 system, is a commonly used measurement of crop health in agricultural applications. The wavelength bands select the visible (red, 660 nm) and infra-red (NIR, 770 nm) and the NDVI value is calculated. The one-way ANOVA method was used to build the relationship between NDVI from GreenSeeker sensor and rice LAI. The variation and correlation model were demonstrated in Figure 4. When the NDVI value increased, the rice LAI value increased. The correlation coefficient (R^2) was 0.728 and a significant positive correlation relationship was verified. This result shows that the automatic measurement based UGS is more reliable so as to manual measurement, and the relationship trend between NDVI and LAI is according to the results from other researchers.

Fungicide and Insecticide Residues in Rice Paddy

Teló, G.M., Marchesan, E., Oliveira, M.L., Coelho, L.L., Zanella, R., and Martins, M.L.

Fungicides and insecticides are commonly used in rice in integrated pest management programs in order to assist in the control of pathogens and pest insects. Integrated pest management programs contribute to high levels of productivity and rice quality. However, the intensive use of pesticides in irrigated rice may pose risks to the quality of the grains and the welfare of environment because of its dissipation and persistence in water and soil. There is a lack of information about dissipation and persistence of pesticide residues in rice. Little is known about the proportion of originally applied pesticides found in rice fields. It is important to have sustainable rice production, keeping the environmental quality and food safety paramount. The objective of this study was to quantify the dissipation and persistence of difenoconazole and azoxystrobin fungicides and lambda-cyhalothrin and thiamethoxam insecticides residues in water, soil, plants, panicles, and rice grains.

The study was conducted in the 2011/12 crop seasons at the Federal University of Santa Maria, Brazil. The treatments consisted of applications of fungicides and insecticides on the aerial parts of the rice plants with four on-field replications. The application of fungicides and insecticides were performed at the same time as the development stage of panicle exertion. Water samples were collected for analysis from plots at intervals of 0, 1, 3, and 6 hours and 1, 5, 10, 15, 20, 30, and 40 days after pesticide application. During the same intervals, rice plant samples were also collected. Rice panicle samples were collected at intervals of 5, 10, 15, 20, and 30 days after pesticide application. Soil samples were collected 1 day before the pesticide application and 1, 15, and 45 days after the application. The analysis in rice carpes was conducted in hull, brown, and polished rice. The chromatographic analysis for azoxystrobin, difenoconazole, and thiamethoxam pesticides were analyzed by Ultra High Performance Liquid Chromatography, and the lambda-cyhlothrin insecticide analysis was performed by gas chromatography.

Residues of fungicides and insecticides were quantified in the irrigation water, with the maximum concentration after application. For the fungicide azoxystrobin and the insecticide thiamethoxam, residues were quantified during the time of monitoring of irrigation water (40 days after application). Fungicidal difenoconazole residues were quantified for up to 20 days after application and lambda-cyhalothrin for up to 6 hours after application. Soil pesticide residues were not quantified. The dissipation of pesticides in plant and panicle showed, in general, a similar performance independent of the pesticide, with persistence in plant and panicle during the monitoring period. Azoxystrobin, difenoconazole, lambda-cyhalothrin, and thiamethoxa residues were quantified in rice hulls. However, residues were not quantified in brown and polished rice.

LSU AgCenter Multi-State Rice IPM Industry Survey

Blackman, B., Autin, T., Hummel, N., Meszaros, A., Stout, M.J., Way, M.O., and Lorenz, G.

Surveys were conducted annually for the 2008 through 2012 rice production seasons. Surveys were distributed at farmer meetings, through county extension email lists, and to readers of the LSU AgCenter rice insects blog via an external link to assess the current integrated pest management (IPM) practices utilized among southern rice-growing states each year and how those practices changed throughout the 5-year period the surveys were conducted. Over 850 surveys were collected from rice-industry personnel, with 530 surveys completed by farmers, and the rest identifying themselves as consultants, extension personnel, or industry-related personnel. Data were analyzed to determine trends in rice water weevil and rice stink bug management among states and survey years, and in relation to farm size and years of farming experience.

Using Low-Altitude Multispectral Imagery and Thermography to Assess the Distribution of Rice Sheath Blight

Zhou, Z.Y., Wang, P., Zhang, J.X., Zang, Y., Lan, Y.B., Zhou, X.G., and Luo, X.W.

Assessment of the location and the rate of development of sheath blight in rice fields is critical to effective control of this disease. This study exploited the potential use of disease mapping technology to assess the distribution of rice sheath blight in the field. The experiment was undertaken in a sheath blight-infested paddy field at Beaumont, TX. The canopy reflectance, multispectral imagery, and thermography of rice were measured in the field in order to monitor the damaged areas caused by sheath blight. The characteristics of canopy spectral reflectance and imageries were analyzed in contrast areas and damaged areas. Sever al disease indexes, THM-RVI, NIR-DVI, NIR-NDVI, were built to assess the distribution of sheath blight. The results indicated that the THM-RVI could be used to identify the damaged areas efficiently. The accurate rate of 120 verification imagery samples selected randomly reached 70%. Results of this preliminary study indicate that it was feasible and reliable to estimate the severity of rice sheath blight based on multispectral imagery and thermography at the canopy level.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Eric Webster

Rice Weed Management in Louisiana

Bergeron, E.A., Webster, E.P., Fish, J.C., and McKnight, B.M.

Many weed management programs begin with a burndown application. These burndown applications can consist of a single herbicide application like glyphosate or a multiple herbicide mixture with glyphosate as the standard product in the mixture. It is more important to apply a burndown herbicide in a timely manner and within the guidelines of the label. It is recommended to apply burndown herbicides at least 4 to 6 weeks prior to planting. This removes any vegetation which can compete with emerging rice seedlings, and it can also reduce the insects that may feed on emerging rice. In many cases, a burndown application at planting may be required even when an earlier treatment is applied in order to remove late emerging weeds and guarantee a weed-free seedbed. Research indicates competition from weeds is more severe within 2 to 3 weeks after rice emergence than weeds which emerge after a 3- to 4-week weed-free period. By delaying the initial burndown application to at planting, the producer risks early-season competition from those weeds even though they may be slowed or dying due to the herbicide application.

Flumioxazin, sold under the trade name Valor, is an excellent addition in a burndown program and provides residual activity on many broadleaf weeds; however, it provides little to no activity on grasses so it should be mixed with a glyphosate-containing herbicide. Thifensulfuron plus tribenuron, sold under the trade name FirstShot, provides excellent activity on many broadleaf weeds and on many aquatic weeds. FirstShot contains the same herbicide combination found in Harmony Extra but in a different ratio and rate. The herbicide ratio in FirstShot allows the plant back interval to decrease from 45 days to no plant back restriction. This provides an excellent tool for a burndown program. Even though FirstShot has no plant back restriction, it should be applied 4 to 6 weeks prior to planting to obtain the benefit of the herbicide. Another pre-package mixture rimsulfuron plus thifensulfuron, sold under the trade name LeadOff, is a new herbicide from DuPont that can be used as a burndown herbicide in rice. This herbicide can provide long residual activity on many broadleaf, grass, and sedge weeds. However, LeadOff has some stringent replanting restrictions for rice and other crops, and these restrictions should be followed exactly as the label states.

Four studies were conducted in 2011, 2012, and 2013 at the Rice Research Station near Crowley, Louisiana, and the Northeast Research Station near St. Joseph, Louisiana. Each trial included 16 broadleaf and/or sedge herbicides applied at early postemergence, mid-postemergence, late postemergence, and salvage. Each application timing was a separate study. Clomazone was applied as a preemergernce application at 336 g ai/ha. These studies evaluated control of hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], Indian jointvetch (*Aeschynomene indica* L.), yellow nutsedge (*Cyperus esculentus* L.), and rice flatsedge (*Cyperus iria* L.). Herbicides applied at the early postemergence timing allowed for re-infestation of the area by jointvetch and other weeds. At the mid-postemergence timing, several herbicides controlled the weeds present and allowed the rice to maximize yields. The herbicides that performed at the mid-postemergence timing were bensulfuron, bispyribac, carfentrazone plus quinclorac, halosulfuron, halosulfuron plus thifensulfuron, imazosulfuron, orthosulfamuron plus halosulfuron, penoxulam plus triclopyr, propanil, and quinclorac. Weed control increased with all herbicides applied as a salvage application; however, halosulfuron, penoxulam, penoxulam plus triclopyr, quinclorac, and triclopyr increased yields compared with the nontreated from 1,340 to 2,320 kg/ha. Yields decreased as initial timing was delayed past the mid-postemergence timing. The mid-postemergence timing appeared to be the most consistent of all the studies in 2012 and 2013 from a weed control and yield standpoint.

Spray mixtures of imazethapyr plus propanil or a pre-package mixture of propanil plus thiobencarb, sold under the trade name RiceBeaux, have been evaluated for potential synergism for control of red rice (*Oryza sativa* L.). Red rice control increased 20 to 30% when imazethapyr at 70 g ai/ha was mixed with propanil plus thiobencarb 1.68 kg ai/ha. This increased control translated into a yield increase. Similar results were observed with imazamox plus propanil plus thiobencarb. The addition of propanil at 1.12, 2.24, 3.36, or 4.48 kg ai/ha to imazethapyr 70 g/ha increased red rice control by 5, 8, 12, and 20%, respectively, up to 50 days after treatment. This increased control resulted in increased yields. Similar results were observed with a imazamox plus propanil mixture. This research also indicates that the addition of a mixture herbicide can be beneficial when broad spectrum control is needed.

The Provisia™ Rice System: A New Vision in Red Rice Control (Grassy Weed Control in Rice)

Harden, J., Carlson, D.R., Mankin, L., Luzzi, B., Stevenson-Paulik, J., Guice, J.B., Youmans, C., Hong, H., Castro, H., Sandhu, R., Hofelt, C., McKean, A., Scott, M., and More, D.

The Provisia™ Rice System, a new non-GM herbicide-tolerant system under development by BASF, will complement the Clearfield® rice system, providing growers with another effective weed control technology and a new tool for resistance management. The system will be a combination of Provisia herbicide with Provisia rice. Provisia herbicide is a postemergence graminicide which controls volunteer Clearfield rice (*Oryza sativa* L.), conventional rice types, red rice, weedy rice, and other common annual and perennial grasses, including barnyardgrass (*Echinochloa crus-galli* L). It is not an ALS herbicide, and thus, provides another mode of action to combat ALS-resistant grasses. In field trials, Provisia rice exhibited excellent tolerance to single and sequential herbicide applications. Optimum control of red rice and other grass species was obtained with sequential applications. Provisia herbicide can be tank-mixed with many common rice herbicides to provide broad spectrum control of broadleaf and grass weeds. Current research is focused on optimization of performance and weed control systems that mitigate the potential for the development of herbicide-resistant weeds. BASF is working with multiple seed partners to bring the Provisia™ Rice System to the market in the latter part of this decade.

Effect of Cruiser Maxx Seed Treatment on Rice Tolerance to Low Rates of Newpath and Roundup Applied Early Postemergence

Scott, R.C., Lorenz, G., Hardke, J., and Davis, B.M.

A positive effect of Cruiser Maxx seed treatment was observed when low rates of Newpath (imazethapyr) and Roundup (glyphosate) herbicides were applied to Roy J rice at the 3- to 4-leaf stage. Newpath rates applied were 73.1, 36.5, and 18.2 ml ha^{-1} (1.0, 0.5, and 0.25 oz per acre) and Roundup rates were 292.3, 146.1, and 73.1 ml ha^{-1} (4.0, 2.0, and 1.0 oz per acre). Herbicide treatments were replicated four times and applied with a CO_2 backpack sprayer at 93.5 l ha^{-1} (10 gal per acre). Rice injury at a given rate of either post treatment was 20-60% less when applied to plots where rice seed had been treated with Cruiser Maxx versus a fungicide alone. The fungicide only treatment consisted of Dynasty, Maxim, Dye, and Apron in a slurry. The "insecticide-treated plots" consisted of the fungicide mix plus 456.3 ml 100 kg^{-1} (7.0 oz per 100 lb seed) of Cruiser Maxx. Canopy heights, individual plant heights, rice heading percentage at 90 days after treatment, and yield were also affected. An overall "safening" affect was observed on all the parameters evaluated.

Effect of Simulated Drift of Residual Herbicides on Rice Growth and Yield

Bond, J.A., Edwards, H.M., Montgomery, G.B., and Walker, T.W.

Glyphosate-resistant weeds, primarily glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), are the principal weed control issue facing growers in Mississippi. Rice is not directly affected by glyphosate resistance, but it is impacted indirectly through off-target movement of herbicides targeting glyphosate-resistant weeds in adjacent fields. Herbicide applications targeting glyphosate-resistant weeds prior to planting soybean often include paraquat and a residual herbicide. Injury symptoms from these applications are complex and the residual herbicide is often difficult to identify from visual symptoms.

A study was conducted in 2013 at the Mississippi State University Delta Research and Extension Center to evaluate the effect of simulated herbicide drift on rice growth and yield. Treatments were arranged as a three-factor factorial within a randomized complete block design with four replications. Factor A was herbicide and included paraquat, fomesafen, and metribuzin. Factor B was application rate and represented 3.2, 6.3, 12.5, and 25% of the use rates of paraquat 0.84 kg ai ha^{-1} (0.75 lb ai/A), fomesafen 0.28 kg ai ha^{-1} (0.25 lb ai/A), and metribuzin 0.28 kg ai ha^{-1} (0.25 lb ai/A). Factor C was application timing and included a very early-postemergence (VEPOST) treatment to rice in the one-leaf stage and a late-postemergence (LPOST) treatment to rice in the four-leaf to one-tiller stage. A nontreated control was included for comparison. Rice injury was visually estimated at 3, 7, 14, 21, and 28 days after each application. Days to 50% heading, mature plant height, and rice yield were also determined. Days to 50% heading, mature height, and rice yields were converted to a percent of the nontreated control. All data were subjected to ANOVA and estimates of the least square means were used for mean separation.

Paraquat injured rice more following LPOST applications at 7, 14, 21, and 28 days after application regardless of application rate. Heading was delayed 4 to 14 days following paraquat, and delays were greater following LPOST applications at 6.3 and 12.5% of the use rate. Mature height was only affected when the two highest rates of paraquat were applied LPOST. Rice yield was reduced more following LPOST applications of paraquat at 12.5 and 25% of the use rate. The highest rice injury from fomesafen was 8% observed following application of 25% of the use rate at both timings. Fomesafen did not influence rice maturity. Rice yield was 94% of the nontreated control following fomesafen at 25% of the use rate, regardless of application timing. Rice yield was not impacted by other fomesafen treatments. Metribuzin LPOST generally injured rice more than VEPOST applications. However, at 14 days after application, rice injury was similar following the two highest rates for both application timings. Rice yield was 86% of the nontreated control following metribuzin at 25% of the use rate, regardless of application timing. Rice yield was not impacted by other metribuzin treatments.

Rice recovered from early-season injury following simulated drift of fomesafen and metribuzin with no reductions in rice yield following either herbicide applied at 3.2, 6.3, and 12.5% of the use rate at either timing. Rice growth, development, and yield were influenced more following simulated drift of paraquat LPOST compared with VEPOST. Growers should be extremely cautious when making herbicide applications containing paraquat near rice fields, especially when applications coincide with the early tillering stage of rice.

Benzobicyclon: a Novel Herbicide for U.S. Rice Production

Sandoski, C.A., Brazzle, J.R., Holmes, K.A., and Takahashi, A.

Benzobicyclon is a novel herbicide that is currently under development by Gowan for use on rice in the USA. The molecule is characterized by excellent safety to both *japonica* and *indica* rice varieties, a favorable toxicological and eco-toxicological profile and offers broad spectrum control of grasses, sedges, and broadleaves at rates of 200 – 300 g ai/ha. Benzobicyclon is a slow releaser of the active triketone metabolite that functions as an inhibitor of *p*-hydroxyphenylpyruvate dioxygenase (HPPD). Benzobicyclon was first registered in Japan in 2001 and has become an important tool in Japanese and Korean paddy rice production. The molecule is currently under review by the USEPA and registration is expected in the next few years.

A Review of Benzobicyclon Trials in Arkansas Rice

Norsworthy, J.K., Sandoski, C.A., and Scott, R.C.

Benzobicyclon is an experimental herbicide being evaluated for possible use in U.S. rice. Approximately 20 field and greenhouse trials have been conducted in Arkansas over the past four years to characterize the efficacy of benzobicyclon on a wide array of weeds when applied preemergence, preflood, and postflood in rice. Additionally, experiments were conducted to evaluate the sensitivity of rotational crops to benzobicyclon. Cotton, corn, soybean, grain sorghum, and wheat exhibited sensitivity to various simulated preemergence-applied half-lives of benzobicyclon in the greenhouse but no injury was observed in the field. In initial greenhouse trials that were watered multiple times daily, benzobicyclon provided a high level of preemergence control of several important grassy weeds, including red rice, and some broadleaf weeds; albeit, symptoms were slow to develop relative to what would be expected for traditional preemergence herbicides in rice. Postemergence applications to nonflooded weeds grown in pots were generally less effective than the same rate applied preemergence, regardless of the weed evaluated. Subsequently, trials moved to the field where preemergence and postemergence applications in combination with other herbicides were evaluated in drill-seeded rice. In these trails, benzobicyclon appeared safe to rice but provided little to no control of all weeds, including barnyardgrass - a weed effectively controlled in the initial greenhouse trial. Subsequently, numerous trials were conducted to determine if applying the compound into water with differing flood depths would increase the compound's efficacy. Benzobicyclon does provide a much higher level of weed control when applied immediately after flooding than when applied preflood and efficacy improves as flood depth increases. Based on trials conducted thus far, benzobicyclon appears to highly effective on ducksalad, arrowhead, Amazon sprangletop (tighthead), and rice flatsedge. It also provides good postflood control of barnyardgrass (including propanil, quinclorac, and ALS-resistant populations), yellow nutsedge, and hemp sesbania (coffebean) if plants are small (2 to 4 inches) at application. With much of the Arkansas rice acres infested with herbicide-resistant barnyardgrass and the fact that acres with resistant sedges are increasing, this herbicide shows exciting promise for use in this region.

Herbicides were applied to Roy J rice at the 3- to 4-leaf stage. Newpath rates applied were 73.1, 36.5, and 18.3 ml ha^{-1} (1.0, 0.5, and 0.25 oz per acre) and Roundup rates were 292.3, 146.2, and 73.1 ml ha^{-1} (4, 2, and 1 oz per acre). Herbicide treatments were replicated four times and applied with a CO_2 backpack sprayer at 93.5 l ha^{-1} (10 gal per acre). Rice injury at a given rate of either post treatment was 20-60% less when applied to plots where rice seed had been treated with Cruiser Maxx versus a fungicide alone. The fungicide only treatment consisted of Dynasty, Maxim, Dye, and Apron in a slurry. The "insecticide-treated plots" consisted of the fungicide mix plus 456.3 ml 100 kg^{-1} (7 oz per 100 lb seed) of Cruiser Maxx. Canopy heights, individual plant heights, rice heading percentage at 90 days after treatment, and yield were also affected. An overall "safening" affect was observed on all the parameters evaluated.

Development of a Novel Herbicide, Benzobicyclon, for California Rice Production

Brazzle, J.R., Alonso, D.F., Holmes, K.A., and Takahashi, A.

The herbicide Benzobicyclon is currently under development by Gowan Company & SDS Biotech K.K. for use in the California rice market. Beginning in 2008 thru 2013, field and laboratory studies have been conducted to evaluate crop safety, weed spectrum, use rates, and guidelines, and fit in resistance management and integrated weed management programs in California.

At a use rate of 200-300 gm ai/ha, benzobicyclon provides excellent sedge and select broadleaf weed control. Strong activity on grasses requires more refined application timing. Benzobicyclon has shown greater activity against *Leptochloa* spp. verses *Echinochloa* spp. Several resistant weed species have been tested under field and laboratory conditions highlighting the benefits of benzobicyclon's novel mode of action. In crop safety studies, rates over 600 gm ai/ha have shown a high degree of selectivity as measured in rice stand, growth, and crop yield. Multiple varieties at several stages of crop growth have been tested. In 2013, aerial applications were conducted to confirm and compliment results observed in smaller scale studies.

Benzobicyclon fits well into the water-seeded production system employed in California. This new mode of action potentially provides rice growers a novel tool to combat the growing resistant weed patterns observed in California. Overall, benzobicyclon has a strong fit as a foundation herbicide in California's integrated weed and resistance management programs.

Potential for Benzobicyclon Under Common Louisiana Rice Cropping Systems

McKnight, B.M., Webster, E.P., Fish, J.C., Bergeron, E.A., and Sandoski, C.

Benzobicyclon is a carotenoid biosynthesis inhibiting herbicide currently marketed for use in Japan. Typical herbicide symptoms in susceptible weed species include bleached, white plant tissue followed by necrosis and plant death. Symptoms are generally slow to develop in susceptible weed species, and past research suggests that benzobicylcon must be applied in a flooded rice field and the flood must be maintained for continued activity. Greenhouse and field studies in recent years have investigated benzobicyclon activity under common mid-south rice production practices. The objective of this research is to assess the activity of benzobicyclon on common rice weeds occurring in the mid-south production area and how common cultural practices influence herbicide activity. Two field studies were initiated at the Louisiana State University AgCenter Rice Research Station near Crowley, Louisiana, in the 2013 growing season.

The objective of the first study was to assess how application timing of benzobicyclon as a single herbicide treatment in a water-seeded production system influenced herbicide activity. Benzobicyclon was applied at seven different timings in this water-seeded study; preplant on dry soil, 24 hours after seeding flood establishment and seeding, 24 hours following draining of the seeding flood, on pegging rice 24 h prior to pinpoint flood establishment, on 3- to 4-leaf rice, 4- to 5-leaf rice, and 6- to 1-tiller rice. The rate of benzobicyclon in all application timings was 246 g ai ha^{-1}, and 1% crop oil concentrate was added to all treatments except for the preplant application.

Barnyardgrass (*Echinichloa crus-galli* L.) control 49 days after the final application was highest in treatments applied 24 hours following seeding flood establishment, on pegging rice, and at the 3- to 4-leaf timing. Benzobicyclon at the same three application timings controlled yellow nutsedge (*Cyperus esculentus* L.) higher than other application timings. Ducksalad [*Heteranthera limosa* (Sw.) Willd.] control 49 days after the final application did not differ across all application timings. The highest control of alligatorweed [*Alternathera philoxeroides* (Mart.) Griseb.] from any application timing was 48% with benzobicyclon applied to 4- to 6-leaf rice. No rice injury was observed, and no difference in rice height was observed at harvest.

The objective of a second study was to assess the influence of benzobicyclon applied in mixture with imazethapyr at different timings in a water-seeded Clearfield production system. Imazethapyr was applied at 105 g ha^{-1} in the first application followed by 70 g ha^{-1} in the second application. Five different application timings were selected to reflect recommendations for imazethapyr application in a water-seeded Clearfield system. Three initial imazethapyr application timings were on pegging rice prior to the pinpoint flood establishment, 24 hours following pinpoint flood establishment, and 10 days after pinpoint flood establishment. Two subsequent imazethapyr application timings were on 2- to 3-leaf rice and on 4- to 5-leaf rice. In all combinations of application timings, imazethapyr was applied alone in both applications and mixed with benzobicyclon at 246 g ha^{-1} in either the first or the second application.

At 35 DAT, hemp sesbania [*Sesbania herbacea* (P. Mill.) McVaugh] control was 99% with imazethapyr plus benzobicyclon at the pinpoint flood timing and prior to pinpoint flood establishment followed by imazethapyr alone. Yellow nutsedge control increased with imazethapyr at 105 g ha^{-1}plus benzobicyclon when applied 24 h prior to pinpoint flood establishment. Ducksalad control increased with the addition of benzobicyclon in either the first or second imazethapyr application when applied in the pinpoint flood followed by 10 days after the pinpoint flood program, and in the 2- to 3-leaf followed by 4- to 5-leaf program. No rice injury was observed across all rating dates, and no height differences were observed at harvest.

Sharpen (Saflufenacil) for PRE and POST Emergent Broadleaf Weed Control in Rice

Oostlander, M., Rhodes, A., and Harden, J.

Sharpen (Saflufenacil) is a protoporphyrinogrn-IX-oxidase (PPO) inhibitor and belongs to the pyrimidinedione class of chemistry. Sharpen represents a new standard for broadleaf weed control that has burndown and residual activity. Sharpen is registered for use PREPLANT (PP) and PREEMERGENCE (PRE) to a number of different crops such as corn, soybeans, small grains and pulse crops. Sharpen is currently registered for use prior to rice with a 14-day preplant interval. Trials were conducted in 2012 – 2013 in the rice growing regions of the USA to assess the tolerance of rice to Sharpen applied pre-emergent. Trials were also conducted to assess the tolerance of Sharpen applied post emergent on rice. Trial results showed good rice tolerance to Sharpen applied at 50 g ai/ha (2 oz/ac) in a PRE application. Post emergent application showed minimal injury to rice at rates up to 50 g ai/ha (2 oz/A) but did change with the adjuvant type, where an MSO adjuvant showed more injury than a COC. When injury was present, it was generally transient, and plants grew out of the injury soon after application. Data from the trials suggest that Sharpen could fit into a weed management program for rice, where sequential combinations and tank mixes with other rice herbicides could be utilized for effective weed management.

Potential of Saflufenacil in Clearfield Rice

Fish, J.C., Webster, E.P., McKnight, B.M., and Bergeron, E.A.

Saflufenacil is a new protoporphyrinogen IX oxidase (PPO) inhibiting herbicide for preplant burndown and selective PRE dicot weed control in multiple crops. Herbicides that inhibit PPO control weeds, by inhibiting the synthesis of chlorophylls, hemes, and cytochromes in the chloroplasts. The aim of these studies was to evaluate the potential uses of saflufenacil when mixed with other herbicides commonly used in rice production.

Three studies were established to evaluate saflufenacil when mixed with multiple propanil and propanil containing products. All three studies had a randomized complete block arrangement design in a two factor factorial. In the first study, Factor A consisted of saflufenacil at 0 and 0.355 kg ai ha^{-1}, factor B consisted of propanil (EC) at 0, 1.12, 2.24, 3.36, and 4.48 kg ai ha^{-1}. In the second study, factor B was changed to propanil (SL) at 0, 1.12, 2.24, 3.36, and 4.48 kg ai ha^{-1}. In the third study, factor B was changed to a propanil plus thiobencarb prepackage mix at 0, 1.51, 3.02, 4.54, and 6.05 kg ai ha^{-1}. All treatments were applied mid-postemergence (MPOST) to 3- to 4- leaf rice. The entire research area received clomazone at 0.336 kg ha^{-1} applied preemergence.

At 8 and 35 days after treatment (DAT), alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.], yellow nutsedge (*Cyperus esculentus* L.), and rice flatsedge (*Cyperus iria* L.) control increased with mixtures containing saflufenacil compared with all herbicides applied alone. At 21 DAT, an increase was shown with alligatorweed control with saflufenacil.

At 8 DAT, crop injury increased in mixtures containing saflufenacil compared with propanil applied alone by increasing injury from 19 to 22% without saflufenacil to 30 to 38% with saflufenacil. At 21 DAT, crop injury increased in mixtures containing saflufenacil compared with propanil applied alone by increasing injury from 16 to 19% without saflufenacil to 25 to 26% with saflufenacil. At 35 DAT, crop injury increased in mixtures containing saflufenacil compared with propanil applied alone by increasing injury from 10 to 14% without saflufenacil to 16 to 20% with saflufenacil. There was no difference in yield with rice treated with saflufenacil plus propanil (EC) or propanil plus thiobencarb compared with the nontreated. An increase in yield was shown with saflufenacil mixed with propanil (SL) at 3.36 kg ha^{-1} compared with the nontreated.

Influence of Saflufenacil on Growth and Yield of Southern U.S. Rice

Montgomery, G.B., Bond, J.A., Edwards, H.M., Walker, T.W., and Eubank, T.W.

Saflufenacil is a PPOase-inhibiting herbicide that exhibits postemergence and residual activity. It is currently labeled for burndown in corn, cotton, soybean, and a variety of other crops. Saflufenacil labeling was updated to include burndown in rice in 2011, but applications are restricted to 15 d prior to planting. Labeling may be updated to include in-season applications in the future. Previous research has indicated that rice cultivar and growth stage can impact rice tolerance to herbicide applications. The objective of this study was to compare the tolerance of five commercial rice cultivars to in-season applications of saflufenacil.

A study was conducted once in 2012 and twice in 2013 at the Mississippi State University Delta Reaseach and Extension Center in Stoneville, MS, to evaluate rice cultivar tolerance to postemergence applications of saflufenacil. Treatments were arranged as a two-factor factorial within a randomized complete block design with four replications. The first factor was cultivar and consisted of inbred long-grain cultivars 'Cheniere' and 'CL151,' inbred medium-grain cultivars 'Caffey' and 'CL261,' and hybrid long-grain cultivar 'CLXL745.' The second factor was herbicide and consisted of no treatment, saflufenacil at 0.05 kg ha^{-1} (0.0445 lb ai/A), and carfentrazone at 0.035 kg ha^{-1} (0.0313 lb ai/A). Treatments were applied when rice reached the 3- to 4-leaf stage. Rice injury was visually estimated at 3, 7, 14, and 28 days after treatment (DAT). Injury data were analyzed following arcsine square-root transformation with evaluation interval included as a factor in the analysis. Normalized difference vegetative index (NDVI) was assessed approximately 4 weeks after flooding. Days to 50% heading was recorded as an indication of rice maturity. Rough rice yield and whole and total milled rice yield were determined at the end of the season. Green-NDVI, days to 50% heading, and rice yields were converted to a percent of the nontreated control for each cultivar. All data were subjected to ANOVA and estimates of the least square means were used for mean separation.

The main effects of cultivar and herbicide treatment and all interactions containing these variables were not significant for days to 50% heading, rice yield (rough, whole, and total milled rice), and NDVI. A main effect of variety was detected for rice injury. Pooled across herbicide treatments and evaluation intervals, CLXL745 (13%) was injured more than CL151 or Cheniere (10 and 9%, respectively). Rice injury was similar at 3 and 7 DAT regardless of cultivar or herbicide treatment. Injury declined to 5% at 14 DAT, and by 28 DAT, injury was only 1%.

Although differences in level of injury was noted among the cultivars evaluated, the injury following saflufenacil was similar to that following carfentrazone, which is currently labeled for in-season applications. Moderate injury was observed following applications of saflufenacil at two times the proposed labeled rate. Rice was able to recover from injury observed following herbicide application with no negative impact on maturity or rough, whole, and total milled rice yield. Results indicate that, even though rice injury occurs following application, saflufenacil is safe for application to rice cultivars currently grown in the southern U.S. rice belt.

Rice Flatsedge (*Cyperu iria* L.) Resistance to Acetolactate Synthase Inhibitors

Schrage, B.W., Norsworthy, J.K., Riar, D.S., and Bond, J.

Cyperus iria L. is a problematic monocot in the Cyperaceae family. Its high reproductive efficiency has rendered it troublesome in tropical regions as well as Midsouth rice. Imidazolinone-resitant (Clearfield) rice was introduced in 2002 to curb rising populations and led to an increase in the application of acetolactate synathase (ALS)-inhibiting herbicides. With 129 resistant biotypes, ALS herbicides have a high resistance tendency compared to other modes of action. The confirmation of ALS-resistant rice flatsedge in 2010 has increased the need for additional research exploring the threat of cross-resistance among biotypes. In 2013, an experiment was conducted at the University of Arkansas Altheimer Laboratory in Fayetteville. Two putative resistant biotypes from Arkansas (AR) and Mississippi (MS) and one known susceptible (SUS) were screened for resistance to various rates of bispyribac, imazamox, and penoxulam herbicides at the 3- to 4-leaf stage. Live/dead counts were taken and biomass was harvested at 21 days after treatment (DAT). Data were subjected to probit analysis to discover the lethal dose required to kill 50% of the population (LD50). Resistance to all herbicides was found in the AR and MS populations based on reduced mortality and less reduction in plant biomass relative to the susceptible standard.

Yield Loss from Early-Season Palmer Amaranth Interference in Rice

Meyer, C.J., Norsworthy, J.K., Riar, D.S., Bararpour, M.T., Schrage, B.W., Bell, H.D, and Hill, Z.T.

In Arkansas, *Amaranthus palmeri* is one of the top 10 most troublesome weeds in rice and is a serious management issue on rice levees. Two field trials were conducted in Pine Tree, Arkansas, in 2013 to determine potential yield losses from early-season interference of *Amaranthus palmeri* in rice. In one trial, *Amaranthus palmeri* was spread at 12, 60, 300, and 1500 seeds/m^2 at planting in both hybrid rice, seeded at 442,000 seeds/ha, and conventional rice, seeded at 1,770,676 seeds/ha to determine if yield losses could result from early-season competition. A herbicide program consisting of a recommended rate of clomazone preemergence (PRE) followed by (fb) fenoxaprop-p-ethyl plus halosulfuron post-flood was applied to all plots to control typical weeds in rice such as *Echinochloa crus-galli* and *Sesbania herbacea.* On average, yield for hybrid rice was 505 kg/ha higher than conventional rice although weed competition reduced yields for both rice types. *Amaranthus palmeri* stand counts were determined in each plot prior to flooding and as stand density increased from 0 to 100 plants/m^2, yield for conventional rice decreased from 4,143 kg/ha to 3,890 kg/ha and yield for hybrid rice decreased from 4,648 kg/ha to 4,395 kg/ha. The second trial assessed various PRE programs containing clomazone, imazosulfuron, thiobencarb, or quinclorac for *Amaranthus palmeri* control to prevent yield losses from *Amaranthus palmeri* prior to flood irrigating. *Amaranthus palmeri* control 10 days after pendimethalin (1,120 g ai/ha) plus thiobencarb (4,480 g ai/ha) DPRE was better than clomazone applied PRE alone. An early postemergence and preflood application of 4,480 g ai/ha of propanil was applied to all plots and rice yield data were analyzed. Highest yields (4,421 kg/ha) were observed in plots with clomazone applied PRE followed by (fb) thiobencarb and was significantly greater than all other treatments except for clomazone PRE fb pendimethalin DPRE. The results from these two experiments suggest that early-seasoninterference from *Amaranthus palmeri* can significantly impact rice yields and PRE herbicide programs containing multiple modes of action can effectively control *Amaranthus palmeri* and prevent potential yield losses.

Non-Chemical Strategies for Preventing ALS- and ACCase-Inhibitor Resistance in Barnyardgrass in Rice-Soybean Production Systems of the Mid-Southern U.S.

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

A herbicide resistance simulation model was developed to understand the risk of barnyardgrass evolving resistance to ALS- and ACCase-inhibiting herbicides in Clearfield® rice. The model was implemented in the STELLA® modeling environment and was initially used to understand the risks of barnyardgrass resistance under commonly used herbicide-based programs for weed management in Clearfield® rice in the Mississippi Delta region. The model is being upgraded to evaluate the influence of various non-chemical production practices on the evolution of resistance. In particular, the value of pre-plant tillage, early planting, delayed planting, combination of tillage and delayed planting, early-flooding, delayed flooding, increased seeding rate, rotating with soybean, and combination of all these strategies. These non-chemical strategies can complement herbicide-based programs and help increase the longevity of the herbicide options available for weed control in Clearfield® rice.

Mitigating Risk of Gene-Flow from Transgenic Cultivars to Weedy Rice by Silencing Seed Dormancy Genes

Ye, H., Feng, J., and Gu, X.-Y.

Gene flow from genetically modified crops into non-domesticated relatives may exacerbate weed problems. Available biotechnologies developed to contain transgenes are potentially leaking. Thus, additional approaches are in need to complement with existing transgene-containing techniques to reduce the risk of gene flow. The objective of this project was to develop such a transgene mitigating (TM) strategy by linking to a primary transgene with RNA-interference (RNAi) structures to silence natural genes for seed dormancy, a key adaptive trait that distributes germination over seasons. The built-in linkage with reduced seed dormancy or increased germination uniformity would make transgene-containing plants less competitive in weed populations and also relatively easy to eliminate by regular weed management practices.

Genes underlying the *SD7-1* and *SD12* quantitative trait loci for seed dormancy were map-based cloned from weedy "red" rice. The *SD7-1* seed dormancy gene also has a pleiotropic effect on red pericarp color, which is identical to the *Rc* gene. Coding sequences of these seed dormancy genes were used to design inverted repeat sequences (IRSs) as RNAi structures to prove the TM concept. The IRSs were ligated with the herbicide resistance gene *Bar* to transform the rice cultivar Nipponbare. Selected transgenic lines were crossed with isogenic lines for *SD7-1* and *SD12* to evaluate silencing effects on gene expression, seed dormancy, and pericarp color, and their linkage with glyphosate resistance in hybrid generations.

T0 lines from seven independent transgenic events were confirmed by southern-blotting, antibiotic, and herbicide resistance assessments. The lines that displayed a single-gene segregation pattern for the transgenic construct/trait in the T1 generation were selected to cross with the isogenic line. The hybrid F_1 plants with (positive) and without (control) the transgenic/construct trait were grown in a greenhouse. The transcription levels of both *SD7-1* and *SD12* and their downstream genes were dramatically reduced in the positive F_1 plants as compared with the negative control. Seeds harvested from the positive F_1 plants displayed white pericarp color and increased germination rate, which was 60% higher than that of the negative control. These results clearly demonstrated that the RNAi construct had silencing effects on both dormancy and pigment traits in the hybrid F_1 generation. In an F_2 population grown in the greenhouse, the herbicide resistance and pigment traits were completely linked. Seed dormancy assessment for the F_2 population is underway. The above observations indicate that the silencing effects on the weedy characters can be passed from the F_1 to higher generation and suggest that the TM strategy could be used to reduce the fitness of transgene-contaminated weedy red rice.

Effect of Fall Residual Herbicides on Rice Growth and Yield

Edwards, H.M., Bond, J.A., Montgomery, G.B., Eubank, T.W., and Walker, T.W.

Thirty-two counties in Mississippi contain populations of glyphosate-resistant (GR) Italian ryegrass. Italian ryegrass residue remaining at planting can impede planting practices, contribute to competition between crop seedlings and established GR Italian ryegrass, and hinder herbicide programs due to inadequate coverage. Mississippi State University recommends fall applications of residual herbicides for control of GR Italian ryegrass. Recommended residual herbicides include clomazone (Command), pyroxasulfone (Zidua), *s*-metolachlor (Dual Magnum), and trifluralin (Treflan). Problematically, pyroxasulfone, *s*-metolachlor, and trifluralin are not labeled for fall application prior to planting rice. Therefore, research was conducted to determine the rice response to residual herbicides applied in the fall prior to planting.

Research was conducted from 2010 to 2013 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate the effect of fall residual herbicides on rice growth and yield. The study was designed as a two-factor factorial within a randomized complete block with four replications and was repeated in space each year. Factor A was residual herbicide and included clomazone, pyroxsaulfone, s-metolachlor, and trifluralin. Factor B was application rate and included one-half, one, and two times (0.5-, 1-, and 2-X) the recommended rates for control of GR Italian ryegrass in Mississippi. Clomazone at 0.43, 0.84, and 1.68 kg ai ha^{-1} (0.38, 0.75, and 1.5 lb ai/A); pyroxasulfone at 0.083, 0.168, and 0.325 kg ai ha^{-1} (0.074, 0.15, and 0.29 lb ai/A); *s*-metolachlor at 0.717, 1.423, and 2.2847 kg ai ha^{-1} (0.64, 1.27, and 2.54 lb ai/A); and trifluralin at 0.841, 1.681, and 3.363 kg ai ha^{-1} (0.75, 1.5, and 3 lb ai/A) were surface-applied in early November each year. Trifluralin treatments were incorporated with two passes in opposite directions with a tandem disk. A control that received no fall residual herbicide was included for comparison. Plots were left undisturbed until rice was planted in mid-May. Rice was managed throughout the growing season to optimize yield. Rice height and 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. The number of days to 50% heading was recorded as an indication of rice maturity. Rough rice yields were adjusted to 12% moisture content. Data for rice height, days to 50% heading, and rough rice yield were converted to a percent of the nontreated control prior to analysis. Data were subjected to ANOVA and estimates of the least square means were used for mean separation.

Pooled across application rate, pyroxasulfone, *s*-metolachlor, and trifluralin reduced rice seedling density 20 to 21% compared with clomazone. Rice injury ranging from 8 to 53% was observed 14 DAE for all herbicides and rates except clomazone. Injury was similar 14 DAE following all rates of pyroxasulfone, *s*-metolachlor, and trifluralin. Rice injury was still visible 28 DAE for all residual herbicides except clomazone. Pooled across application rate, pyroxasulfone, *s*-metolachlor, and trifluralin reduced rice height 21 DAE and delayed maturity compared with clomazone. Rough rice yields were similar following all residual herbicides applied at 0.5-X rates. Rough rice yields were lower following 1-X rates of pyroxasulfone and trifluralin compared with clomazone or *s*-metolachlor. Applications at 2-X rates reduced yield in plots treated with pyroxasulfone, *s*-metolachlor, or trifuluralin compared with clomazone.

Pyroxasulfone and trifluralin applied at 1-X rates negatively influenced rice growth, development, and yield. Although rough rice yields were not reduced following *s*-metolachlor at the 1-X rate, early-season injury and reductions in seedling density and height would preclude this treatment from being applied in the fall before rice. Therefore, only clomazone should be utilized as a fall residual herbicide treatment targeting GR Italian ryegrass prior to planting rice.

Activity of Benzobicyclon on Common Rice Weeds

McKnight, B.M., Webster, E.P., Fish, J.C., Bergeron, E.A., and Sandoski, C.

Field and greenhouse studies were established to evaluate the activity of benzobicyclon on common weed species occurring in rice cropping systems in the Mid-South. Benzobiccyclon is a carotenoid biosynthesis inhibiting herbicide currently marketed for use in Japan. Typical herbicide symptoms in susceptible weed species include bleached plant tissue followed by necrosis and plant death. A field study was conducted at the Louisiana State University AgCenter Rice Research Station near Crowley, Louisiana, and the greenhouse study was conducted at the Louisiana State University Campus in Baton Rouge, Louisiana.

In the field study, 91-cm diameter by 30-cm deep galvanized rings were installed in individual plots for treatment containment. The area was surface irrigated to encourage weed seed germination. Once weeds emerged, a permanent flood was established. No rice was planted in the plot area or rings to encourage uniform weed emergence. The timing selected for application of benzobicyclon was when ducksalad [*Heteranthera limosa* (Sw.) Willd.] had reached the spoon growth stage. Benzobicyclon was applied at nine different rates: 33, 66, 132, 198, 264, 528, 792, 1056, and 1320 g ai ha^{-1}. Ratings were collected at four timings following application on four weed species; ducksalad, barnyardgrass (*Echinichoa crus-galli* L.), Indian jointvetch (*Aeschynomene indica* L.), and yellow nutsedge (*Cyperus esculentus* L.).

At 21 and 35 DAT, ducksalad control was 85 to 99% when treated with benzobicyclon at 132 g ha^{-1} or higher, suggesting this species is very susceptible to benzobicyclon. At 49 DAT, the highest barnyardgrass control was 81% when treated with benzobicyclon at 1,320 g ha^{-1}. Indian jointvetch and yellow nutsedge control was highest when these weeds were treated with 1,320 g ha^{-1} of benzobicyclon with 70 and 75% observed control, respectively. Ducksalad control was not different among any treatment at rates of 132 g ha^{-1} to 1,320 g ha^{-1}, with 96 to 99% control. At 10 DAT, yellow nutsedge control was 30% when treated with 1,320 g ha^{-1}; however, control increased to 75% at 49 DAT, suggesting several weeks are necessary for control of this species.

In the greenhouse study, three- to six-leaf yellow nutsedge plants were transplanted into plastic containers designed to maintain a 5- and 10-cm flood depth. Plants were allowed to establish for 7 days before a flood was introduced and herbicide treatments were applied. Five rates of benzobicyclon were applied: 264, 528, 1,056, 1,584, and 2,112 g ha^{-1} in both a 5- and 10-cm flood. Visual control ratings were collected at 14, 21, and 28 DAT. At the final rating, 28 DAT, plants were harvested and data collected including plant height, leaf and tuber counts, whole plant fresh weight, root weight, and aboveground tissue weight.

At 28 DAT, the highest yellow nutsedge control was oberved when treated with 1,056 g ha^{-1} of benzobicyclon in the 10-cm flood. The tallest plants were the nontreated plants in the 5-cm flood at 66 cm and were not different in height from the nontreated plants in the 10-cm flood. Nontreated plants also had the most leaf and tuber numbers at the conclusion of the study and were higher in number than plants receiving any rate of benzobicyclon. The highest whole plant fresh weight was observed in the nontreated plants in the 5-cm flood and was not different from the whole plant fresh weight observed in the nontreated plants in the 10-cm flood.

When a permanent flood is maintained following herbicide application, benzobicyclon exhibits activity on common rice weed species found in Louisiana rice cropping systems. This research suggests that control with benzobicyclon increases with deeper flood water and the flood must be present and maintained for the herbicide to be active. Benzobicyclon, in combination with cultural practices, has shown effective weed control in these studies and a fit within herbicide programs recommended for Louisiana rice production.

Weed Control Demonstration of Five Rates of Benzobicyclon Applied at Two Maintained Flood Depths to Rice Weeds

Davis B.M., Scott, R.C., and Sandoski, C.A.

Gowan Company has reached an agreement to develop and register the herbicide benzobicyclon for use in US rice. With more and more weeds becoming resistant to current rice herbicides, a new herbicide is needed. Benzobicyclon is a HPPD inhibitor with promising weed control and rice tolerance. A trial was initiated in the summer of 2013 at the University of Arkansas at Pine Bluff, Research Farm near Lonoke, AR, to determine the efficacy of multiple rates of benzobicyclon applied at two flood depths to rice weeds. Rates consisted of 0, 50, 75,100,125, and 150 g ai/a. Two flood depths of 5 and 10 cm were established once the weeds reach the 10-cm height. Treatments were applied using a CO_2 pressurized backpack sprayer calibrated to deliver 93 L/ha. Data were collected weekly. This study was not replicated and was established to help determine the direction of future research. In addition due to the water solubility of this compound all treatments must be applied and maintained in individual plots. Targeted weeds consisted of barnyardgrass, tighthead sprangletop, broadleaf signalgrass, duck salad, and hemp sesbania. At 8 days after application, control of most weeds was less than 75% at either flood depth. However, by 39 DAA, 150 g ai/a applied at both the 5- and 10-cm flood controlled barnyardgrass, tighthead sprangletop, and duck salad at 99%.

Propanil Rates with Imidazolinone Herbicides for Weed Control

Fish, J.C., Webster, E.P., Bergeron, E.A., McKnight, B.M., and Blouin, D.C.

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 Louisiana State University AgCenter Rice Research Station and the Mississippi State University Delta Research and Extension Center to evaluate herbicide mixtures and their impact on several weed species. Previous data indicate a potential for synergism between propanil and imazethapyr when mixed for control of red rice (*Oryza sativa* L.) and other weed species.

Two studies were established to evaluate the potential synergism between propanil and imazethapyr or imazamox. The experimental design was a randomized complete block with four replications in a two-factor factorial arrangement of treatments. In the first study, factor A consisted of imazethapyr at 0 and 70 g ai ha^{-1}. Factor B consisted of propanil at 0, 1.12, 2.24, 3.36, and 4.48 kg ai ha^{-1}. In the second study, imazamox at 0 and 44 g ai ha^{-1} was substituted for imazethapyr for factor A.

Red rice control at 14 days after treatment (DAT) provided a synergistic response when imazethapyr was added in a mixture with propanil at 2.24, 3.36, and 4.48 kg ha^{-1}. Control was increased from an expected value of 75, 76, and 76% control of red rice to 81, 85, and 87%, respectively. When imazamox was substituted for imazethapyr, a synergistic response mixed with propanil at 3.36 and 4.48 kg ha^{-1}. Barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv] control with all imazethapyr plus propanil mixtures resulted in an additive response. Imazamox plus propanil at 1.12 kg ha^{-1} resulted in a synergistic response.

At 21 DAT, imazethapyr plus propanil at 4.48 kg ha^{-1} increased red rice control from 87 to 93%, while all other mixtures resulted in an additive response. Similar results where shown with imazamox by increasing red rice control from 84 to 90% with propanil at 3.36 kg ha^{-1} and from 81 to 89% control with propanil at 4.48 kg ha^{-1}, and an additive response for control from all other mixtures. Barnyardgrass control with all treatments, including imazethapyr or imazamox plus propanil, resulted in an additive response.

At 49 DAT, imazethapyr mixed with propanil at 4.48 kg ha^{-1} increased red rice control from 82 to 93% control. Imazamox plus propanil at 1.12, 2.24, 3.36, and 4.48 kg ha^{-1} increased red rice control from 73 to 80, 84, 83, and 84% control, respectively. Barnyardgrass control with imazethapyr plus propanil at 1.12 kg ha^{-1} was antagonistic by decreasing control from 78 to 64% control. All rates of propanil when mixed with imazamox resulted in additive response for barnyardgrass control. All herbicide mixtures resulted in higher yields compared with imazethapyr or imazamox alone.

A mixture of propanil at 4.48 kg ha^{-1} plus imazethapyr at 70 g ha^{-1} or imazamox at 44 g ha^{-1} provided a synergistic response for control of red rice. The increased weed control is a valuable response when used in the Clearfield system to help manage or reduce the development of herbicide-resistant red rice. The higher rates of propanil when mixed with imidazolinone herbicides were synergistic for barnyardgrass, as well as increased control of browntop millet [*Panicum ramosum* (L.) Staph], Amazon sprangletop [*Leptochloa panicoides* (J. Presl) Hitch.], and hemp sesbania [*Sesbania herbaccea* (Mill.) McVaugh].

The Effect of RiceBeaux® on the Translocation and Absorption of ^{14}C-imazamox in Red Rice (*Oryza* spp.)

Jones, T.N., Carson, K.L., Senseman, S.A., Telo, G.M., McCauley, G.N., Wherley, B.G., and Way, M.O.

The Clearfield® rice production system has been increasingly used by rice growers to control troublesome weeds such as red rice. Newpath® (imazethapyr) and Beyond® (imazamox) are imidazolinone herbicides that are commonly utilized in this system. These herbicides have historically exhibited excellent control of red rice. However, multiple cases of red rice resistance to imidazolinone herbicides have been observed in the United States and Brazil. RiceBeaux® is a registered herbicide produced by RiceCo that is comprised of two familiar rice herbicides, propanil, and thiobencarb. Used alone, RiceBeaux® provides no control of red rice; however, when tank-mixed with imazamox or imazethapyr, enhanced red rice control has been observed.

This study was established to characterize the interaction of RiceBeaux® on the translocation and absorption of imazamox using ^{14}C-imazamox. TX-4 red rice plants were treated with 1 µl of ^{14}C-imazamox, and plants were harvested at eight separate timings. Six samples were harvested from each plant and analyzed using Liquid Scintillation Spectrometry in order to quantify radioactivity.

Significantly more ^{14}C-imazamox was recovered from the cuticle when imazamox was applied alone at all timings. Imazamox+RiceBeaux® resulted in significantly higher absorption of ^{14}C-imazamox at 24, 48, and 96 hours after treatment. Results indicate RiceBeaux® may allow more imazamox to cross the lipophilic cuticle to reach the sites of action, resulting in enhanced red rice control. This interaction may explain the enhanced red rice control seen in field studies when RiceBeaux® was tank-mixed with imidazolinone herbicides.

Selectivity of Bispyribac-Sodium and Penoxulam on Tropical J*aponica* Rice in Eastern Uruguay

Saldain, N.E. and Sosa, B.

Rice acreage of the eastern Uruguay is located from 32° to 34° latitude south and 54° longitude west. To get a higher proportion of the rice yield potential, seeding date must be done in October, but in some years, our farmers started seeding in the last decade of September. Climate change is going on and forecasts estimated that the frequency of extreme events at our latitude will be higher than normal. A scenario with temperatures lower than normal at the beginning of the seeding season will be more frequent. Consequently, herbicide selectivity has to be studied to recommend a safe use of this very important input. The objective was to study bispyribac-sodium and penoxulam selectivity on tropical *japonica* rice cv. INIA Tacuarí and cv. Parao.

A field experiment was conducted at the Experimental Unit of Paso de la Laguna (UEPL sp.) in 2011 and in 2012. Either bispyribac-sodium or penoxulam is an ALS inhibitor showing excellent barnyardgrass weed control in post emergence application. INIA Tacuarí was selected from a cross between Newbonnet/NewRex L 79, being the parental a line selected for the progeny of a natural cross between NewRex/unknown. Instead, Parao was derived from a cross between INIA Tacuarí /L1844 (L43/C190). L43 and C190 were selected locally derived from a cross between Bluebelle/Lebonnet and Lemont/L143tx; respectively. L143tx was a material selected locally on a F_3-material introduced from Texas. INIA Tacuarí and Parao were released by National Institute of Agriculture Research (INIA sp.) in 1992 and in 2012; respectively. Herbicide treatments evaluated were: a check, plots without use of herbicide treatment and hand weeding, 40 and 80 g ai ha^{-1} of bispyribac-sodium and 36 and 72 g ai ha^{-1} of penoxulam. Treatments evaluated were randomly assigned to the plots and were displayed in a randomized complete block design layout with three replications. Each trial was seeded on Oct-06-2011 and Oct-04-2012 and the herbicide treatments were applied at 2- to 3-leaf stage and flooding was done on Nov-04-2011 and Nov-08-2012, respectively. A CO_2-backpack sprayer was used to apply herbicide treatments, delivering 140 L ha^{-1}. Plants m^{-2}, flowering date, plant height at harvest, rice yield, and yield components were determined. Rice yields (kg ha^{-1}) were adjusted by head and milled yield, chalky, and stained grain percentages and were expressed at 13% moisture content. Proc Mixed was used for analysis of variance and Proc GLM was run for regression analysis of variance. If it was necessary, half-filled grains $panicle^{-1}$, chalky and stained grain percentages were transformed by square root of the sum of the variable value plus 0.5.

A combined analysis with the trials carried out was run and a significant interaction between year and variety was found (p=0.0197), in consequence, the results obtained were discussed by variety. In average for INIA Tacuarí, there was no reduction on rice yield with bispyribac-sodium rate increase; however, a negative linear model was significantly fitted with panicles m^{-2}. The model was y= 541.2582 -1.1948 x; r^2= 0.57; n= 18 (p=0.0180). In regards to the fitted model of flowering date, it showed 3 or 6 days of delaying compared to the check due to the rate of bispyribac-sodium under lower temperature than normal during the early vegetative stage of rice in 2011-12 but this fact was not happened in 2012-13. For penoxulam rates, a negative linear relationship was significant fitted with rice yield. The model was y= 10058 – 17.4451 x; r^2= 0.53; n= 18 (p=0.0004). Instead for panicles m^{-2}, a significant linear relationship was found with penoxulam rates in 2011-12 but it was not detected in 2012-13. The model fitted was y= 548.4749 – 1.5886 x; r^2=0.61; n=9 (p=0.0032). With regards to flowering, a quadratic model was fitted (p= <0.0001), showing a delay until 48 g ai ha^{-1} of penoxulam in 2011-12, by contrast, a slightly shorten of the flowering date was observed (p= <0.0001) in 2012-13. In the case of Parao over the average, it was not possible to fit any model between bispyribac-sodium rates and rice yield, however, the number of panicles m^{-2} was reduced significantly in 2011-12 but there was a no significant slight reduction in 2012-13. The model fitted was y= 592 – 1.7565 x; r^2= 0.53; n=9 (p=0.0262). Also in 2011-12, flowering date was delayed 2 to 4 days with respect to the check when bispyribac-sodium rate increase. With regards to penoxulam rates, it was significantly fitted different models with rice yield depending of the year. In 2011-12, the model was a linear one, being y= 9712 -19.4778 x; r^2= 0.5; n=9 (p=0.0340); otherwise in 2012-13, a quadratic model was significantly fitted. The adjusted model was y= 11325 -58.0516 x + 0.4697 x^2; r^2=0.73; n=9 (p=0.0195). In both years, a quadratic model was fitted significantly between penoxulam rates and the panicles m^{-2}, being the model y= 587 – 3.5176 x + 0.0302 x^2; r^2=0.42; n=18 (p=0.0156). Finally, for the flowering date, there was not found a delay in any of the years studied.

When bispyribac-sodium and penoxulam had been applied on rice at early vegetative stage under cooler season, growth was stunted compared to the check. Bispyribac-sodium may be used safely at 40 g ha^{-1} on INIA Tacuarí as well as Parao, just showing a slight flowering delay on INIA Tacuarí. Penoxulam did not reduce rice yield on INIA Tacuarí but did on Parao, looking more sensitive at the highest rate. Penoxulam application on Parao should be used at the lower rate specially, when air temperature was below 21°C around spraying date.

Tolerance of Rice to Pyroxasulfone Applied PRE

Meyer, C.J., Norsworthy, J.K., Riar, D.S., Bararpour, M.T, Schrage, B.W., Bell, H.D., and Hill, Z.T.

Pyroxasulfone was recently registered as a protoporphyrinogen oxidase (PPO) inhibitor in corn and soybean that provides control of annual grasses and small-seeded broadleaves, including *Amaranthus palmeri.* A field trial was conducted in Stuttgart, Arkansas, in 2013 to assess the potential for pyroxasulfone carryover to rice based on applied half-lives. Pyroxasulfone was applied PRE at the recommended rate for corn and soybean of 149 grams active ingredient per hectare (2.5 oz/acre) and the 1/2X, 1/4X, 1/8X, 1/16X, 1/32X, and 1/64X rates. Stand counts of plants per 0.5 m^2 were determined 3 weeks after treatment (WAT) and percent injury of the crop was rated at 2, 4, 5, 6, and 11 WAT. Additionally, plots were harvested at maturity and yields were compared to evaluate yield loss of treated plots relative to the untreated check. Three nonlinear models were used to fit the data for stand counts, injury 2 WAT, and yield data with R^2 values of 0.91, 0.95, and 0.77, respectively. At the 1/4 X rate, the predicted mean stand loss was 75 plants/m^2 and the predicted mean injury at the same rate was 59% with both estimates resulting from exponential decay models. The harvest data were more variable and exhibited a quadratic relationship with pyroxasulfone rate, likely due to the ability of the rice that emerged to tiller, compensating for the reduced stand, and recover from visual injury symptoms, such as stunting. These results suggest pyroxasulfone should not be used in rice to control early-season weeds. Additionally, carryover injury from applications of pyroxasulfone to a previous crop should not be a concern because pyroxasulfone is short-lived in the soil and rice did show tolerance to pyroxasulfone at very low rates (1/32X and 1/64X).

Barnyardgrass Control in Conventional Rice Herbicide Programs

Edwards, C.B., Bond, J.A., Eubank, T.W., Montgomery, G.B., and Edwards, H.M.

Barnyardgrass (*Echinochloa crus-galli*) is the most common and troublesome weed of rice in Mississippi. Although the Clearfield® system has provided a tool to help manage barnyardgrass, sustainability of this technology is a growing concern. Four Mississippi counties are known to contain populations of barnyardgrass resistant to ALS-inhibiting herbicides, including Newpath, Beyond, Regiment, and Grasp. Barnyardgrass populations resistant to propanil and/or quinclorac are also common in Mississippi. Furthermore, one Mississippi population of barnyardgrass exhibits multiple resistances to quinclorac, ALS-, and ACCase-inhbiting herbicides. Conventional herbicide programs provide an opportunity to rotate herbicide modes-of-action to help alleviate selection pressure on barnyardgrass with ALS-inhbiting herbicides used in Clearfield® rice production. Research is conducted annually in Mississippi to evaluate barnyardgrass control with conventional herbicide programs.

Research was conducted from 2009 to 2013 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate barnyardgrass control with conventional herbicide programs. The experiment was designed as a randomized complete block with four replications. Herbicide treatments were chosen to avoid selection pressure on barnyardgrass with ALS- and ACCase-inhibiting herbicides. Bolero, Command, Facet, Prowl H_2O, RiceBeaux, and SuperWham were utilized in different combinations and at different application timings. Application timings included preemergence (PRE), delayed-preemergence (DPRE), early-postemergence (EPOST) to rice in the two- to three-leaf stage, mid-postemergence (MPOST) to rice in the three- to four-leaf stage, and late-postemergence (LPOST) to rice in the four-leaf to one-tiller stage. Visual estimates of rice injury and barnyardgrass control were recorded 7, 14, and 28 days after each application. Rough rice yield was adjusted to 12% moisture content. Data were subjected to ANOVA and estimates of the least square means were used for mean separation.

Although rice injury up to 16% was observed 7 days after some treatments, the injury was transient, and no injury was observed 14 days after any treatment. Herbicide application timing was critical for barnyardgrass control. For example, control was reduced when Prowl H_2O plus Facet were applied EPOST followed by SuperWham LPOST compared with the same treatments applied DPRE followed by MPOST (76 vs. 90% at 28 days after LPOST application). Total postemergence programs without Command controlled barnyardgrass less than those that included Command EPOST. Rough rice yields were lower following Facet EPOST followed by RiceBeaux LPOST and Prowl H_2O plus Facet EPOST followed by SuperWham LPOST compared with other sequential herbicide programs.

Data indicated that barnyardgrass can be managed in rice, even if it is resistant to ALS- and ACCase-inhibiting herbicides. However, multiple applications of postemergence and residual herbicides were needed to achieve adequate control of barnyardgrass. When barnyardgrass does emerge, the timing of the postemergence herbicide is critical. A postemergence herbicide application should include premixes or tank-mixtures of herbicides with multiple modes of action. In the event that a propanil-resistant barnyardgrass population evolves multiple resistances to ALS- and ACCase-inhibiting herbicides, control options will be severely limited.

Evaluation of Herbicide Resistance in Roadside Barnyardgrass Populations Collected from Eastern Arkansas

Bagavathiannan, M.V. and Norsworthy, J.K.

Arable weed populations present outside of cultivated fields can serve as reservoirs for herbicide resistance traits and aid in the long-distance dispersal of resistance in the landscape. In Arkansas rice production, barnyardgrass is a prime resistant weed with widespread resistance to propanil and quinclorac. ALS-inhibiting herbicide-resistant barnyardgrass is also becoming a growing issue in this region. Surveys were conducted in the Mississippi Delta region of eastern Arkansas to understand the prevalence of barnyardgrass populations on roadside habitats (road verges, field shoulders, and ditchbanks) and the level of herbicide resistance in them. Five hundred randomly selected survey sites were visited and 350 barnyardgrass samples were collected. The samples were screened for resistance to propanil, quinclorac, imazethapyr, and glyphosate. Resistance to propanil and quinclorac were commonly found in roadside barnyardgrass populations, although at variable frequencies. Results indicate that roadside populations are important components of the meta-population for barnyardgrass and they need to be adequately managed to prevent the spread of resistance.

Salvage Treatments in Rice

Bergeron, E.A., Webster, E.P., Fish, J.C., and McKnight, B.M.

A study was established at the Louisiana State University AgCenter Rice Research Station near Crowley, Louisiana, to evaluate herbicides with predominantly broadleaf and/or nutsedge activity. The study had a randomized complete block design with four replications. 'Clearfield 111' rice was planted on March 27, 2013. The entire study area was treated with clomazone at 336 g ai/A as a preemergence to control grasses. A post-flood application of fenoxaprop at 122 g ai/ha was applied to control late emerging grasses. Salvage treatments were applied to rice in the 4- to 6-tiller rice at 73 days after planting. Herbicides applied to rice in a salvage situation were bensulfuron at 42 g ai/ha, bispyribac at 28 g ai/ha, carfentrazone at 17 g ai/ha, carfentrazone plus quinclorac at 440 g ai/ha, halosulfuron at 53 g ai/ha, halosulfuron plus thifensulfuron at 39 g ai/ha, imazosulfuron at 157 g ai/ha, orthosulfamuron at 70 g ai/ha, orthosulfamuron plus halosulfuron at 73 g ai/ha, penoxulam at 35 g ai/ha, penoxulam plus triclopyr at 340 g ai/ha, propanil at 4.48 kg ai/ha, quinclorac at 600 g ai/ha, saflufenacil at 50 g ai/ha, and triclopyr at 280 g ai/ha. Indian jointvetch (*Aeschynomene indica* L.) and hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh] control, and rice injury were visually evaluated at 14, 28, and 42 days after treatment. Rice was harvested on July 30 with a small plot combine and yield was adjusted to 12% moisture.

At 14 DAT, Indian jointvetch control was 95 to 96% when treated with all herbicides evaluated except carfentrazone, propanil, and triclopyr with 90 to 91% control. Indian jointvetch control increased to 97 to 98% when treated with all herbicides except carfentrazone with 91% control. At 7 days prior to harvest, Indian jointvetch control was above 90% when treated with most herbicides evaluated; however, control declined with bensulfuron 59%, carfentrazone 70%, and propanil 88%. Hemp sesbania was harder to control due to the large size of the plants at application. At 14 DAT, bispyribac, penoxulam plus triclopyr, and saflufenacil controlled hemp sesbania 95 to 98%; however, bensulfuron, carfentrazone, and triclopyr controlled hemp sesbania less than 80%. Hemp sesbania control had similar trends at 28 and 42 DAT.

No injury was observed from the late season applications, and rice plant height at harvest was 97 to 104 cm with no differences observed. Rough rice yield was 10,270 kg/ha from rice treated with halosulfuron; however, no difference in yield occurred with rice treated with bispyribac, carfentrazone, imazosulfuron, orthosulfamuron, orthosulfamuron plus halosulfuron, penoxulam, penoxulam plus triclopyr, quinclorac, and triclopyr with yields from 9,020 to 9,720 kg/ha.

Producers should not rely on salvage applications to manage weed problems; however, sometimes unforeseen circumstances dictate these applications. With the number of herbicides available for use in rice some have labels that support salvage applications. Halosulfuron is a herbicide that is legal to apply in many salvage situations and often fits the weed spectrum present in rice fields in the late season in Louisiana.

Management of Weedy Rice in a Clearfield Rice System

Webster E.P., Fish J.C., McKnight, B.M., and Bergeron, E.A.

Clearfield hybrid rice (*Oryza sativa* L.) was introduced in 2003 and is resistant to the imidazolinone family of herbicides. Imazethapyr and imazamox are the two herbicides labeled for use on Clearfield rice in the United States. Hybrid rice seed has a history of dormancy, and it can become a weedy plant if allowed to establish the following growing season as an F_2. Clearfield F_2 plants can vary in phenotype and are often resistant to imazethapyr and imazomox. These resistant F_2 plants can become a tremendous weed problem when Clearfield hybrid rice is grown in consecutive years. Another problem with the Clearfield rice technology is outcrossing potential of Clearfield rice with red rice (*Oryza sativa* L.).

A producer location was identified in 2008 near Estherwood, Louisiana, with a history of three consecutive growing seasons of Clearfield hybrid rice production. This location was determined to have both weedy hybrid and red rice outcrosses. A long-term study was established in 2009 through 2012 to evaluate four different rotations to better determine the best management practices for managing weedy rice plants. The rotations used were: 1) Roundup Ready soybean followed by (fb) Clearfield hybrid rice fb Roundup Ready soybean fb Clearfield hybrid rice; 2) Roundup Ready soybean fb Roundup Ready soybean fb Roundup Ready soybean fb Clearfield hybrid rice; 3) fallow fb fallow fb Roundup Ready soybean fb Clearfield hybrid rice; and 4) fallow fb Clearfield hybrid rice fb Roundup Ready soybean fb Clearfield hybrid rice. The herbicide programs and cultural practices were consistent across a given rotation.

In 2009, the field was divided into two 0.4 ha blocks. One 0.4 ha block was planted to Roundup Ready soybean and treated with glyphosate at 1.12 kg ai/ha plus dimethenamid at 1.12 kg ai/ha in the first trifoliate leaf stage. A second application of glyphosate at 1.12 kg/ha was applied at 14 to 21 days later. The area was maintained weed free. A second 0.4 ha block remained fallow and was treated twice with glyphosate at 1.12 kg/ha and fb tillage 14 days after each glyphosate application. Both 0.4 ha blocks were maintained weed-free in order to prevent added seed to the seed bank. In 2010, each 0.4 ha block was further divided into 0.2 ha blocks following the previously described rotation scheme. Clearfield rice was treated with 105 g ai/ha imazethapyr fb 105 g/ha imazethapyr 14 days later fb 44 g ai/ha imazomox at panicle differentiation. Weedy rice plants were counted in each 0.2 ha block planted to rice. The soybean/rice rotation had 2.5 weedy rice plants/m^2 and the fallow/rice rotation had 6.5/m^2. This indicates that the use of the Roundup Ready soybean rotation helped reduce the weedy rice population. In 2011, the area was planted to Roundup Ready soybean and treated as previously described. At harvest, there was no weedy rice plants observed. In 2012, the entire area was planted to Clearfield hybrid rice and treated as previously described. The total number of weedy rice plants was obtained and an average/m^2 was determined. The rotation scheme of soybean/soybean/soybean/rice reduced the total number of weedy rice plants to 37 plants, or 0.018 plants/m^2. The fallow/fallow/soybean/rice rotation reduced weed rice plants to 73 plants, or 0.036 plants/m^2, and the soybean/rice/soybean/ rice rotation resulted in 860 weedy rice plants, or 0.43 plants/m^2. The highest population, 1,840 plants, or 0.909 plants/m^2, was observed with the fallow/rice/soybean/rice rotation. The most successful program employed a 3-year soybean program in 2009, 2010, and 2011 fb Clearfield rice in 2012.

In 2013, another long-term study was established consisting of five different rotations. The same size blocks were established, 0.2 ha. The rotations used were: 1) Roundup Ready soybean followed by (fb) Clearfield rice fb Roundup Ready soybean fb Clearfield rice; 2) Roundup Ready soybean fb Roundup Ready soybean fb Roundup Ready soybean fb Clearfield rice; 3) fallow fb herbicide-resistant rice fb Roundup Ready soybean fb Clearfield rice; 4) fallow fb herbicide-resistant rice fb Roundup Ready soybean fb Clearfield rice; 5) Clearfield rice fb Roundup Ready soybean fb herbicide-resistant rice fb Clearfield rice. A similar weed control program was used in the 2013 study as those used in the previous study. However, rotation 2 received glyphosate at 1.12 kg/ha plus dimethenamid at 1.12 kg/ha plus pyroxasulfone at 90 g ai/ha at the first trifoliate leaf stage. Prior to rice harvest and 2 weeks following soybean harvest weedy rice plant counts were determined. Weedy rice plants for each rotation were determined: rotation 1 - 17.2 plants/m^2; rotation 2 - 25.1 plants/m^2; rotation 3 - 0.3 plants/m^2; rotation 4 - 5.2 plants/m^2; and rotation 5 - 7.8 plants/m^2. This research indicates that long-term crop rotation, herbicide rotation, and employing different production practices can be used to manage weedy rice plants.

Effects of High Night Temperature and Abscisic Acid (ABA) on Rice (*Oryza sativa* L.) Physiology

Mohammed, A.R., Chen, M-H., and Tarpley, L.

High night temperature (HNT) is known to decrease rice yields. The impacts of abscisic acid (ABA) on higher plants have been the subject of many studies. However, little or no work has been carried out on rice responses to ABA under HNT-stress conditions. This study determined the effects of ABA on rice leaf photosynthetic rate (P_N), photochemistry, respiration, and physiology under HNT-stress conditions.

Plants were grown under ambient night temperature (ANT) (25°C) and HNT (30°C) in the greenhouse. They were subjected to a HNT through use of continuously controlled infrared heaters, starting from boot stage of the rice plants until harvest. Night temperatures were imposed from 2000h until 0600h. Plants were treated with ABA at boot stage of the rice plant. Net photosynthesis (P_n) of the penultimate leaves was measured between 1000 h and 1200 h using a LI-6400 portable photosynthetic system (LI-COR Inc., Lincoln, Nebraska, USA), 5 days after treatment (DAT). Respiration rates were measured on the penultimate leaves between 2400 h and 0200 h using a LI-6400, 5 DAT. Pollen viability was determined using a staining technique (IKI) 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, width, surface area, volume, and chalkiness 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.

High night temperature decreased P_N (5%), stomatal conductance (21%), spikelet fertility (5%), and yield (6%) and increased respiration rate (74%) and grain chalkiness (221%). The application of ABA increased P_N (6%) as a result of increased stomatal conductance (18%), quantum yield (8%), and electron transport rate (8%), under HNT. In addition, application of ABA decreased non-photochemical quenching (41%) and respiration rate (33%), under HNT. The ABA-treated plants grown under HNT showed increased spikelet fertility (10%) and yield (13%) as a result of increased P_N and decreased respiration. We appreciate the funding provided by Valent Biosciences, Libertyville, IL, USA, in support of this project.

Abstracts of Papers on Rice Culture
Panel Chair: Dustin Harrell

Methane Emissions from Delayed-Flood Rice on a Silt-loam Soil as Affected by Previous Crop and Cultivar in Arkansas

Rogers, C.W., Brye, K.R., Smartt, A.D., Norman, R.J., Gbur, E.E., Hardke, J.T., Slaton, N.A., Frizzell, D.L., and Castaneda, E.

Rice (*Oryza sativa* L.) production in the United States has been cited as a key agricultural contributor of the greenhouse gas methane (CH_4). Few research studies have addressed the effects of cultural management practices on drill-seeded, delayed-flood rice production in the midsouthern United States, particularly in Arkansas. Rice production in Arkansas predominately occurs on silt loam soils (50% of production), following soybean (*Glycine max* L.) as the previous crop (70% of production), with hybrid rice planted (50% of production), which was only introduced in the last decade. Therefore, research was conducted during the 2012 growing season at the Rice Research and Extension Center, near Stuttgart, AR, to assess the effects of previous crop (rice or soybean) and cultivar (standard-stature pure-line, semidwarf pure-line, and hybrid) on CH_4 emissions from a DeWitt silt loam (fine, smectitic, thermic, Typic Albaqualfs). A chamber-based method using a 30-cm diameter chamber with gas samples collected at 0, 20, 40, and 60 min after chamber closure was used. Flux measurements were determined weekly from flooding until flood release and every other day for one week following flood release, with an additional sample taken 18 d after flood release. Linear interpolation and numerical integration were performed to calculate seasonal CH_4 emissions from the individual flux measurements. Grain yield was determined by harvesting the five inner rows of individual plots with a research-grade plot combine. Results indicated that following panicle differentiation fluxes rapidly increased, and when soybean was the previous crop, fluxes remained generally lower than when rice was the previous crop until heading (P<0.05). Peak fluxes from all treatments occurred near heading, and following heading, fluxes decreased from all treatments until flood release. In particular, fluxes from the hybrid cultivar following rice exhibited a dramatic decrease from the peak flux of 18.7 mg CH_4-C m^{-2} h^{-1} to 8.5 mg CH_4-C m^{-2} h^{-1} in one week. Similarly, the peak flux of 8.3 mg CH_4-C m^{-2} h^{-1} for the hybrid cultivar following soybean significantly decreased to 5.0 mg CH_4-C m^{-2} h^{-1} in the same time period. This rapid decline was not observed for either of the pure-line cultivars. Seasonal emissions differed based on previous crop and cultivar (P < 0.05). Area-scaled emissions from rice following soybean were less (127 kg CH_4-C ha^{-1}) than from rice following rice (184 kg CH_4-C ha^{-1}). The hybrid cultivar emitted 111 kg CH_4-C ha^{-1}, which was less than either the standard-stature cultivar's emissions (186 kg CH_4-C ha^{-1}) or the semidwarf cultivar's emissions (169 CH_4-C ha^{-1}), which did not differ. Yield-scaled emissions followed a similar pattern to area-scaled emissions, where hybrid emissions were lower [11.1 kg CH_4-C (Mg grain)$^{-1}$] than either the standard-stature or semidwarf emissions [21.9 kg CH_4-C (Mg grain)$^{-1}$ and 18.3 kg CH_4-C (Mg grain)$^{-1}$, respectively], which did not differ. Results from this study indicate the importance of cultural management practices (i.e., previous crop in rotation and cultivar selection) on CH_4 emissions from drill-seeded, delayed-flood rice production. Continued research and data assessing current management practices will allow more accurate assessments of the carbon footprint of rice and establish the long-term sustainability of common management practices in Arkansas and the midsouthern United States.

Methane Emissions From Direct-Seeded, Delayed-Flood Rice Grown on a Clay Soil

Smartt, A.D., Brye, K.R., Rogers, C.W., Norman, R.J., Hardke, J.T., Roberts, T.L., Gbur, E.E., Duren, M., and Frizzell, D.L.

Methane (CH_4) is a greenhouse gas with a global warming potential 25 times greater than that of carbon dioxide (CO_2). Due to the production of CH_4 under prolonged flooded-soil conditions, flooded rice (*Oryza sativa* L.) cultivation is a major contributor to agricultural CH_4 emissions, second only to enteric fermentation. While several studies examining CH_4 emissions from rice have been conducted in California, Texas, and Louisiana, only recently have studies been initiated in Arkansas under the direct-seeded, delayed-flood management systems that are

predominant in much of the mid-southern United States. In order to adequately estimate and mitigate CH_4 emissions from rice cultivation, it is important to have data representing the range of regional, climatic, and cultural variability throughout the nation. Until now, no CH_4 emissions data have been collected from rice produced on clay soils in Arkansas. Therefore, research was conducted during the 2012 growing season at the Northeast Research and Extension Center (NEREC) in Keiser, Arkansas, to examine the factors that affect CH_4 emissions from rice produced on a Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts). The experimental treatments were non-N-fertilized bare soil, non-N-fertilized rice, and optimally N-fertilized rice. Methane samples were collected by syringe at 20-minute intervals from 30-cm diameter, enclosed-headspace chambers and fluxes were calculated by measuring changes in headspace CH_4 concentrations over time. Methane flux measurements were conducted weekly during the flooded portion of the season and every other day following flood release. Season-long CH_4 emissions were estimated by linear interpolation between flux measurements. Methane fluxes increased over time throughout vegetative growth in both the N-fertilized and non-N-fertilized rice, peaking at 4.8 and 0.9 mg CH_4-C m^{-2} hr^{-1}, respectively, immediately following 50% heading. Methane fluxes then decreased over time, approaching 0 mg CH_4-C m^{-2} hr^{-1} by the time of flood release (76 days after flood establishment). In the bare-soil, CH_4 fluxes remained near zero throughout the flooded portion of the season, with a post-flood-release CH_4 flux of 2.5 mg CH_4-C m^{-2} hr^{-1} occurring at 5 days after flood release. Post-flood-release CH_4 fluxes in the N-fertilized and non-N-fertilized rice treatments peaked at 0.8 and 1.2 mg CH_4-C m^{-2} hr^{-1}, respectively, and also occurred 5 days after flood release. Total season-long emissions were estimated to be 1.8, 8.9, and 35.6 kg CH_4-C ha^{-1} for the bare soil, non-N-fertilized rice, and N-fertilized rice, respectively. Results from this study indicate that CH_4 emissions from rice grown on a clay soil under common Arkansas cultural practices may be substantially less than emissions estimated from previous studies. The low emissions measured in this study, coupled with the magnitude of Arkansas rice production and extent of production on clay and clay loam soils (> 40%) in Arkansas, indicate that CH_4 emissions from mid-southern U.S. rice cultivation may be substantially overestimated. Further research on mid-southern emissions from various regions and cultural practices are important to more accurately assess current greenhouse gas emissions and to mitigate negative impacts on the environment.

Greenhouse Gas Emissions, Irrigation Water Use, and Arsenic Concentrations; a Common Thread in Rice Water Management

Anders, M.M., Linquist, B.A., Adviento-Borbe, M.A., McClung, A., van Kessel, C., Chaney, R.L., Henry, C.G., Kerr, S., and Hendrix, D.

Rice (*Oryza sativa L.*) has, historically, been grown as a flooded crop in the United States. As competition for water from industry and municipal users has grown, it was realized that the volume of water needed to flood fields throughout the growing season was not sustainable and either new water sources needed to be found or water use in rice production would need to be reduced. In all the U.S. rice producing states, there is pressure on the rice industry to reduce water consumption. Against this background, an irrigation water study was established in 2011 at the University of Arkansas, Rice Research and Extension Center to evaluate the effect of reduced water management on rice production, water efficiency, greenhouse gas emissions, and grain arsenic content. The study consisted of six water treatments, from wettest to driest: 1) flood, 2) AWD/40-Flood, 3) AWD/60, 4) AWD/40, 5) RR/60, and 6) RR/40. Alternate wetting and drying (AWD) treatments were flooded to a 10-cm depth at the V4-V5 growth stage and held at the 10-cm water depth for 10 days after which they were allowed to dry to the targeted percent of soil water holding capacity (/60 or /40). The AWD/40-flood treatment was managed as AWD until the plants reached the R0-R1 growth stage then flooded until draining for harvest. Row-watered (RR) treatments were planted on a bed-furrow system with water applied in the furrow whenever the designated soil water capacity was reached. Three hybrid varieties (CLXL745, XL723, XL753) were used over the four site-years. Four replications were used with each variety planted into 4.24 x 30.5-m plots. Plots were managed in a rice-soybean rotation all three years with an additional continuous rice rotation added in 2013.

Average irrigation water use across all treatments and years was 6,396-m^3 ha^{-1} while grain yields averaged 9,362 kg ha^{-1} and irrigation water efficiency 712 m^3 water Mg^{-1} grain. For the rice-soybean rotation, grain yields averaged over three years were 10,703 kg ha^{-1} for the standard flood treatment followed by 10,543, 10,119, 9,828, 7,362, and 7,116 kg ha-1 for the AWD/40-Flood, AWD/60, AWD/40, RR/60, and RR/40 treatments, respectively. There were no significant differences in grain yields between the flood and AWD treatments. Irrigation water applied to each treatment ranged from 8,087 m^3 for the flooded treatment to 6,031, 5,574, 4,527, 8,675, and 6,636 for the AWD/40-

Flood, AWD/60, AWD/40, RR/60, and RR/40 treatments, respectively. Both row-watered treatments used nearly the same amount of irrigation water as the flood treatment but had significantly lower grain yields. Reductions in water use from the flooded treatment were 25, 31, and 44% for the AWD/40-flood, AWD/60, and AWD/40 treatments respectively. There was a corresponding increase in water efficiency measured as m^3 irrigation water Mg^{-1} rice for the AWD/40-flood, AWD/60, and AWD/40 over the flooded treatment of 31, 36, and 62% respectively.

Greenhouse gas measurements were collected on CLXL745 in the flood, AWD/40-flood, AWD60, and AWD/40 treatments during the 2012 and 2013 seasons. Total global warming potential (GWP) (methane plus nitrous oxide) averaged 2,878 kg CO_2 eq ha^{-1} $season^{-1}$ for the flooded R-S rotation and 4,804 kg CO_2 eq ha_{-1} season in the continuous rice rotation. These values were reduced in the R-S rotation to 1,678, 295, and 435 kg CO2 ec ha-1 season-1 for the AWD/40-flood, AWD/60, and AWD/40 treatments, respectively. For the continuous rice rotation these values were 2,397, 485, and 611. In all AWD treatments, nitrous oxide emissions were greater than in the flood with these values more than offset by reductions in methane emissions. Methane emissions were greater and nitrous oxide emissions lower in the continuous rice rotation compared to the rice-soybean rotation.

Whole-grain arsenic levels were measured from all 2011 and 2012 treatments. Arsenic content, over all treatments was similar for XL753 and CLXL745 while it was significantly lower for XL723. Arsenic levels decreased from 0.24 mg kg-1 in the flood treatment to 0.02 mg kg-1 in the RR/40 treatment. There was a strong trend of decreasing As content as the period of time the field was dry during the growing season increased.

In total, these results illustrate a strong relationship between water management and water use efficiency, GHG emissions, and grain arsenic content and suggest that adopting water saving irrigation approaches will address environmental concerns and provide a safer food product.

Rice Yields and Greenhouse Gas Emissions Using Alternate Wetting and Drying Irrigation in California

Linquist, B., Adviento-Borbe, A., Mutters, R., Greer, C., and Espino, L.

Current water management for rice production in California is to keep the field continuously flooded. Such practices provide high yields, good weed control, and high N-use efficiency. Furthermore, recent research has shown that on the highly impermeable California rice soils, water is used efficiently. However, there is increasing concern that growing rice under continually flooded conditions can lead to other problems including high greenhouse gas (GHG) emissions (especially methane), arsenic (As) uptake in rice, and methyl mercury production. Alternate wetting and drying (AWD) refers to water management practices in rice systems whereby fields are flooded, the inflow water stopped, and the field allowed to dry before being reflooded again. Some preliminary research has shown that rice yields can be reduced substantially under some AWD practices in California. Our objective was to evaluate AWD management practices in rice systems under drill- and water-seeded conditions to determine if yields can be maintained. Furthermore, we wanted to identify appropriate N rates for AWD systems and determine the amount of greenhouse gas fluxes being emitted from each system.

In the summer of 2012, a research site was established to evaluate three different water management practices each replicated three times. The treatments were (1) water-seeded conventional (WS-Conv), (2) water seeded with flood maintained till canopy closure – then AWD (WS-AWD), and (3) drill seeded with AWD (DS-AWD). These treatments were determined based on previous experience. The plots are large (greater than 0.2 ha) and will be adequate for various other measurements and treatments. Within each plot, a soil moisture probe was put in place to constantly measure soil moisture content. Reflooding was always done when the soil moisture reached 35% water by volume.

Nitrogen management for these systems will likely be different due to different water management strategies which affect N dynamics. In 2013, an N rate trial was established with five N rates ranging from 0 to 240 kg/ha was established in each plot. Greenhouse gas (GHG-methane and nitrous oxide) emissions were also measured from these systems using vented chambers and sampling frequently during critical management practices and at least weekly during other periods.

Rice grain yields were high and averaged 10,500 kg/ha across all treatments. Water management had no significant effect on yields. In the N rate trial, the response to N was also similar among the different water management treatments. When no fertilizer N was added, yields averaged 4,600 kg/ha across treatments. In all water management treatments, the N rate that provided the highest yields (10,400 kg/ha across all treatments) was 180 kg N/ha. Greenhouse gas emissions varied considerably between treatments – especially for methane (CH_4). The WS-Conv treatment which was flooded the entire season had much higher CH_4 emissions (144 kg CH_4-C ha^{-1}) than the other treatments which were 68 and 17 kg CH_4-C ha^{-1} for the WS-AWD and DS-AWD, respectively. N_2O emissions were low for all treatments.

These results are different than have been observed previously where it has been shown that yields are reduced if the soil becomes aerobic. While this is encouraging from various aspects, more research needs to be conducted in this area. Furthermore, these research plots are relatively small. Even if these systems are viable at this scale, it may be very difficult to implement AWD at a field or irrigation district scale.

The Effects of Water Management on Rice Yield and Greenhouse Gas Emissions

Barron, M.A., Kongchum, M., and Harrell, D.

This study focused on evaluating the changes in greenhouse gas (GHG) emissions from rice fields associated with changes in water management practices. Ninety percent of the world's rice is grown in a flooded, anaerobic soil. Anaerobic conditions lead to increased GHG emissions, particularly those of methane (CH_4) and nitrous oxide (N_2O), compared with crops grown in upland, aerobic systems. Therefore, if water management practices are altered, there presumably would be corresponding changes in GHG emissions. However, the extent of the change in emissions is unknown. It is also important to consider the potential implications that changing water management practices would have on the agronomics and economics of producing a commercial rice crop. Current rice cultivars are bred to be grown in an aquatic, anaerobic environment. Growing one of these cultivars in aerobic conditions can dramatically reduce yields by increasing the incidence of pest and pathogen damage, as well as increased competition with weeds. For rice grown in aerobic conditions, chemical control of these increased pressures would cause a drastic increase in input costs, making production cost prohibitive. Therefore, rice water management strategies must be evaluated for their ability to reduce GHG emissions while preserving the agronomic and economic potential in order to maintain the viability of commercial rice production in the U.S. This experiment evaluated four water management strategies:

1. Traditional rice water management in a delayed flood system – rice is grown in aerobic conditions until a permanent flood is established at first tiller and maintained until two weeks before harvest.
2. Straighthead water management – the rice field is drained to a crack two weeks after the initial flood, then re-flooded until two weeks before harvesting.
3. Intermittent flooding – the rice field is flooded at first tiller, but the initial flood is allowed to reside. Once the soil dries, the paddy is then re-flooded. This cycle is repeated until two weeks before harvest.
4. Semi-aerobic rice management – the rice field is flush irrigated bi-weekly throughout the growing season.

There were three replications within each experimental plot. Grain yield for each plot was measured and recorded for both the first and second (ratoon) crop harvests. Weekly headspace emissions measurements for CH_4, N_2O, and CO_2 were conducted from first crop flooding to second crop harvest using diffusion chambers constructed of clear Plexiglas. The 15-mL gas samples were withdrawn from the septum at the top of the chamber using a 20-mL gas-tight syringe at intervals of 0, 30, and 60 minutes. Additionally, outside air samples within each treatment were taken for comparison. Floodwater heights, soil moisture, and air temperature inside the chamber were recorded for calculating emission rates. Soil redox potential (Eh) and pH were also measured within each treatment. Gas samples were analyzed for CH_4, N_2O, and CO_2 using a Varian CP 3800 Gas Chromatograph equipped with FID and ECD. Raw data were recorded and used to calculate the GHG flux per unit area. The data were entered into SAS statistical software and analyzed using analysis of variance (ANOVA) to measure the significance among treatments followed by a mean comparison determined by Duncan's Multiple Range Test.

For my results, I expected traditional water management practices to produce the most GHG emissions and also the highest rice yields, while aerobic practices produced the least GHG emissions and the lowest rice yields. A simple linear regression analysis was performed for the average flux of CH_4 in each of the water management regimes for the first crop. The traditional, straighthead, and intermittent flooding water management practices all showed increases in CH_4 emissions over time with respective R^2 values of 0.012, 0.234, and 0.020. The semi-aerobic rice management showed a decrease of CH_4 emissions over time with an R^2 value of 0.563. Further analysis is required, but these initial results highlight the GHG mitigation potential of semi-aerobic rice management.

The Effect of Various Water Management Strategies on Rice Yield, NUE, and Soil Chemical Properties on a Sharkey Clay Soil

Atwill, R.L., Walker, T.W., Harrell, D.L., Krutz, L.J., and Massey, J.H.

The Mississippi Alluvial Aquifer is heavily relied on for irrigating intensively managed crops in the "Delta." The 30-year decline of this important resource is cause for concern regarding its sustainability. Therefore, irrigation of crops, including rice, should be done in the most efficient manner. The objective of this study was to evaluate rice irrigation strategies with the ultimate goal of maintaining or improving grain yield while decreasing water use.

An experiment was conducted in Stoneville, MS, in 2013 on Sharkey clay (Chromic Epiaquerts) soil. Six popular southern USA cultivars ('Cheniere,' 'CL151,' 'CLXL729,' 'CLXL745,' 'Jupiter,, and 'Presidio') were drill-seeded in a randomized complete block design within each of four irrigation schemes. The irrigation schemes were: 1) Continuous flooding, 2) Flush irrigation (aerobic), 3) Intermittent irrigation, and 4) Straighthead drain irrigation. Plots were managed similar to what is recommended for drill-seeded, delayed-flood rice culture. At maturity, plots were harvested with a small plot combine equipped with a Harvest Master Grain Guage. Grain yields were estimated based on 12% grain moisture content. Total aboveground biomass was collected from 0.9 m of row when rice reached the panicle emergence growth stage. Biomass was oven-dried at 60°C for 48 h or until a constant weight was achieved. Samples were then ground and analyzed for total N content. Throughout the season, soil pH and oxidation reduction potential were measured using Sensorex electrodes connected to a Cambell Scientific CR1000 data logger. Watermark soil moisture sensors were inserted 10 cm into the soil and in each water management area within 2 d prior to the onset of the irrigation treatments. The watermark sensor was used to trigger irrigation timings for the flush and intermittent irrigation schemes. For both flush and intermittent irrigation schemes, when the watermark sensor reached the 20 to 30 centibar range, the irrigation event was triggered. In the intermittent scheme, a full flood was established and allowed to soak between cycles. For the flush irrigation, the field was flooded up, maintained for 12 hours, and released. A flow meter was installed so that total water use could be recorded for each irrigation treatment.

Grain yield and total N uptake were not affected by the interaction of cultivar and irrigation scheme. Pooled over cultivars, water usage was 35% less for flush irrigation relative to continuous flooding; however, grain yield and total N uptake for flush irrigation were approximately 40% less compared to all other irrigation schemes. Grain yield and total N uptake were the greatest and not different from each other with continuous flooding, intermittent irrigation and straighthead drain irrigation. Intermittent and straighthead drain irrigation used 25% less water compared to continuous flooding. Clear differences were observed in the ORP for each of the irrigation schemes.

These data suggest there are two alternative water management schemes that can potentially reduce water usage while maintaining yields. Nitrogen management would need to be altered to achieve greater yields in the flush irrigation treatment. Finally, the need for a continuous flood was not warranted in this study.

Drip Irrigation of Rice - 5-Year Summary

Vered, E.

FAO projections for 2050 are an additional 2.3 billion people or a 30% increase in population, needing more water and more food. In Asia, over 50% of water available for irrigation is used for irrigated rice. In India, for example, as much as 15,000 liters of water are used to produce 1 kg of rice. With the expected population growth, we must use water more efficiently. Our plan is to grow rice with 500 liters water per kg rice.

The rice crop is also one of the great polluters of the earth. Methane emissions from rice paddies as a result of decomposing organic matter in anaerobic conditions are much higher than any other crop. Nitrogen is supplied to rice throughout the season and fertilization while flooding causes leaching of great amounts of nitrogen into groundwater. Flood runoff pollutes lakes and rivers with nitrogen. Hazardous chemical compounds such as pesticides are dispersed in the same manner. A drip irrigation system provides fertilizers and pesticides directly to and around the plants' root system, necessitating less chemical inputs and preventing runoff pollution of rivers and water channels.

Another issue is the workload. Today, most rice is grown in the developing world, on small, family farms with manual work. Young people leave the farms looking for a higher income and less strenuous work. In order to keep the rice farms going, it is necessary to develop efficient farming methods for rice.

Irrigating rice with a drip system enables mechanical sowing of rice in the field, saving the labor of transplanting. It can also be used as a delivery system for pesticides and herbicides as well as for fertigation, saving more work and energy.

Experiments were conducted in Texas, Italy, India, and China to determine:

1. The feasibility of using sub-surface drip irrigation for rice crops.
2. Rice varieties suitable for growing under drip irrigation. Some varieties have the potential for higher yields with drip irrigation.
3. Growing methods including crop coefficients, nutrient requirements, drip system layout, and plant spacing.

Conclusions:

1. A suitable rice hybrid is essential for yields of over 10 t/ha.
2. Optimal drip irrigation can reduce the amount of water and fertilizer needed to grow rice.
3. High yields are achievable with drip even on slopes or with saline water.
4. Drip chemigation prevents leaching and runoff of nutrients and pesticides into water sources.
5. Drip irrigation of rice prevents methane emissions associated with flooded paddy fields.
6. Drip irrigation of rice is not only feasible but more environmentally and economically sustainable than flooding rice paddies.

Our vision for the future is to use drip irrigation as a delivery system for all the plants' needs. As we now chemigate pesticides and chemical fertilizers, we hope to supply the plant with biological and hormonal treatments in the future, saving even more on chemical inputs, energy and labor.

Cover Crop, Soil Amendments, and Variety Effects on Organic Rice Production in Texas

Dou, F., Zhou, X., McClung, A., Storlien, J., Lang, Y., Torbert, A., Hons, F.,
Wards, B., Kresovich, S., and Wight, J.

The major challenges in organic rice production include nutrient improvement, weed management, and variety selection. In this study, we tested the effects of two soil amendments on organic production in southcentral USA. The 2011-12 winter cover crops were established successfully with full coverage. The amount of dry biomass were 5,257 and 5,780 kg/ha for clover and ryegrass, respectively. Plots were cultivated and drill seeded but high weed pressure in the fallow plots resulted in very poor stands. Only results of rice grain yields from clover and ryegrass treatments were presented. Cover crops had a similar effect on rice grain yield, although numerically, rice grain yield under ryegrass treatment was higher than that under clover treatment. Compared to Presidio, Tesanai had significantly higher grain yield. Soil amendments did not have significant effect on rice grain yield. Compared to the control, the 168 kg N/ha and 235 kg N/ha soil amendment rates increased rice grain yields by 11%. There was no difference in rice grain yields between the two N rates, indicating that 168 kg N/ha was sufficient for organic rice production in terms of N supply. Compared to Presidio, Tesanai had greater plant height and appeared to be more competitive with weeds. Aboveground biomass of the rice crop was affected by the rate of soil amendments rather than the type of soil amendments. Rice milling yield was significantly affected by cover crop and rice variety.

Impact of Organic Production Management on Variety Yield and Grain Arsenic Accumulation

McClung, A.M., Duke, S., and Chaney, R.L.

The demand for organically produced rice increases each year. Organic rice production offers economic benefits to growers because the crop can be sold at a premium and input costs are generally lower. The objective of this experiment was to determine the agronomic performance of rice cultivars grown under organic and conventional field management. The study was conducted in Beaumont, TX, during 2009, 2010, and 2011 and evaluated 14 rice cultivars that included medium and long grains, aromatics, and allelopathic germplasm. The organic studies were conducted on certified organic land following a winter cover crop (white clover) that was plowed down in the spring followed by application of 1680 kg/ha of Nature Safe (13-0-0; made from feather, meat, and blood meal) applied at planting. The conventional fields were fallowed for two years and then drill seeded with 224 kg/ha of urea applied in a three-way split. The experimental design consisted of a randomized complete block with four replications. Data were collected on plant stand, heading, height, days to harvest, grainfill duration, yield, total and whole milling yield, and total grain arsenic. The main effects year, cultural management, and variety were significantly different for essentially all traits, as were their interactions. As had been seen in previous studies, rice grown under the organic system had reduced plant stands, earlier days to heading and maturity, a shorter grainfill period, and shorter plant height as compared to conventional management. Although there was no significant difference in head rice yields, organic management had significantly higher field yield, total milling yield, and total grain arsenic than the conventional system. There was a significant cultural management x variety interaction for most traits but correlations between the variety means under organic and under conventional management were generally >0.60, indicating similarities in varietal performance under either cultural system. Exceptions to this were plant stand, total milling yield, and total grain arsenic, which were not significantly correlated between the two cultural management systems. There were few significant correlations among the agronomic traits measured under the conventional system. However, under organic management, yield was positively correlated with maturity, height, and grainfill (r= 0.54, 0.76, and 0.43, respectively). In the organic system, the highest yielding cultivars were Tesanai 2 (11,035 kg/ha), Rondo (8,690 kg/ha), PI 312777 (7,928 kg/ha), PI 338046 (7,925 kg/ha), and Wells (7,870 kg/ha) while the lowest yielding cultivars were Colorado (5,163 kg/ha) and Sierra (5,139 kg/ha). When combining field yield with whole milling yield (i.e. whole milled rice per acre), the best performing cultivars under organic management were Jupiter (4,973 kg/ha) and Tesanai 2 (4,447 kg/ha), while Sierra (2,566 kg/ha) and Colorado (2,459 kg/ha) were the poorest. No trait was significantly correlated with grain arsenic under conventional management, however, under the organic system, where there was a two-fold range in total grain arsenic of the milled rice, grain arsenic was positively correlated with height, maturity, grainfill, and yield (r= 0.47, 0.53, 0.57, and 0.65, respectively). Sierra (0.09 ppm) and Colorado (0.11ppm) had the lowest grain arsenic accumulation under organic production, although they were also the lowest yielding. These results indicate that under organic management, agronomic traits associated with increased yield potential are also associated with greater grain arsenic accumulation. The varieties with the highest organic yields were all of indica origin (Tesanai 2, Rondo, and the two allelopathic germplasms, PI312777 and PI 338046) however, these also had moderate to high grain arsenic levels. Other research has shown that cultivars exist that accumulate low levels of grain arsenic (e.g. Zhe 733) even under arsenic (MSMA)-treated soils and that draining rice fields during the growing season dramatically reduces grain arsenic levels. Under organic management, maintaining a season-long flood is critical for weed control. A next step would be to determine if weed suppressive, allelopathic germplasm could be advantageous in an organic management system that incorporated field draining to reduce grain arsenic accumulation or if using germplasm that does not accumulate grain arsenic would be a better approach.

Rice Nitrogen Uptake and Yield as Affected by Simulated Rainfall and Nitrogen Fertilizer Amendment

Dempsey, R.J., Slaton, N.A., Roberts, T.L., Norman, R.J., DeLong, R.E., and Massey, C.G.

Rice (*Oryza sativa* L.) requires a significant amount of nitrogen (N) fertilizer to optimize grain yield. Ammonia (NH_3) volatilization is one of the primary N-loss mechanisms in Arkansas rice production and represents a financial loss to the grower and a threat to the environment. Our objectives were to compare the effects of simulated rainfall timing and amount with and without urease- and nitrification-inhibiting amendments on ammonia (NH_3) volatilization, N uptake, and/or grain yield of rice.

Two experiments were conducted in 2013 on an alkaline Calhoun silt loam in Arkansas. Urea (Urea), urea + urease inhibitor N-(n-butyl) thiophosphoric triamide (Urea-NBPT), urea + nitrification inhibitor Nitrapyrin (Urea-I), and urea + NBPT + Nitrapyrin (Urea-Mix) were applied at 112 kg N ha^{-1} and compared to a no-N control. Each N source was subjected to three simulated rainfall timings of i) no water, ii) simulated rainfall applied before N application, or iii) simulated rainfall applied after N application. Simulated rainfall was applied 4 (Trial A) and 18 hr (Trial B) before N application and 14 (Trial A) and 5 hr (Trial B) after N application. The permanent flood was established 8 (Trial A) and 13 d (Trial B) after simulated rainfall and N application. The experiment was a split-plot design with trial being the main plot and the 4 (N source) × 3 (rainfall timing) factorial as the sub-plot. Nitrogen uptake and grain yield were analyzed using Fisher's protected LSD method with α=0.10. Rice grain yield was influenced by the main effects of N source (P=0.0007) and simulated rainfall timing (P=0.0288). The grain yield of rice receiving no N averaged 5,082 kg ha^{-1}. Rice fertilized with Urea-NBPT (8,148 kg ha^{-1}, LSD=366), and Urea-Mix (8,068 kg ha^{-1}) produced similar yields, and were significantly greater than the yields of rice fertilized with Urea (7,428 kg ha^{-1}) and Urea-I (7,413 kg ha^{-1}), which produced similar yields. When averaged across N sources, rice treated with no simulated rainfall (8,028 kg ha^{-1}, LSD=317) produced the greatest yield, but it was not different than the yield of rice receiving simulated rainfall applied after N (7,769 kg ha^{-1}). When simulated rainfall was applied before N application (7,510 kg ha^{-1}), rice yield was similar to the yield produced by simulated rainfall applied after N but less than the yield produced with no simulated rainfall.

Two additional experiments were conducted at the same time and location as the rainfall simulation trials evaluating simulated rainfall amount and urease amendment. Urea or Urea-NBPT was applied at 112 kg N ha^{-1} and compared to a no-N control. Each N source was subjected to six simulated rainfall amounts of 0, 3.2, 6.4, 12.7, 19.1, or 25.4 mm. The permanent flood was established 12 (Trial A) and 6 d (Trial B) after N application and simulated rainfall. Ammonia volatilization (in a semi-static chamber), N uptake, and grain yield were regressed on simulated rainfall amount, allowing for linear, quadratic, and cubic terms with coefficients depending on N source. Non-significant (P>0.15) model terms were removed sequentially and the model was refit until a satisfactory model was obtained. Ammonia volatilization loss was evaluated only in Trial A. Cumulative NH_3 volatilization was influenced by a significant N source by simulated rainfall amount interaction (P<0.0001). Cumulative NH_3 loss from Urea-NBPT ranged from 0.3 to 2.4% of the applied N and was similar across simulated rainfall amounts. In contrast, cumulative NH_3 loss from Urea ranged from 0.3 to 9.6% of the applied N and was greatest with no simulated rainfall and decreased non-linearly (quadratic) as rainfall amount increased. Cumulative NH_3 loss from Urea-NBPT was significantly lower than Urea when simulated rainfall was <19.1 mm. Rice N uptake was influenced by a significant non-linear (cubic) N source by simulated rainfall amount interaction (P=0.0211). For each N source, the trials shared common linear (Urea, 2.02; Urea-NBPT, -4.77), quadratic (Urea, -0.345; Urea-NBPT, 0.442), and cubic (Urea, 0.010; Urea-NBPT, -0.011) coefficients but had different intercepts. The intercepts for Trial A were 83.7 (Urea) and 98.3 (Urea-NBPT); Trial B were 106.6 (Urea) and 121.1 (Urea-NBPT). Within each trial, N sources were significantly different when simulated rainfall amounts were <0.5 mm and between 12.5 and 23.0 mm. Rice grain yield was influenced by a significant linear N source by simulated rainfall amount interaction (P=0.0004). For Urea-NBPT, rice yields were constant across simulated rainfall amounts in both trials. For Urea, rice yields decreased linearly as simulated rainfall amounts increased for both trials. For Trial A, rice yields fertilized with Urea-NBPT were greater than Urea with ≥7.5 mm simulated rainfall. Trial B yields were similar when ≥2 mm of simulated rainfall was applied.

Results from these trials suggest that the urease inhibitor, NBPT, may reduce N loss and possibly delay nitrification under favorable soil conditions. Additional research is required to gain a better understanding of the processes that occur between the time of urea-N application and the establishment of the permanent flood.

Evaluation of Nitrification and Methods to Minimize Denitrification Loss for Rice

Fitts, P.W., Walker, T.W., Krutz, L.J., Golden, B.R., Varco, J.J., Gore, J., Corbin, J.L., and Atwill, R.L.

The dynamic nature of N and the flooded soil environment pose challenges to N management. Ideally, an N fertilizer could be applied in a window from planting to preflood with the N being converted to or remain in the ammonium (NH_4^+) form until after a permanent flood is established. However, NH_4^+ is subject to nitrification and nitrate (NO_3^-) 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 evaluated nitrification and subsequent denitrification for soils where rice is produced in the delayed-flood system. Furthermore, few studies have examined the ability of commercially available products to stabilize N in the NH_4^+ form. To this end, laboratory experiments were conducted in 2010, 2011, and 2012 at USDA-ARS in Stoneville, MS, to quantify the nitrification potential of soils having a history of rice production, and evaluate the nitrification inhibitor dicyandiamide's (DCD) effectiveness at reducing nitrification rates on clay soils. Field research was conducted in 2011, 2012, and 2013 at the Delta Research and Extension Center in Stoneville, MS, to evaluate the effectiveness of DCD and a sulfur-polymer coated urea (Agrium XCU™ 43-0-0-4S SGN 250) compared to urea alone on Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts) soil.

Laboratory experiments were performed utilizing a non-fertilized control, and urea-N was added at approximately 115 mg N kg^{-1} of soil. The nitrification potential study was arranged in a completely randomized design using 7 soils, 6 sample timings, and 3 replications, and the experiment was duplicated in time (runs). Dicyandiamide (5, 10, and 15% of the N rate) was applied with urea in the nitrification stabilizer experiment which was analyzed as a split plot design with soils as the whole plot and sample timing as the subplot, with three replications for each treatment. Treatments were arranged in a completely randomized design, and the experiment was duplicated. The NH_4^+ disappearance data from both laboratory experiments were subjected to PROC NLIN and fit to a first order kinetics model and the rate constant parameter was used to determine the number of days when half the total recovered inorganic N was in the NH_4^+–N form (half-life). The field experiment consisted of 13 treatments that included combinations of N rates (84 and 168 kg N ha^{-1}), N sources, and application timings replicated four, three, and four times in 2011, 2012, and 2013, respectively. DCD was dissolved in urea liquor (23% N) to make final concentrations of 5, 10, and 15% DCD-N. Agrium was broadcast applied in its solid form. The controls included urea applied at the same rates at 12 and 1 days before flood establishment (dbf). 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 $\alpha = 0.05$.

Nitrification potential differed among soils with half-life values ranging from 3.9 to 9.2 days. The Sharkey clay soil at Stoneville, MS had the greatest nitrification potential at 3.9 d half-life. Results indicated that the half-life values of the nitrogen stabilizer experiment ranged from 4.2 to 15.2 d. Urea–DCD half-life values tended to increase with increasing concentration of DCD resulting in a 1.6 to 3.6 fold increase when compared to urea–N treatments. In the field, urea application at 12 dbf resulted in approximately 1900 and 1700 kg ha^{-1} less grain yield compared to 1 dbf application at 168 and 84 kg N ha^{-1}, respectively. Fifteen percent N as DCD produced an 18% grain yield advantage when compared to non-amended urea at the lower N rate. Grain yield tended to increase with increasing concentration of DCD when 84 kg N ha^{-1} was applied; however, DCD concentration was not as important at the 168 kg N ha^{-1} application rate. Agrium applied 12 dbf resulted in a similar yield compared to urea–DCD treatments at both N levels. However, Agrium resulted in yields approximately 730 kg ha^{-1} less than the urea–N treatments applied 1 dbf for both N rates.

These studies suggested ammonium disappearance can be rapid in some rice production soils, but can be slowed considerably with DCD. Furthermore, DCD and Agrium (XCU™ 43-0-0-4S SGN 250) effectively minimized grain yield loss compared to urea applied at 12 dbf.

Field-Scale, On-Farm Evaluation of the N-STaR Program: Successes and Opportunities

Roberts, T.L., Norman, R.J., Slaton, N.A., Hardke, J., Greub, C.E., Shafer, J., Mazzanti, R., Schmidt, L., and Fulford, A.M.

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. 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 US 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.

Over the course of the last decade, researchers have worked diligently to develop a soil-based N test, which has been correlated and calibrated to predict N rates for rice produced on both silt loam and clay soils. The soil technology referred to as the Nitrogen Soil Test for Rice or N-STaR is the first soil-based N test for rice that will provide field-specific N rates for rice produced in the Mid-south 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 and recent work has been completed for clay soils. One of the unique aspects of the N-STaR protocol is the influence of rice rooting depth and soil sampling depth to predict the proper N rate recommendation. For rice produced on silt loam soils, N-STaR requires a 0-45 cm soil sample, whereas rice produced on clay soils requires a 0-30 cm soil sampling depth. These depths are based on the rice rooting depth as well as the predictive ability of the calibration curves that were developed. During the spring of 2012, the N-STaR program was released for producers to use on silt loam soils and was followed by the release of the clay calibration curve in the spring of 2013. Interest in the N-STaR program has continued to grow and field-scale strip trials as well as production-scale experiments have been conducted to verify the ability of N-STaR to predict field-specific N fertilizer rates.

Since the inception of the N-STaR program, field-scale trials have been conducted on a total of 22 production fields across the state of Arkansas on both silt loam and clay textured soils. The purpose of these trials was to determine the ability of N-STaR to predict the yield-maximizing N rate and also educate producers, consultants, and county agents about the soil sampling protocol and what to expect from this new technology. The purpose of the N-STaR program is to predict the correct N rate to maximize rice yields, which can result in both increases and decreases in the N rate recommendation when compared to the producer practice or the current Arkansas N recommendations. Fields have been selected that test both of these scenarios and although the majority of the fields selected for implementation of these trials recommended N rates that were lower than the producer had intended to apply, the fields recommending higher N rates resulted in some of the most profitable situations. When looking at the net returns to N, the increases in profitability due to increased N rate often results from significant yield increases due to the increased N rate while all other input factors remain constant. The 2013 production year was also the first year where the N-STaR recommendation was used on all Arkansas Rice Research and Verification Program (RRVP) fields and was a great learning opportunity as to when and where the N-STaR program can have the greatest impact on rice yields and producer profitability. During the 2013 growing season, there were two field trials where the N-STaR N rate recommendation did not perform as expected and has allowed researchers to better understand potential problems that can occur. Identification of the field's correct soil texture (clay vs. silt loam) and proper sampling depth are the two factors that must be properly completed in order for N-STaR to predict the correct N rate. Research is currently on-going to determine ways to address these issues to ensure that producers are getting an accurate and reliable N rate recommendation for their rice crops.

Rice Rooting Depth on Silt Loam Soils as Indicated by Assimilation of ^{15}N-labeled Ammonium Sulfate

Roberts, T.L., Norman, R.J., Slaton, N.A., and Fulford, A.M.

Soil test development relies on three factors for success 1) proper soil sampling, 2) proper methodology (e.g., chemical or biological), and 3) the ability to correlate with crop nutrient uptake and grain yield. Proper soil sampling provides the foundation for a sound and effective soil analysis procedure and ultimately fertilizer calibration and fertilizer rate predictions, but often times the identification of proper sampling techniques, especially soil sampling depth, is overlooked. During soil test development, soil sampling depth is often limited to the plow layer or 0-10, 0-15, or 0-20 cm depths.

The importance of rice rooting depth has come to the forefront with the development and implementation of N-STaR. Current recommendations require that a 0-45 cm soil sample be taken on silt loam soils when using the N-STaR soil-based N test to accurately predict the N rate required to maximize rice yields. N-STaR uses a direct steam distillation technique developed by Bushong et al. (2008) and quantifies potentially mineralizable soil N, primarily in the form of amino acids, amino sugars and NH_4-N. During the correlation and calibration of N-STaR, the method's highest predictive ability was found to occur when the soil was sampled from 0-45 cm. Rice rooting depth in Arkansas has been well documented and research has shown that rice roots can penetrate as deep as 72 cm on silt loam soils. Following the release of the N-STaR calibration curves, questions arose concerning the validity of the 0-45 cm soil sampling depth recommendation as there has been no previous work to justify whether rice produced in Arkansas had the ability to take up a significant amount of N found at depths > 30 cm.

Therefore, a study was established using ^{15}N-labeled $(NH_4)_2SO_4$ to determine if rice roots were penetrating and actively utilizing N from depths >30 cm. During 2009 and 2010, research trials were conducted on six silt loam soils across the primary rice producing regions of Arkansas to determine if rice roots were assimilating N at soil depths up to 60 cm. A modified fertilizer injection system was developed to inject ^{15}N-labeled $(NH_4)_2SO_4$ at depths of 30, 45 and 60 cm, below the rice crop in an undisturbed soil profile. Statistical analysis indicated that fertilizer placement depth was the only factor significantly influencing the fertilizer N uptake efficiency (FNUE) (p<0.0001). As fertilizer placement depth increased, there was a decrease in N recovery with FNUE values of 93, 40, and 9% for the 30, 45, and 60 cm depths, respectively. These findings indicate that roots of rice produced on silt loam soils are able to penetrate and utilize N at depths of 30 to 60 cm. Previous research that indicates a significant amount of potentially mineralizable N at depths up to 60 cm coupled with the data presented here identify the need for modified soil sampling depths during the development of soil based N tests such as N-STaR.

Nitrogen Concentration in Rice Floodwater Following Fertilization Application

Beckwith, A.G., Daniels, M.B., Hallmark, C.R., and Hesselbein, J.L.

Agriculture is considered to be a leading source of nutrients delivered to the Gulf of Mexico and thus contributing to the hypoxia issue. Arkansas is the leading rice-producing state in the nation. Besides the environmental concerns, rice farmers are looking for ways to be more efficient in nutrient applications due to high fertilizer prices. In Arkansas, nitrogen is typically applied in split applications with the first application before first flood and a second mid-season application where the nitrogen is directly applied to flooded fields using aerial application. Previous plot-scale studies have shown that nitrogen concentrations in flooded rice fields can dissipate in a matter of days. The purpose of this study was to determine changes in nitrogen concentration in rice floodwater following fertilizer applications on a commercial rice field. To determine how the concentration of nitrogen in rice floodwater changes and how long it takes it to move into the soil, water samples were collected using Sigma 900 automated water samplers located in three different rice bays within a private, commercial rice field. The samplers were situated on the edge of a rice field and the water intake hose was placed seven meters out in the bay. The intake nozzle was secured to a piece of rebar driven into the ground to prevent it from moving. Once the floodwater was deep enough for the sampler to collect a sample the units were turned on. For the first 24 hours, a sample was collected every hour. On the second day, a sample was collected every three hours. On the third day, a sample was collected every six hours. On the fourth day, two samples were collected, every 12 hours. The samplers were then set to collect one sample a day for the remainder of the 14-day study. Samples were processed in the field and shipped to the Arkansas Water Resources Center lab for analysis. Based on an initial review of the data, we see that the nitrogen concentration is decreasing at a rate to be practically nonexistent in the floodwater by day 11 or 12. This work should help to show that the rice field is its own ecosystem and that only in extenuating circumstances, heavy rain after flood up, would significant water with nitrogen concentrations leave the field and possibly contribute to any downstream issues.

Rice Growth and Yield Responses to Selected Yield-Enhancing Products

Slaton, N.A., Roberts, T.L., Norman, R.J., DeLong, R., and Shafer, J.

Products that contain humic acids, microbes, or other substances (termed biostimulants) are marketed and make claims to increase crop yield, crop health, fertilizer nutrient uptake efficiency, and/or the release of nonlabile soil nutrients. Unbiased research information regarding the validity of such claims is lacking and is needed to aid growers and consultants in making informed decisions regarding whether to use such products. Our objective was to assess rice (*Oryza sativa* L.) growth and yield responses to the application of three biostimulants that are marketed in the mid-South. Research was conducted at five site-years with Hydra-Hume DG (HHDG; Helena Chemical Co., Collierville, TN), three site-years with Titan-Accomplish (TA; Loveland Products Inc., Loveland, CO), and two site-years with Carbon Boost (CB; FBSCiences Inc., Collierville, TN). Treatments in the HHDG trials included four N and P fertilizer rate combinations [0 and 168 kg preplant MicroEssentials (The Mosaic Company, Plymouth, MN) kg^{-1} plus 0 and 112 kg preflood urea-N ha^{-1}] and four Hydra-Hume DG rates (0, 1x, 5x, and 10x rates with 1x = 45 kg ha^{-1}). The Titan-Accomplish trial treatments consisted of two preflood urea-N rates (sub- and near-optimal N) that differed among site-years, and five TA treatments including 1) no TA + no P and K, 2) Trt 1 + TA sprayed to soil preplant, 3) no TA + 29 kg preplant P + 74 kg preflood K ha^{-1}, 4) P + K with TA applied to preplant P fertilizer, and 5) P + K with TA applied to P (preplant) and K (preflood) fertilizers. The CB trial consisted of two preflood urea-N rates (sub- and near-optimal N) that differed among site-years, and six CB treatments 1) no CB, 2) 877 mL oz CB ha^{-1} applied preplant, 3) 877 mL CB preplant followed by (fb) 584 mL CB preflood ha^{-1}, 4) 584 mL CB preflood fb 584 mL CB midseason ha^{-1}, 5) 877 mL CB preplant fb 584 mL CB midseason ha^{-1}, and 6) 877 mL CB preplant fb 584 mL CB preflood fb 584 mL CB midseason ha^{-1}. The CB was applied directly to triple superphosphate fertilizer for the preplant treatment and urea fertilizer for the preflood and midseason (52 kg urea-N ha^{-1}) treatments. All plots received 29 kg P (CB- treated or untreated) as triple superphosphate preplant, 56 kg K ha^{-1} as muriate of potash preplant, the designated preflood urea-N rate treatment (CB-treated or untreated), and midseason N applied at 52 kg urea-N ha^{-1}. ANOVA was performed using the Mixed procedure in SAS v9.2 where site-year was the main plot, N rate was the subplot and product (HHDG, TA, or CB treatment) was the sub-subplot and all terms were considered as fixed effects in the model.

In all product trials, the main effects of preflood N rate and site-year had significant effects on rice grain yield (not discussed), but the main effects of HHDG, TA, and CB had no significant (P<0.05) effect on rice yield. More specifically, neither the main effect of HHDG (P=0.1895) nor the 2- (P=0.6077 and 0.4296) and 3-way (P=0.4715) interactions involving the HHDG had a significant effect on rice grain yields. Grain yields averaged across all other treatment effects ranged from 5,950 to 6,050 kg ha^{-1} among the four HHDG rates. Likewise, the main effect (P=0.2129) and interactions (P=0.3244 to 0.9428) involving TA treatments also had no significant effect on rice grain yield. Grain yields averaged across all other treatment effects ranged from 7,802 to 8,181 kg ha^{-1} among the five TA treatments. The main effect of CB (P=0.6342), averaged across all other treatments, had no significant effect on grain yield but its interaction with preflood N rate was marginally significant (P=0.0614). The interaction showed that rice that received no CB produced similar yields as all other treatments that received CB with the exception of CB Treatment 3 (877 mL CB preplant followed by (fb) 584 mL CB preflood ha^{-1}) fertilized with the suboptimal N rate, which produced the lowest average yield of rice fertilized with the suboptimal N rate. The failure of these products to show consistent benefits at sub- and near-optimal N rates suggests that the products are not ready for field use since they had little to no effect on rice yield. Although biochemicals that may be able to stimulate crop growth, yield and nutrient uptake likely exist, our results suggest that HHDG, TA, or CB had no benefit or detriment to rice growth and yield in these growing environments. Therefore, it seems reasonable that biostimulant manufacturers should provide information regarding the probability and a range of magnitude that crop yields will be increased should the product be applied and address the specific the growing conditions under which yield responses are most likely to occur before they are allowed to market such products.

Validation of Soil-Test-Based Phosphorus and Potassium Fertilizer Recommendations for Rice

Fryer, M.S., Slaton, N.A., Roberts, T.L., Norman, R.J., DeLong, R., Dempsey, R., and Parvej, R.

Soil testing is used by farmers to determine which fertilizers and how much of each are needed to ensure that phosphorus (P), potassium (K) and some micronutrients do not limit crop yields. The acceptance of precision agriculture has increased the demand for soil testing and variable rate fertilizer application. The potential benefits of precision agriculture technologies depends on the accuracy of soil-test based fertilization guidelines. Our research objective was to evaluate the accuracy of soil-test-based P and K fertilizer recommendations for flood-irrigated rice provided by the University of Arkansas, Division of Agriculture. Seven validation trials were successfully established in eastern Arkansas during 2013. The fertilizer recommendations for each site were determined from composite soil samples (0-10 cm) collected from the control plot of each block before planting. Each trial contained a total of six treatments that involved four K_2O rates and two P_2O_5 (0 and 29 kg P ha^{-1}) rates including 1) the recommended P rate plus 0 kg K ha^{-1}, 2) the recommended P rate plus 56 kg K ha^{-1}, 3) the recommended P rate plus 84 kg K ha^{-1}, 4) the recommended P rate plus 112 kg K ha^{-1}, 5) the recommended K rate plus the second P_2O_5 rate, and 6) no P and K fertilizer. Only two P rates were used because years of research in Arkansas have shown the relationship between rice yield and soil test P is poor. Triple superphosphate and muriate of potash were used to prepare treatments. Single-degree-of-freedom contrasts were used to make specific statistical comparisons among treatments. The three yield comparisons include 1) P fertilizer alone compared to no fertilizer, 2) K fertilizer alone compared to no fertilizer, and 3) P and K fertilization compared to no fertilizer. For this report, significant yield differences were identified for comparisons at two levels of significance ($\alpha = 0.05$ or 0.25).

Soil test P and K results were interpreted using the logic of the yield of rice grown on soil having i) Very Low and Low soil test levels are expected to respond positively to fertilization, ii) a Medium soil test level is expected to show a significant response to fertilization less than one-half of the time, and iii) Optimum or Above Optimum soil test levels are not expected to respond favorable or negatively to fertilization. Soils with a Medium soil test level were interpreted as having a correct response unless a yield loss from fertilization occurs. The seven sites included two clayey soils and five silt loams. Of the seven sites, no P or K fertilizer was recommended on the two clay soils, which had Optimal or Above Optimal soil-test P (≥36 ppm) and K (≥131 ppm) levels. The addition of P or K had no effect on rice yield for evaluations made at 0.05 or 0.25, indicating that recommendations accurately predicted rice response to fertilization.

The five silt loam soils had Very Low (1), Low (3), or Medium (1) soil-test P levels (plus soil pH >6.0) and would have received a recommendation for P fertilizer. Phosphorus fertilization did not increase rice grain yield at the five sites but decreased rice grain yield at two of the sites (mean loss 5.6%) when results were interpreted at $\alpha = 0.25$. Therefore, soil test interpretations correctly identified the response to P fertilization at only one of the four sites having suboptimal soil test P. For all sites soil-test P accurately predicted the need for P fertilization to increase crop yield at 43% of the seven sites. Soil-test K was Medium at three sites and Low at two sites, but rice yield did not benefit from K at any of the five sites benefited from K. Similar to P, K fertilization decreased yield at one (7% loss, $\alpha = 0.05$) or two (average 4.5% loss, $\alpha = 0.25$) of the five sites. The current interpretation of soil-test K accurately predicted yield response to K at four ($\alpha = 0.05$) or three ($\alpha = 0.25$) of the seven sites. The most common error made by recommendations was a Type B error in which the current interpretation of soil test results recommended P and/or K fertilization, but rice yield was not affected. First year research results indicate that our current interpretation of soil test results for rice is accurate only for identifying soils that will not respond to P and K. Additional site-years of research are needed to verify the accuracy and consistency of these results.

Waterbirds, Rice, and Crawfish

Huner, J.V., Romaire, R.R., and Musumeche, M.J.

Crawfish have always been a part of the South's rice landscape. Intentional cultivation of crawfish, *Procambarus* sp., with rice began in Louisiana in the 1950s. Initially, crawfish perpetuated themselves in these artificial wetlands and were harvested when fields were dewatered for rice harvests. Later, fields were intentionally reflooded in the fall following rice harvests, and crawfish were harvested during the cool season prior to spring planting of rice. Rice stubble and ratoon re-growth served as the basis for the food web that sustained crawfish growth. In 2013, 162,088 ha of rice and 73,295 ha of crawfish were cultivated in Louisiana. Much of the crawfish was cultivated in rice fields in some rotation with rice.

Mature crawfish are stocked in the spring after the rice crop is permanently flooded. These subsequently burrow into levees where they reproduce. Females emerge from burrows in the fall following rice harvest when the fields are refilled with water. Some farmers will raise rice and crawfish continuously in each year. In that case, restocking of crawfish is often not necessary. Most farmers, however, do not follow crawfish with rice crops. Rather, fields are fallowed or planted with a crop like soybeans or sorghum. Rice will be planted the following spring and crawfish restocked. This management practice is favored because crawfish densities tend to be low enough to ensure growth to larger, more valuable size.

Area devoted to crawfish based on forage management includes: crawfish sole crop, no rice: 11,725 ha; crawfish sole crop, rice as forage not harvested: 10,995 ha; rice-crawfish-rice-crawfish: 10,260 ha; and rice-crawfish-fallow or crop: 40,315 ha. So, 84 % of crawfish are cultivated with rice and 69% of the rice is harvested.

Waterbirds have always been attracted to rice fields because the shallow water/moist soil habitat provides rice seed, weed seeds, roots, corms, macro-invertebrates, including crawfish, and small vertebrates, especially amphibians and fishes. The addition of crawfish to the rice landscape ensured that shallow water/moist soil habitat was available year round. The absolute amount of animal food resources available to waterbirds was dramatically increased because fields that would otherwise not hold water were filled from fall into the following spring. Predaceous wadingbirds – herons, egrets, ibises, spoonbills and storks – benefitted greatly from this cornucopia of energy rich animal prey.

Where crawfish are cultivated in monoculture, so-called crawfish rice is often planted in late July or August to reduce oxygen depletion that would otherwise occur when rice straw is flooded in harvested ricefields. This management scenario provides moist soil/shallow water habitat for shorebirds that migrate through the area at that time, referred to by ornithologists as "fall" migration!

Most crawfish production is concentrated in south-central and southwestern Louisiana. The southwestern Louisiana working rice-crawfish wetland region has been declared a continentally Important Bird Area by the National Audubon Society because it supports over 70 species of resident, seasonal, and migratory waterbirds, many of which are listed as "species of conservation concern." These include waterfowl, wadingbirds, rails, coots, shorebirds, gulls, and terns. In addition, numerous terrestrially-oriented bird species utilize this landscape. Over 65% of the state's 479 recorded bird species have been documented in the region.

The dramatic loss of adjacent coastal wetlands over the past half century emphasizes the critical importance of the region's working wetland landscape for waterbird conservation. For this reason, reduction in rice cultivation in the region over the past decade is especially disturbing.

Rice Planting Date Effects on Yield and Grain Quality

Walker, T.W., Atwill, R.L., Corbin, J.L., Fitts, P.W., and Golden, B.R.

The impacts of planting date on rice grain yield are well established. Changes in weather patterns, genetics, and cultural practices concomitantly impact the optimum dates of planting. Climatic conditions during anthesis through the grain maturation period impact yield and quality. This study was conducted to evaluate the impacts of planting date on grain yield and quality parameters, including whole milled rice and chalk content.

Studies were conducted from 2007 to 2013 at the Delta Research and Extension Center (DREC) in Stoneville, MS, on Sharkey clay soil. Multiple pure line cultivars and F_1 hybrids, largely selected based on grower popularity, were drill-seeded at five to seven planting dates starting as early as March 7 and as late as June 12. Dates of planting were separated by an average two weeks each year. The area for each planting date was managed similar to MSU Extension Service recommendations to control pests. Plots were fertilized with 170 kg N ha^{-1} when rice reached the 5- to 6-leaf stage and within two days prior to permanent flood establishment. Plots were drained 10 to 14 days prior to harvesting with a small-plot combine equipped with a weigh system and moisture sensor. Samples were collected in the combine for milling and chalk analyses. Yield data were standardized to 12% moisture content, transformed into percent relative yield (%RY) by finding the highest average planting date for each cultivar or hybrid each year, and then averaged over all varieties/hybrids within each year to determine the final %RY. Percent RY was subjected to PROC NLIN to determine optimum period of planting, and the rate of change when rice was planted after the optimum. Paddy rice was milled and separated using a Zaccaria PAZ-1-DTA system. Approximately 100 whole milled rice kernels were subjected to image analyses using the WinSeedle Pro 2005a™ to determine the percent chalk. A stability index was calculated for each cultivar from the 2013 chalk and milling measurements by dividing the standard deviation by the mean and multiplying by 100.

Results from 2007 through 2013 planting date studies suggested the optimum planting period for rice in Mississippi was from March 20 to April 23. After April 23, rice yields declined by 0.2% per day. Within 2013, an interaction between planting date and cultivar was present ($P \leq 0.0001$) for chalk. Chalk percentages for Bowman, Cheniere, CL152, Presidio, and Taggart were unaffected by planting date. Pooled over planting date, these five cultivars resulted in the lowest amount of chalk with a range of 2.3% for Presidio to 4.7% for CL152. XL753 averaged 10.4% chalk but was highly variable (stability index of 33) due to a drastic improvement (4% chalk) when planted in June. Pooled over all cultivars, June-planted rice resulted in the least amount of chalk (4%). Whole milled rice followed a similar trend. The June-planted rice pooled over cultivar produced the greatest whole milling percent (64%). Pooled over planting date, Taggart and CLXL745 resulted in the lowest whole milled rice at 49 and 51%, respectively. However, both increased dramatically (12 to 15%) from early planting to the latest planting. On average, Cheniere and Mermentau were two of the highest milling cultivars (63%) but only increased by 6% when comparing the earliest planting date to the last planting date.

These data demonstrate the impacts of the interaction of cultivar and environment on yield and grain quality parameters (% chalk and whole milled rice). Research like this can be implemented in breeding and agronomic research programs to develop cultivars that are more stable across a wider range of environments so that end-users have a less variable product.

Effect of Insecticide Seed Treatments and Seeding Rates on Grain Yield of Three Rice Cultivars

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A study was initiated in 2013 on the silt loam soils at the Rice Research and Extension Center (RREC) near Stuttgart, AR, to examine the impact of insecticide seed treatments and seeding rates at different planting dates on the grain yield of three rice (*Oryza sativa* L.) cultivars currently grown in the southern United States. Two planting dates were used, early (April 9) and late (June 5). The three rice cultivars chosen for the study were the Arkansas long-grain, standard-stature 'Roy J', the Louisiana long-grain, Clearfield, semidwarf 'CL152,' and the RiceTec long-grain, standard-stature 'XL753.' Roy J was seeded at rates of 33.7, 44.9, 56.1, 67.4, and 78.6 kg/ha. CL152 was seeded at rates of 33.7, 44.9, 56.1, 67.4, and 78.6 kg/ha. XL753 was seeded at rates of 11.2, 16.8, 22.5, 28.0, and 33.7 kg/ha. For insecticide seed treatments, cultivars were treated with Dermacor X-100 (91.3-109.6 ml/ha), CruiserMaxx Rice (4.58 ml/kg), or no insecticide. All cultivars received the same base fungicide seed treatment regardless of insecticide seed treatment. The treatments were arranged in a randomized complete block factorial design [3 (insecticide seed treatment) x 5 (seeding rate)] with four replications. Analysis of variance was performed on the grain yield data utilizing SAS 9.2 (SAS Institute, Cary, NC). Differences among means were compared using Fisher's protected least significant difference (LSD) procedure at a P=0.05 probability level.

At the early planting date, there were no significant differences in grain yield for CL152 or Roy J for seed treatment or seeding rate. For XL753 at the early planting date, all seeding rates had significantly higher grain yield than the lowest seeding rate (11.2 kg/ha). The highest seeding rate (33.7 kg/ha) produced significantly more grain than all other seeding rates. Across all cultivars at the early planting date, significant differences in grain yield were observed for seed treatment and seeding rate. Dermacor insecticide seed treatment significantly increased yield compared to no insecticide seed treatment. The highest seeding rate for all cultivars (78.6 kg/ha for CL152 and Roy J; 33.7 kg/ha for XL753) produced significantly greater yields compared to all lower seeding rates except the second highest seeding rate.

At the late planting date, Dermacor insecticide seed treatment significantly increased yield compared to CruiserMaxx and no insecticide seed treatment across all cultivars. For XL753 at the late planting date, the two highest seeding rates of 28.0 and 33.7 kg/ha produced significantly higher grain yields than the three lowest seeding rates. Across all cultivars at the late planting date, significant differences were observed for seed treatment and seeding rate. Dermacor insecticide seed treatment significantly increased yield compared to CruiserMaxx and no insecticide seed treatment. The two highest seeding rates produced significantly greater yields than all lower seeding rates.

Simple linear regression was also used to evaluate the interaction of seed treatment and seeding rate for each cultivar and planting date. At the early planting date, Dermacor and CruiserMaxx insecticide seed treatments produced noticeably higher yields at lower seeding rates compared to no insecticide seed treatment. As seeding rate increased, the yield difference progressively decreased. At the late planting date, the same general response was observed. However, only Dermacor had significantly higher yields at all seeding rates. CruiserMaxx and no insecticide seed treatment had similar yields at all seeding rates.

The single-year study indicates that seeding rate recommendations need to be reevaluated when insecticide seed treatments are used. In addition, planting date may also have an impact on insecticide seed treatment selection. Recommendations for seeding rates are supported by data collected primarily in the absence of insecticide seed treatments. Since greater than 60% of rice planted in Arkansas receives an insecticide seed treatment, seeding rate recommendations may also need to change to accurately reflect their performance with insecticide seed treatments. Results from this study are consistent with field-based observations from Extension specialists in recent years.

Principles and Application of Cultivation by Design

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Rice cultivation is one of the oldest agricultural subjects. Development of this discipline has experienced a long-term and experience-based process. Over the past 30 years, rice cultivation developed rapidly and has moved toward a new science-based stage instead of traditional experience. These changes have make the "precision design" become possible.

According to the previous studies and our findings, we proposed "Cultivation by Design" (CD), which is based on the principle of growth and development of high-yielding rice and focuses on the dynamic changes of key population indicators of designed yield. This article was present a brief introduction to the theory and methodology of precise and quantitative rice "Cultivation by Design."

"Cultivation by Design" was based on a certain region's climate, varieties, and soil conditions to determine the goals of rice yield and to design the growth and development process, population development indicators, and cultivation regulation measures. It was characterized by the precise quantification of the amount and timing of agronomical factors, including transplanting density, N fertilization, and water management, according to the objective law governing rice yield formation. In the past five years, we conducted the theoretical research on high-yielding rice cultivation and applied the nationwide investigations on high-yielding rice cultivation and proposed this new theory and methodology "Cultivation by Design." Based on this methodology, we conducted numerous rice cultivation trials in different areas within China and results indicated that trends of high yield were repeated stably between regions and years and that remarkable progress had been achieved. It was a new rice cultivation methodology that obtains high yield by improving quality of rice population. We appreciate the support provided by the national sci-tech support plan in China (2011BAD16B14, 2012BAD04B08).

HeadSet: A New Energy Source for Rice

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HeadSet is a foliar applied nutritional product that has shown the ability to increase yields and quality of rice (*Oriza sativa*) by boosting plant energy levels. The active ingredient of HeadSet is GA 142, which is a nutrient source extracted from seaweed plants (*Ascophyllum sp.*). This active ingredient has two modes of action in rice. First, it stimulates an increase in the photosynthetic activity of the rice plant. Secondly, it enhances mineral absorption by increasing enzymatic activity responsible for nutrient uptake.

An N-Tester SPAD meter was utilized in grower fields to measure the chlorophyll content of rice with and without treatments of HeadSet at 1.4 L/ha (1 pt/A). Data collected from 17 field trials resulted in an average increase of 8.4% in the chlorophyll rate of rice when applied between panicle initiation and 10% heading. Additional laboratory research has documented a 15X increase in nitrogen reductase and a 7X increase in phosphatase activity in the roots of rice. The increase in enzyme activity is required to supply the enhanced photosynthetic activity.

The increase in photosynthetic activity and enzyme production has been shown to increase yields. Data from 17 replicated university and third party trials conducted from 2008-2012 show the benefit of HeadSet applications in rice. The average yield from more than 50 treatment comparisons in rice shows an average increase of 367.4 kg/ha (328 lbs/A) when applied between panicle initiation and 10% heading. Additionally, data from five trials conducted in 2010 resulted in an increase of 3 to 5% in milling quality. Yield and rice quality results have been further documented on growers' fields in demonstration trials using yield monitors at harvest. These results demonstrate that HeadSet can benefit growers by enhancing rice productivity.

Effects of High Night Temperature and 1-Methylcyclopropene (1-MCP) on Rice (*Oryza sativa* L.) Physiology

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Heat stress is known to increase ethylene production, which can cause leaf chlorophyll degradation and membrane damage in rice (*Oryza sativa* L.) plants. Degradation of chlorophyll is associated with decreased photosynthetic rate, and damage to the membranes is associated with increased respiration and decreased transport of photo-assimilates. The objective of this study was to determine if application of the ethylene perception inhibitor, 1-methyl cyclopropene (1-MCP), can minimize ethylene-triggered chlorophyll degradation and membrane damage under high night temperature (HNT).

Plants were subjected to 30°C day temperature and 22°C, 24°C, or 28°C night temperature, starting from 2000 h until 0600 h. The 1-MCP was applied at mid-boot stage of the rice plant. Leaf photosynthetic rate, respiration, membrane stability, chlorophyll concentration, pollen viability, and grain yield were determined.

Our results indicated that plants grown under 28°C (HNT) had greater chlorophyll degradation and membrane damage. In addition, plants grown under HNT showed decreased leaf photosynthetic rate, pollen viability and yield, and increased respiration compared to plants grown under 22°C night temperature. The 1-MCP-treated plants showed less chlorophyll degradation and membrane damage compared to untreated plants grown under HNT. In addition, 1-MCP-treated plants grown under HNT showed increased leaf photosynthetic rate and pollen viability and decreased respiration compared to untreated plants grown under HNT. Increased photosynthetic rate and pollen viability and decreased respiration due to 1-MCP application increased rice yield under HNT (28°C). We appreciate the funding provided by AgroFresh Inc., Philadelphia, PA, USA, in support of this project.

Modeling of Rice Response to Temperature and Photoperiod for California Major Rice Varieties

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The development of rice through tropical, subtropical and temperate ranges is affected by temperature and photoperiod sensitivity. The ability to predict developmental stages is essential for efficient rice crop management. Management decisions--which are often based on crop development (i.e. planting date, weed management, flood water height management)--can significantly affect yield and profitability. Environmental factors such as water temperature and air temperature may affect crop development and must be considered when making management decisions. This research focuses on understanding rice developmental stages as influenced by environmental factors such as air and water temperature and photoperiod sensitivity. In this study, we are testing the overall hypothesis that the importance of temperature (air and water) and photoperiod sensitivity varies depending on variety and growth stage.

The overall objective of this research is to develop a model that accurately predicts important growth stages for rice to enable farmers to make better management decisions. To achieve this objective, we will use historical data from region-wide variety trials and additional data from field and greenhouse trials to (i) quantify the effect of air and water temperature and photoperiod sensitivity on rice development and (ii) develop a predictive model of the principal growth stages of rice, including panicle initiation (PI), heading (H), and physiological maturity (PM). While previous studies focused on model development have primarily identified time to H, little is known about other crucial growth stages such as PI and PM. This model will be used to develop a unique predictive tool for California (CA) rice farmers that will help them make more informed management decisions throughout rice crop development.

Nine major CA rice varieties were selected for this study: M104, M105, M202, M205, M206, M410, CM101, S102, and L206. These varieties were chosen to represent a range of photoperiod, crop duration, and grain size. Historical data were obtained from University of California Cooperative Extension (UCCE) Rice Variety Evaluation tests (RVE) 2000-2012 for all varieties. Only data for the H stage were collected during this time, and there is lack of data for PI and PM stages. Therefore, field trials are being conducted (2011-current) in addition to the RVE to obtain data for the PI and PM stages as well. A greenhouse study at University of California Davis Vegetable Crops facility supplements field data by permitting more precise observation of photoperiod sensitivity effect on time to PI, H, and PM. Staggered planting dates and the controlled temperature environment of the greenhouse are used to quantify the effect of photoperiod on development. All varieties are planted at two-week intervals from the beginning of April through mid-June in 2012 and 2013.

The preliminary results from greenhouse study indicate three groups of varieties based on their response to photoperiod: photoperiod sensitive (M401), moderately photoperiod sensitive (CM101, M104, M105, M202, M205, and M206) and photoperiod non-sensitive (S102 and L206) varieties. Two models are developed to predict the time to H stage: Thermal-time model and Photo-thermal model. The Thermal-time model is based on temperature, while the Photo-thermal model considers temperature and variety-specific photoperiod sensitivity. Historical and field data from CA rice variety trials and data from greenhouse studies on rice photoperiod sensitivity were used to calibrate and validate the models. Results indicate the superiority of the Photo-thermal model in prediction of heading for M202, while the Thermal time model better predicts the time to heading for varieties L206 and S102. This is further supported by our greenhouse study preliminary results.

For the next phase of this project, we will continue development of a highly reliable predictive model for time to the principal crop development stages (PI, H, PM) of all major CA rice varieties. Continued research and model development will lead to accurate predictability of these critical growth stages as affected by variety, temperature, day length, air, and water temperature.

Sensitivity of Measured Evapotranspiration and Growth Stage of Rice in the Mid-South

Reba, M.L., Counce, P., Henry, C.G, Vories, E., and Chiu, Y.

Rice is a major food grain crop of the world. The Arkansas produces nearly 50% of the rice produced on over 1 million ha in the United States. Water use is high and strategies for using less water and producing similar yields are underway. The majority of rice production relies on groundwater extraction. Declining groundwater levels threatens the long-term use of this source. A study looking at detailed water use of a production-sized field took place in 2012 in northeastern Arkansas. The field was planted with a hybrid variety of rice known for their shorter growing seasons and heartiness under drier conditions. The field was instrumented with eddy covariance sensors to measure carbon, heat, and water fluxes. The components of the energy balance and water balance were measured with additional sensors. Eddy covariance sensors collected wind, carbon, and water flux data at 10 Hz, while the energy balance data were collected and averaged over 30 minutes. Limited research has been done in the humid south rice producing areas with eddy covariance methods of measuring evapotranspiration. Crop growth staging was completed for 80 plants in five areas of the field to understand growth and track production. Water use measured from the eddy covariance system was compared to other available methods to determine bias and variability. Insight was gained on water use of the crop during the production season for the hybrid variety studied and linked to crop growth.

Effect of Climate-Related Stress on Rice Yield Performance – Development of a Preliminary Site-Specific Yield Forecasting System

Wilson, L.T., Yang, Y., and Wang, J.

This paper addresses the impact of genetic improvement, agronomic and pest management, and key climate-related stress variables on rice yield performance across the six U.S rice-producing states from 1960 to the present. Analysis of data from Tabien et al. (2008) suggests that approximately 45% of the yield increase since the end of WWII can be attributed to genetic improvements with the remaining increase due to advances in cultural practices and improvements in agronomic and pest management. In contrast, year-to-year fluctuations in grain yields are largely the result of climatic and biotic stresses that can occur throughout the course of crop development. We assembled 53 years of yield and climatic data for each of the six rice-producing states for use in estimating the effect of climatic stressors on rice yield. For each year's data and for each state, eight climatic stress variables were estimated for both the stage of crop growth occurring prior to the initiation panicle differentiation, herein defined as the vegetative stage, and following the estimated timing of panicle differentiation, herein defined as the reproductive stage. The effect of genetic improvement on yield variability was estimated as a linear factor of time. The impact of each climatic stress variable was estimated using simple linear regression, stepwise multivariate linear regression, full model multivariate linear regression, and stepwise multivariate non-linear regression. The impact of each climatic variable on yield depends on the stage of crop growth (vegetative vs reproduction development), with approximately 88% of the variability in yield that was not explained by cultivar improvement captured by the full model multivariate linear regression model. Additional analyses were conducted to determine the effect of harvest date (as a surrogate for the plant date) and a select number of associated climatic stressors on yield and grain quality. Herein, we present an overview of results from these analyses. A preliminary site-specific yield forecasting system is suggested.

The Impacts of Palisade® Rates and Nitrogen Fertilization on 'CL151' Lodging

Corbin, J.L., Walker, T.W., Fitts, P.W., and Atwill, R.L.

'CL151' has become a popular cultivar for southern USA rice production because of its high yield potential and red rice control. It accounted for approximately 10% of the planted hectarage in Mississippi when averaged over 2012 and 2013. Expansion of CL151 has been tempered because of its propensity to lodge, which can decrease harvest efficiency, grain quality, and yield. The objective of this study was to evaluate the effectiveness of Palisade® (trinexapac-ethyl), a plant growth regulator in mitigating lodging for CL151

This study was conducted on a Sharkey clay (*Chromic Epiaquerts*) soil in 2012 and 2013 at the Delta Research and Extension Center (DREC), Stoneville, MS, in 2012 on a Dundee silt loam (*Typic Endoaqualfs*) in Shaw, MS, and in 2013 on a Commerce silt loam (*Fluvaquentic Endoaquepts*) in Greenville, MS. The experiment consisted of a factorial combination of treatments. Factor A was Palisade® rate and levels were 0, 96, 193, and 385 mL ha^{-1}. Factor B was nitrogen timing with levels being 100% of the N was applied preflood (PF) or 75% was applied PF and the remaining was applied at panicle differentiation (PD). Factor C was Palisade® timing with levels being PD and PD +14 days. Treatments were arranged in a randomized complete block design and replicated four times. Response variables included lodging (percent of the plot and severity), plant height, and grain yield. Data were subjected to analysis of variance in PROC GLM and means were separated with Fisher's LSD at a 95% confidence interval.

For the Dundee silt loam in 2012, percent lodging was influenced by Palisade® rate. Lodging was greatest (26%) when no Palisade® was applied, but 96 mL ha^{-1} reduced lodging to less than 2%. Lodging severity was also influenced by Palisade® rate. Lodging severity was 2.0 with no Palisade® and 1.1 when the highest rate was applied. Plant height was affected by Palisade® rate. As the rate of Palisade® was increased, the plant height decreased. Plant height was reduced by 18% with the highest rate of Palisade®. Plant heights were also greatest when the N was applied 100% PF. Grain yield was affected by Palisade® rate and timing. Grain yield decreased from 13,622 kg ha^{-1} when no Palisade® was applied compared to 10,739 kg ha^{-1} when the highest rate was used.

In 2013, lodging occurred at only one location. For the Sharkey clay percent lodging was affected by Palisade® rate and nitrogen application. Lodging was highest (25%) when no Palisade® was applied and N was applied 100% PF. Palisade® rate impacted lodging severity. Lodging severity was 2.3 with no Palisade® and 1.1 when the highest rate was applied. Plant height was influenced by Palisade® rate and timing for both soil types. Plant heights were greatest when no Palisade® was applied and were shortest when the highest rate of Palisade® was applied at the PD+14 timing. Nitrogen application also impacted plant height. Plant heights were greatest when N was applied 100% PF. Grain yield was affected by Palisade® rate on the Commerce silt loam. Grain yield was 12,694 kg ha^{-1} when no Palisade® was applied and decreased to 11,808 kg ha^{-1} when the highest rate of Palisade® was used. On the Sharkey clay soil, grain yield was influenced by nitrogen application. When N was applied 100% PF grain yield was 12,558 kg ha^{-1} and decreased to 11,670 kg ha^{-1} with the split application of N. In summary, these data suggest that Palisade® is effective in reducing plant height, which in turn can reduce lodging incidence. However, it is also evident that higher rates of Palisade® can potentially have a negative impact on grain.

Abstracts of Posters on Rice Culture
Panel Chair: Dustin Harrell

Drip Irrigation of Rice – 5-Year Summary

Vered, E.

FAO projections for 2050 are an additional 2.3 billion people or a 30% increase in population, needing more water and more food. In Asia, over 50% of water available for irrigation is used for irrigated rice. In India, for example, as much as 15,000 liters of water are used to produce 1 kg of rice. With the expected population growth, we must use water more efficiently. Our plan is to grow rice with 500 liters water per kg rice.

The rice crop is also one of the great polluters of the earth. Methane emissions from rice paddies as a result of decomposing organic matter in anaerobic conditions are much higher than any other crop. Nitrogen is supplied to rice throughout the season and fertilization while flooding causes leaching of great amounts of nitrogen into groundwater. Flood runoff pollutes lakes and rivers with nitrogen. Hazardous chemical compounds such as pesticides are dispersed in the same manner. A drip irrigation system provides fertilizers and pesticides directly to and around the plant's root system, necessitating less chemical inputs and preventing runoff pollution of rivers and water channels.

Another issue is the workload. Today, most rice is grown in the developing world, on small, family farms with manual work. Young people leave the farms looking for a higher income and less strenuous work. In order to keep the rice farms going, it is necessary to develop efficient farming methods for rice.

Irrigating rice with a drip system enables mechanical sowing of rice in the field, saving the labor of transplanting. It can also be used as a delivery system for pesticides and herbicides as well as for fertigation, saving more work and energy.

Experiments were conducted in Texas, Italy, India, and China to determine:

1. The feasibility of using sub-surface drip irrigation for rice crops.
2. Rice varieties suitable for growing under drip Irrigation. Some varieties have the potential for higher yields with drip irrigation.
3. Growing methods including crop coefficients, nutrient requirements, drip system layout, and plant spacing.

Conclusions:

1. A suitable rice hybrid is essential for yields of over 10 t/ha.
2. Optimal drip irrigation can reduce the amount of water and fertilizer needed to grow rice.
3. High yields are achievable with drip even on slopes or with saline water.
4. Drip chemigation prevents leaching and runoff of nutrients and pesticides into water sources.
5. Drip irrigation of rice prevents methane emissions associated with flooded paddy fields.
6. Drip irrigation of rice is not only feasible but more environmentally and economically sustainable than flooding rice paddies.

Our vision for the future is to use drip irrigation as a delivery system for all the plants' needs. As we now chemigate pesticides and chemical fertilizers, we hope to supply the plant with biological and hormonal treatments in the future, saving even more on chemical inputs, energy, and labor.

Soil Test Phosphorus and Potassium Trends Across Time in Arkansas Rice Fields

DeLong, R.E., Slaton, N.A., Roberts, T.L., and Norman, R.J.

Soil testing is used to determine which fertilizers and how much of each fertilizer are needed to maintain soil fertility and/or ensure that nutrient deficiencies do not limit crop yields. Farmers in the mid-South USA send soil samples to private and public/university soil test laboratories for analysis and fertilizer recommendations. The University of Arkansas Marianna Soil Test Laboratory now receives about 200,000 soil samples each year and summarizes the information annually by geographic location, crop, and soil series. The annual summaries allow university personnel the unique opportunity to monitor soil chemical properties across time to observe short- and long-term nutrient management trends. Our primary objective was to document how pH and soil-test (Mehlich-3) P, K, and Zn availability indices have behaved across time and show trends in soil sampling that have occurred since 2006. Soil samples collected using the field average (e.g., not grid soil samples) collection method that were submitted to the University of Arkansas Soil Test Laboratory between 1 January 2006 and 31 December 2012 and requested fertilizer recommendations for rice were used to examine trends for soils used to produce rice. The mean and median soil test P, K, and Zn values were calculated for each calendar year and regressed across time to define the 7-year trend. Soil test data from selected counties were examined to compare the range of chemical properties for soil samples collected using the grid and field average techniques. Grid soil samples were summarized without information regarding what crop will be planted and therefore may include soils that are used for crops other than rice.

The number of total (all crops) field average samples submitted between 2006 and 2012 has averaged 60,495 but has declined by 3,302 samples per year. Grid soil samples have increased from 14,838 to 133,470 samples per year, an increase rate of 19,743 samples per year, and now account for 71% of all samples submitted. Field acreage sampled using the field average method for rice fertilizer recommendations has ranged from 390,595 (2011) to 636,773 (2009) per year with each composite sample representing an average of 42 (2006) to 49 (2012) acres. The acres sampled (not including grid soil samples) for rice fertilizer recommendations represent an average of 35% of the annual rice acreage. Considering this information plus the fact that some proportion of soil samples from Arkansas is sent to private soil test laboratories for analysis, fields in Arkansas that are cropped to rice are apparently soil sampled at least once every two or three years. The median values of soils where the previous crop was rice and soils that were to be planted to rice showed that the median soil pH has remained constant at 6.5 since 2008 whereas soil-test P, K, and Zn have declined linearly by an average of 0.6 ppm P, 2.7 ppm K, and 0.2 ppm Zn per year from the mean of the initial median values of 28 ppm P, 121 ppm K, and 4.2 ppm Zn since 2006. The median values suggest that approximately one-half of the Arkansas rice acreage has Very Low and Low soil test P (<26 ppm P) and K (<131 ppm) values and require fertilization. Possible reasons for the soil P, K, and Zn declines could be reduced fertilization, the soils and/or farmer practices represented by the samples have changed over time, rice and rotational crop yields have increased resulting in greater crop nutrient removal rates, and/or some farmers are removing/baling crop residues and selling the biomass for livestock feed or energy production (e.g., removal of crop resides increases crop nutrient removal). More specific information detailing the percentages of acres (from field average samples that will be cropped to rice) that have Very Low, Low, Medium, Optimum, and Above Optimum soil test P, K, and Zn values will also be presented.

Buildup Programs for Soil Test P and K in Fields with Rice-Soybean Rotations

Stevens, G., Rhine, M., Heiser, J., and Dunn, D.

Allowing farmers the option to select the build-up time for achieving target soil P and K levels in fields provides flexibility when purchasing fertilizer. An eight-year experiment was conducted in Missouri on fields with rice-soybean rotations to determine the optimum P and K buildup program for both crops.

University of Missouri (MU) soil test laboratory recommendations for P and K fertilizer are based on three components: target level, crop removal, and build-up. Target level is the amount of extractable nutrient found in a soil at which point applying more fertilizer containing the nutrient will probably not increase crop yields. Crop removal is how much the nutrient is reduced in the soil annually from harvested forage, grain, or fiber. Build-up is the additional fertilizer needed above crop removal to increase low- and medium-testing soil P and K to the target fertility levels for crop production.

Soil P and K build-up can be slow or fast depending on the economic situation of the farmer. Total fertilizer applied in slow and fast build-up programs is about the same amount, but the cost may be spread out over more years in slow build-up periods. The current soil test recommendation system used by MU allows growers to select the number of years over which to build-up soils. This decision has a large effect on the amount of fertilizer that a farmer will purchase and apply in a given year. If a grower does not select a build-up period, the soil test lab uses an 8-year default build-up time to calculate fertilizer recommendations.

Research was conducted to determine which build-up strategy is the most profitable to manage crop nutrients in row crop and forage production. Long build-up programs help farmers manage their financial resources by spreading fertilizer costs over several years. However, growers need information concerning the magnitude of yield loss that may occur early in an 8-year build-up as compared to a shorter build-up (1 to 4 years).

An experiment was established in 2004 at the Missouri Rice Research Farm at Qulin, Missouri. Two rice pans were used with soybean and rice rotated between them each year. The experimental design was a randomized complete block with four replications. Permanent markers were placed to help locate research plots in following years. In the spring before fertilizer applications were made, composite soil samples were collected from each plot and analyzed at the MU Delta Center Soil Lab. Yield goals used to calculate P and K fertilizer recommendations were 3,024 kg ha^{-1} for soybean and 6,804 kg ha^{-1} for rice. Standard treatments included an untreated check, 1-year, 4-year, and 8-year buildup fertilizer programs. Treatments were included to compare using soybean versus rice soil test target levels. Current MU target soil P buildup for rice is 39 kg Bray-P ha^{-1} and soybeans is 50 kg Bray-P ha^{-1}. Target ammonium acetate extractable K is 140+ (5.6XCEC) for rice and 246+ (5.6XCEC) for soybeans. Rice received 168 kg N ha^{-1} in a 3-way split application program.

Initially, we were concerned that using rice target thresholds would decrease soybean yields and that shorter buildup time would produce higher yields than long buildups but that did not happen. All of the fertilizer programs produced more rice and soybean yields than the untreated check (N only for rice). But, there was not a yield advantage to bringing up P and K levels faster than 8 years.

On a low fertility soil, soybean and rice yields were increased by P and K fertilizer applications. Averaged over the 7-year life of the study, results showed that crops on 1-year, 4-year, and 8-year PK buildup programs produced the same amount of yield. Since the current default buildup in MU recommendations is 8 years, we found no evidence that this should be changed.

Effect of Irrigation Management and Silicon Fertilization on Rice Yield

Rhine, M.D., Stevens, W.E., Heiser, J., Dunn, D., and Nathan, M.

Silicon (Si) promotes rice (*Oryza sativa*) yield in many ways. Rice with adequate Si levels is found to have increased disease resistance, as well as resistance to abiotic stresses such as salinity and dry soil. In 2012, we sampled rice straw from Missouri fields that were under both flood and center pivot irrigation regimes. The University of Florida has developed methods for testing soil and rice straw Si concentrations. The lab procedures were developed for the Everglades area where Si deficiency is common. Based on soil tests, 1,400 kg Si ha^{-1} are recommended by UFL for fields testing less than 54 kg Si ha^{-1}. Missouri soil samples from graded rice fields with deep cuts averaged 25 kg Si ha-1. Fields with sandy areas tested 3.8 kg Si ha^{-1}. Based on this recommendation, Si fertilization could significantly benefit rice production on Missouri soils for increased stress resistances and yield.

An additional benefit to Si fertilization could be its effect on arsenic (As) concentrations in rice grain. Arsenic in rice tissues reduces yield by producing panicles without grain called "straight heads." Arsenic and Si react almost identically in the soil. In drained fields, arsenate, As [V], and silica ions are adsorbed on oxidized iron particles. When fields are flooded for rice, ferric iron +3 is reduced to the ferrous form +2 releasing As and Si into solution where they can be taken up by rice roots. For this reason, tissue Si and As content are usually higher in rice than crops such as corn and wheat.

Two proven methods to significantly reduce As in rice grain are silica fertilization and growing rice without flooding. Recent research showed that As in rice grain was reduced by applying soluble silica fertilizer. Silicon competes with As ions for root entry points. Given the Si deficiencies found in Missouri rice, and the desire to reduce As concentrations in rice grain, the objective of this experiment is to evaluate the effect of irrigation treatments and soil amendments of a calcium silicate-based fertilizer on yield and As concentration of rice grain in Southeast Missouri.

This experiment was conducted on three locations in 2013: continuous and intermittent flooded rice in Hayward, MO, aerobic sprinkler irrigated rice in Portageville, MO, and flooded rice in Glennonville, MO. Plots were seeded with RiceTec CLXL745 and treated with six different rates of calcium silicate at emergence (0, 500, 1000, 1500, 2000, and 2500 kg CaSi ha^{-1}). Nitrogen was applied during first tiller at a rate of 170 kg N ha^{-1}. Irrigation treatments began at first tiller and continued through harvest. Pre-harvest whole plant samples were taken and separated for analysis of As (grain) and Si (leaves and stem) concentrations. Silicon was measured using the University of Florida Si methods. Arsenic was quantified using ICP-MS analysis.

Arsenic samples are in the process of being analyzed, so no data was available at this time. Silicon samples of aerobic rice showed an increase in tissue Si as CaSi rate increased ($R^2 = 0.8666$). However, applications of CaSi as high as 2,500 kg CaSi ha^{-1} on aerobic rice did not surpass critical Si levels indicated by the University of Florida. Silicon concentrations in flooded rice were much higher than aerobic treatments, ranging from 62,750 to 73,375 mg Si Kg^{-1} but were not significantly different. University of Florida recommends Si fertilization for tissue samples with less than 34,000 mg Si kg^{-1}, which explains why significant differences could be found on aerobic rice, which was deficient of Si, but not flooded rice.

Grain yield of aerobic rice was found to be numerically higher with additions of CaSi. Grain yield of plots with 500 kg CaSi ha^{-1} were found to be significantly higher than the untreated check. Grain yields of flood irrigated rice with amendments of CaSi in Hayward, MO, were not statistically different from untreated checks. Grain yield of rice in Glennonville, MO, showed no significant increase from CaSi applications. However, grain yield of all applications of CaSi were numerically higher than untreated checks.

When untreated checks were found to be deficient of Si, applications of CaSi proved to increase rice Si uptake, which translated into a yield increase. Given that tissue samples on untreated flood rice were found to have sufficient Si, significant increases in yield were not expected. Also, CaSi takes time to break down in the soil, meaning that plots may not have fully utilized the application. These plots will be maintained for two more years to see if any subsequent differences can be found in yield or arsenic uptake.

Silicon is an important element in rice productivity. In situations where Si may be deficient, Si fertilization looks to be a plausible way to correct that deficiency. However, in order to reach critical Si levels on fields which are heavily deficient of Si or under aerobic conditions, rates of silicon may need to be increased beyond the range of this study.

Effects of Early Planting of Rice on the Yields of Main and Ratoon Crops

Liu, G., Dou, F., Tarpley, L., and Mohammad, A.R.

Rice variety and planting date are two most important factors influencing rice yield and grain quality. Planting rice in the optimum period of time is critical to achieve high grain yield and good milling quality. Currently, planting of hybrid rice is expanding in the US since it can produce 15-25% greater yield compared to most conventional rice. This paper presents the updated information on determining early planting date for maximizing rice yield and grain milling quality using selected conventional rice cultivars and hybrids.

Field experiments were conducted in a randomized complete block design with four replications in Beaumont, Texas, during 2008-2009. "Early planting" (late March) and "normal planting" (mid April) were used for main crop (MC). Three inbreds (Bowman, Cocodrie, and Presidio) and three hybrids (Clearfield XL729, Clearfield XL745, and XL723) were selected. Rice plots were harvested at 10" stubble height for ratoon crop (RC). A total of 236 kg N ha^{-1} was applied on inbreds at MC, 169 kg N ha^{-1} on hybrids and 151 kg N ha^{-1} at RC for both inbreds and hybrids.

For MC grain yield, no consistent pattern occurred for inbreds but lower temperature during reproductive stage favored higher grain yield. Hybrids generally had higher MC yield if planted at normal planting date. For the inbreds, early planting rice had a higher total (main and ratoon) yield than normal planting. RC grain yield was correlated significantly with MC grain yield. Planting date also affected rice milling yield. For MC, hybrids had higher milling yield in normal planting than those in early planting. Effect of planting date on MC milling yield varied with years. For RC, early planting favored milling yield for most cultivars. Our results suggested that planting date selection rely on specific cropping system. If ratoon rice is applied, early planting may have higher total yield potential.

1-Methylcyclopropene (1-MCP) Prevents Transplanting Shock in Rice (*Oryza sativa* L.)

Mohammed, A.R. and Tarpley, L.

Rice (*Oryza sativa* L.) seedling growth in the nursery and the transplanting shock experienced by seedlings affect the subsequent plant stand, growth, and development of transplanted rice. The study's objective was to determine if application of 1–methylcyclopropene (1-MCP) to the seedlings prior to transplanting can prevent the transplanting shock.

Plants were transplanted 21 days after emergence with root pruning (0%, 25%, or 50%). Three days prior to transplanting, one set of plants was treated with 1-MCP (25 g ai ha^{-1}) and the other set was treated with Latron (adjuvant 0.25%; control). Plant height, numbers of tillers and leaves, and chlorophyll concentration (SPAD index) were determined weekly. Leaf photosynthetic rate was measured 5 days after transplanting. Root dry weight, shoot dry weight, and root length were determined at harvest (4 weeks after transplanting).

Our results indicated that root pruning did not have an effect on plant height, number of leaves, root dry weight, or root length. However, root pruning had negative effects on number of tillers, chlorophyll (SPAD) concentration, shoot dry weight and net photosynthetic rate. Plants treated with 1-MCP showed greater number of tillers, chlorophyll concentration, root dry weight, and net photosynthetic rate compared to the plants of the control. Our results indicate that application of 1-MCP prior to transplanting can prevent the transplanting shock treatment effect in rice. We appreciate the funding provided by AgroFresh Inc., Philadelphia, PA, USA, in support of this project.

Small-Plot Validation of N-STaR for Rice Produced on Clayey Soils in Arkansas

Greub, C.E., Roberts, T.L., Norman, R.J., Fulford, A.M., and Slaton, N.A.

Nitrogen fertilizer costs represent as much as 30% of the total input costs for most rice producers and often times is the largest single item expenditure. With rising production costs, especially in the form of N fertilizer, implementation of N-STaR to predict field-specific N rates is becoming more and more important and will be essential for the long-term sustainability of Arkansas rice production. The benefits of N-STaR are not just about optimizing economic or agronomic returns but making environmentally sound N fertilizer decisions. The objective of this study was to evaluate the ability of N-STaR to predict the field-specific N rates required to maximize rice yield on clay soils in Arkansas. During the 2012 growing season, data collection was finalized and correlation and calibration curves were developed for rice produced on clay soils. Statistical analysis indicated that the 0-30 cm soil sampling depth provided the best estimate of potentially mineralizable-N for rice produced on clay soils and ultimately N rate predictions using N-STaR. Following the completion of the correlation and calibration curves, the next logical step is to conduct field validation trials in locations and production settings that are different than the locations where the curves were developed to verify the accuracy of the calibration curves.

Field validation of new technology is most often associated with verification of model predictions but has been used to determine the accuracy of soil test correlation and calibration equations. Predicting N availability from legumes and cover crops has been widely investigated and field validation of these prediction equations is a logical step that must be completed prior to widespread acceptance. Field validation studies can provide researchers the opportunity to verify the accuracy of their calibration equations, while demonstrating the technology to producers. Replicated, side-by-side comparison of N-STaR rate recommendations across a wide variety of crop rotations, soil series, and native soil N levels is a key step in the release and incorporation of this new soil-based N test.

To facilitate the incorporation and understanding of the N-STaR program, field validation studies were implemented to evaluate the ability of N-STaR to predict the field-specific N rates required to maximize rice yield on clay soils in Arkansas. Prior to flooding, soil samples to a 30 cm depth were taken and analyzed by N-STaR, a direct steam distillation procedure. These field trials compared N rates from three calibration curves developed to predict 90, 95, and 100% relative grain yield (RGY), to the standard recommendation for rice (*Oryza sativa* L.) grown on clay soils (202 kg N ha^{-1}). In addition to looking at varying N rates with a location, researchers were also interested in the response of different rice cultivars to both increased and decreased N rates. At a single location the N-STaR N rates were applied to six different rice cultivars and included both pureline and hybrid rice varieties. Nitrogen fertilizer rates predicted from the three calibration curves ranged from 22 to 252 kg N ha^{-1}. Rice yields obtained using the 95% RGY prediction curve resulted in yields that were not statistically different than the standard N rate across all locations and cultivars. Similarly, rice yields obtained from the N-STaR 100% RGY curve were equal to or greater than the standard N rate at all of the study sites. Comparison of rice aesthetics within a field trial highlighted visual differences in rice height and color, with little to no difference in rice yield. These results indicate the importance of field-scale demonstration trials of the N-STaR technology to educate producers, consultants and extension personnel prior to full release of this soil-based N test for rice grown on clay soils. Further research with these validation studies will focus on the interaction of site-specific N rates and cultivars with rice disease pressure. Currently these studies do not incorporate disease monitoring or evaluation, but there have been noticeable differences within specific situations. A better understanding of the interaction of these three important factors; variety selection, N-STaR N rate and disease incidence will only provide further support for the use of the N-STaR program.

Summary of N-STaR N Recommendations in Arkansas During 2013

Williamson, S.M., Roberts, T.L., Scott, C.L., Norman, R.J., Slaton, N.A., Fulford, A.M. and Greub, C.E.

Traditionally nitrogen (N) recommendations for rice in Arkansas were based on soil texture, cultivar, and previous crop—often resulting in over-fertilization, thus decreasing possible economic returns and increasing environmental N loss. For years. researchers have tried to develop a N soil test that would allow them to better predict the actual N needs for a particular field. After many years of research at the University of Arkansas, the long quest for soil-based N recommendation for rice came to fruition in 2010 when Roberts et al. correlated several years of direct steam distillation results obtained from 45 cm soil samples to plot-scale N response trials across the state and developed a site-specific soil based N test for Arkansas rice. After extensive field testing, the Nitrogen Soil Test for Rice (N-STaR) became available to the public in 2012 with the initiation of the University of Arkansas N-STaR Soil Testing Lab in Fayetteville, Arkansas.

In an effort to summarize the effect of the N-STaR program in Arkansas, samples submitted to the University of Arkansas N-STaR Soil Testing Lab during 2013 were categorized by county and soil texture. Samples were received from 311 fields from 70 farmers across 27 Arkansas counties. Arkansas county and Mississippi county evaluated the largest number of fields, with 57 and 51 fields, respectively. The samples received were from 174 silt loam fields and 137 clay fields. The N-STaR N rate recommendations for these samples were then compared to the producer's estimated N rate or the standard Arkansas N rate recommendation of 165 kg N ha^{-1} for silt loam soils and 180 kg N ha^{-1} for clay soils and divided into three categories—those with a decrease in recommendation, no change in recommended N rate, or an increase in the N rate recommendation. There was a decrease in the N recommendation for 197 fields (63%) with an average decrease of 35 kg N ha^{-1}. No change in N recommendation was found for 20 fields, while 94 fields had an increase in N recommendation, with an average increase of 18 kg N ha^{-1}.

Of the 197 fields where there was a decrease in the N rate recommendation, 106 of those were from silt loam fields and 91 came from fields labeled as clay, with the average decrease was found to be 28 kg N ha^{-1} for silt loams and an average decrease of 43 kg N ha^{-1} for the clay soils. The fields where an increase in recommendation was found were from 58 silt loams and 36 clays with an average of 17 and 19 kg N ha^{-1}, respectively. Soil texture was found to be a significant factor ($p<0.0001$) in the fields with a decrease in recommendation but was found to not be significant in the fields that had an increase in recommendation. This difference in significance may be largely due to the lower limits of the N-STaR calculations for a clay textured soil. County was found to be a significant factor in fields that showed an increase ($p < 0.05$) and a decrease ($p < 0.0001$) in recommendation suggesting that certain areas of the state may be prone to N savings potential due to cropping systems and soil series. These results show the importance of the N-STaR program and can help target areas of the state that would most likely benefit from its incorporation.

Improving Sustainability with Hybrid Rice

Hamm, C.E. and Ottis, B.V.

Sustainability in agriculture is gaining momentum, particularly among the production sectors within the industry. The rice industry is no exception. Sustainability to the rice grower simply means maximizing profits through high yields, sound cultural practices and technology while being good stewards of the land. Sustainability to the general public or consumer means providing a high quality affordable product with minimal environmental consequence. In order to meet the demands of the time, advancements in technology and farming methods must be realized to address an ever-growing population and shrinking land availability. Planting hybrid rice, or SmartRice, is the first step toward improving sustainability for rice growers and consumers alike.

SmartRice has a per capita yield advantage of 15-20% over inbred rice varieties, which alone provides farmers with an added economic advantage while faced with ever increasing input costs. This also means that 15-20% less land is required to grow the same amount of grain. SmartRice capitalizes on heterosis, or hybrid vigor, to produce more tillers per plant and a more robust root system than inbred varieties. A larger root system allows for more efficient mining of soil nutrients and drought tolerance. Research has shown that SmartRice is a viable option under a sprinkler/pivot irrigation system using up to 30% less water than the delayed flood approach. In addition to producing more grain per unit volume of water, nitrogen uptake efficiency is also higher than all other long-grain varieties. Improved nitrogen uptake efficiency allows farmers to reduce nitrogen usage by as much as 15% on average while maintaining higher yields. Environmental advantages of SmartRice also include emitting 35% less carbon per bushel produced and sequestering up to 12% more carbon from the atmosphere than the next leading rice variety.

Research efforts are being expedited to improve on the sustainable qualities of SmartRice. Improvements in yield, steps to improve grain chemistry, disease tolerance, herbicide tolerance, and desirable phenotypes are at the forefront of these efforts. The goal of SmartRice is to continue to lead the way in providing the best options for improving sustainability for rice growers and consumers.

Seasonal Fluctuation of N-STaR Soil Test Values Taken at Various Soil Depths

Scott, C.L., Roberts, T.L., Williamson, S.M., Greub, S.M., Norman, R.J., Slaton, N.A., and Fulford, A.M.

In an effort to better manage nitrogen (N) fertilizer costs and increase the profitability of rice production in Arkansas, producers have begun to utilize the Nitrogen Soil Test for Rice (N-STaR) which allows field-specific N rate recommendations based on potentially mineralizable soil N. N-STaR is a direct steam distillation (DSD) procedure that indexes the availability of soil N and compares it to previously correlated and calibrated rice response parameters on silt loam soils. The N-STaR program was released to producers for silt loam soils in the spring of 2012 and has seen substantial interest from around the state of Arkansas. Although the correlation and calibration portion of the N-STaR program has been completed, there are still many questions that need to be addressed in regards to the basic application and implementation of N-STaR for rice production. A primary question that often rises from producers and consultants is "when is the best time to take my N-STaR soil samples?" In order to provide the best soil sampling recommendations for our producers a study was implemented to determine how soil depth and time of year influence the N-STaR soil test values.

The objective of this study was to determine seasonal changes of N-STaR soil test values at different sample depths. Samples were taken over a 1-year period beginning October 2012 and ending October 2013. Soil samples were taken from three fields at the Arkansas Agricultural Research and Extension Center (AAREC) in Fayetteville, AR; two fields at the Pine Tree Branch Station near Colt, AR, and two fields from the Newport Research Station near Newport, AR. Samples were collected from each field at a depth of 15 cm using a soil probe and a depth of 45 cm using a N-STaR soil sample bucket. Soil samples were then oven dried at 72 C for 48 hours, ground to pass through a 2-mm sieve, and analyzed using the N-STaR method. Statistical analyses were conducted using JMP Pro 10. This study was run as a repeated measure with sampling depth as a factor over time. There were significant differences among sampling times within three of the fields sampled at depth of 15 cm. Field A2A East at AAREC (p=0.0003), Location 1 and Location 2 at Newport with p= 0.0041 and p=0.0093, respectively. However, no significant differences were determined among any sampling times at the 45-cm depth.

Rice rooting depth has been determined to be approximately 45 cm on a silt loam soil and is also the depth where the best correlation and calibration of N rate response was determined. Therefore, the recommended sample depth for silt loam soils submitted for N-STaR soil testing is 0-45 cm. The variability in the 0-15 cm depth can be attributed to seasonal variation in surface soil due to microbial population fluctuations and natural cycling of N. Changes in both organic and inorganic-N in the surface soil will influence the N-STaR soil test value but may also indicate why this soil depth was not as effective at predicting rice response to N fertilizer and N rate predictions. This serves to further underscore the importance of following the 45-cm soil sampling depth recommendation for rice grown on a silt loam soil as shallower soil sampling depths are more prone to changes in N-STaR soil test values and could lead to incorrect N rate recommendations. The consistency of the N-STaR values in the 45-cm sampling depth results over time would result in similar N rate recommendations throughout the year and suggest that samples can be taken well in advance of rice planting to ensure that samples are analyzed and returned to the growers prior to N fertilizer application. Results of this study support previous findings that indicated the stability of the N fraction quantified using the N-STaR method and suggest that soil samples, when taken to the proper depth, are accurate over a wide time frame. Rice is most often grown in rotation with soybean and the results of this study suggest that N-STaR samples could be taken during the soybean growing season for use in the following rice crop. Further work will be conducted to determine if current crop species, such as soybean, has an influence on the N-STaR soil test value in-season. Current N-STaR sampling protocols encourage producers to sample soils in a timely fashion between fall crop harvest and rice planting, but the data from this study and future studies may indicate that the sampling window for N rate recommendations using the N-STaR program is much larger than previously thought.

Cover Crop, Soil Amendments, and Variety Effects on Organic Rice Production in Texas

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Hons, F., Wards, B., Kresovich, S., and Wight, J.

The major challenges in organic rice production include nutrient improvement, weed management, and variety selection. In this study, we tested the effects of two soil amendments on organic production in southcentral USA. The 2011-12 winter cover crops were established successfully with full coverage. The amount of dry biomass were 5,257 and 5,780 kg/ha for clover and ryegrass, respectively. Plots were cultivated and drill seeded but high weed pressure in the fallow plots resulted in very poor stands. Only results of rice grain yields from clover and ryegrass treatments were presented. Cover crops had a similar effect on rice grain yield, although numerically, rice grain yield under ryegrass treatment was higher than that under clover treatment. Compared to Presidio, Tesanai had significantly higher grain yield. Soil amendments did not have significant effect on rice grain yield. Compared to the control, the 168 kg N/ha and 235 kg N/ha soil amendment rates increased rice grain yields by 11%. There was no difference in rice grain yields between the two N rates, indicating that 168 kg N/ha was sufficient for organic rice production in terms of N supply. Compared to Presidio, Tesanai had greater plant height and appeared to be more competitive with weeds. Aboveground biomass of the rice crop was affected by the rate of soil amendments rather than the type of soil amendments. Rice milling yield was significantly affected by cover crop and rice variety.

Water, Soil, and Variety Effects on Rice Production in the Greenhouse

Dou, F., Soriano, J.B., and Tabien, R.E.

Rice is typically grown flooded in Southern U.S. rice belt. However, the prevailing shortage in water supply may potentially affect rice production in the area, especially in western Houston, TX. The objective of this study was to assess different water management practices, including permanent flooding, alternative flooding, and saturated moisture effects on rice production in a greenhouse. In this study, two varieties, Cocodrie and Rondo, were evaluated using clay and sandy loam soils. The rice grain, the percentage of the filled grain, grain weight, panicle number, tiller number, and total biomass at harvest were affected by water management and variety. Compared to Rondo, Cocodrie was less affected by aerobic water management. Also, rice crop planted in sandy loam soil was more affected by different water management practices. Our greenhouse study indicates that Cocodrie and clay soil are more suitable to aerobic rice production in terms of yield performance.

Validation of N-STaR in Mississippi

Atwill, R.L., Walker, T.W., Corbin, J.L., and Fitts, P.W.

Historically, rice cultivars were subjected to classical N rate studies on multiple soil types over multiple years to determine the "recommended" fertilizer rate. This was done because of the dynamic nature of N, especially in the dry-seeded, delayed-flood rice culture common to much of the southern USA. Recently, the development of the Nitrogen Soil Test for Rice (N-STaR) has made it possible to predict N needs on a field by field basis for coarse- and fine-textured soils. The objective of this research was to test the model's effectiveness for soils where rice is produced in Mississippi.

Replicated N rate response experiments were conducted in Mississippi in 2012 and 2013 on clay and silt loam soils. Nitrogen rates ranged from 0 to 235 kg N ha^{-1} on silt loam soils and from 0 to 270 kg N ha^{-1} on clay soils. In addition, a replicated strip trial was conducted at DREC on Sharkey clay soils with N rates, ranging from 0 to 250 kg N ha^{-1}. Soil samples were collected in the spring of each year and analyzed by the University of Arkansas N-STaR soil test laboratory. The 95 and 100% RGY N-STaR recommendations were compared to the response models developed from the rate response study. Data from each N rate response study were subjected to a quadratic model. The first derivative of the quadratic was used to determine the N rate at which the maximum grain yield was achieved (N_{max}). N_{max} served as the comparison to the 100% RGY N-STaR recommendation. N_{max} was substituted into the quadratic model to solve for the maximum yield (Y_{max}). Ninety-five percent of the maximum yield potential (Y_{95}) was entered into the quadratic response model to solve for the N rate that would achieve 95% of the yield potential (N_{95}). N_{95} was used as the comparison for the N-STaR 95% RGY recommendation.

In three of the four silt loam soil locations, the 95% RGY N-STaR recommendation was higher (44, 37, and 74 kg N ha^{-1}) compared to that of the classical approach. Grain yield increases at the same three locations were 4, 4, and 5%. N-STaR results for 100% RGY on silt loam soils resulted in an N rate reduction at all sites (12, 111, 30, and 7 kg N ha^{-1}) compared to classical approach. Three of the four sites showed no difference in grain yield compared to the classical approach. The differing site resulted in an 8% yield loss when both the 95 and 100% RGY N-STaR recommendations were used. For the clay soil sites, the N-STaR recommendations were consistently lower, averaging 80 kg N ha^{-1} less than the classical-based recommendation. Resulting grain yield losses if the 95 and 100% RGY N-STaR recommendation was used were 12 and 10%, respectively, compared to the classical approach.

These data suggest the N-STaR recommendations for Mississippi silt loam soils can potentially maintain grain yield and reduce N rates. However, for clay soils, the N-STaR recommendations are insufficient in optimizing N recommendations for rice production. In Mississippi, research is needed to more closely correlate and calibrate the current N-STaR recommendation model.

The Influence of Soil Total Carbon on Yield and Nitrogen Uptake in Continuously Flooded Rice Paddy Soils Dominated by Peat

Espe, M.B., Kirk, E., van Kessel, C., Horwath, W.H., and Linquist B.

Agriculture on peat soils has a well-documented negative impact on peat subsidence, leading to undesired environmental consequences. Rice cultivation has the unique potential for peat soils to remain agriculturally productive while reducing these environmental impacts, as continuously flooded conditions reduce soil subsidence substantially. However, peat soils have unique fertility requirements that must be better understood for rice cultivation to be successful. Specifically, this study sought to quantify the amount of nitrogen supplied to a rice crop from peat mineralization across a wide range of soil organic carbon (SOC). A total of 10 nitrogen rate trials over three seasons were established over a range of SOC from 2.5 to 23% in the Sacramento-San Joaquin Delta. Nitrogen fertilizer rates of 0, 40, 80, 120, and 160 kg N/ha were applied in each trial in a randomized complete block design with four replicates. Additionally, 20 nitrogen-omission plots were established in 2013 to observe yield response outside of the rate trials across the range of SOC. Yield response to nitrogen application was greatest in the 2.5 and 23% SOC trials, with little to no yield response in the intermediate range of 10-15%. The nitrogen-omission plots mirrored this trend, with the greatest yields observed in the 10-15% SOC range and with lower nitrogen-omitted yields occurring in the 2.5% and the >23% SOC range. Economic optimum nitrogen rates were calculated based on these results and showed optimum rates of 150 kg/ha for the 2.5% SOC and 173 kg/ha for the 23% SOC soils, with no nitrogen application being optimum in the 10-15% SOC range. These results suggest that nitrogen availability from peat mineralization is highest for peat soils in the 10-15% range, with nitrogen availability decreasing in soils with higher SOC. Further study is needed to understand the impacts of applying economic optimum nitrogen rates on the rate of subsidence of high SOC soils and to better understand the mechanism behind decreased nitrogen availability in these soils.

Planting Date Effect on Rice Grain Yield of Select Cultivars in Arkansas On-Farm Trials

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Norman, R.J., Wamishe, Y., and Cartwright, R.

Arkansas is the leading rice-producing state in the U.S. representing approximately 47% of the total planted acreage. The goal of the University of Arkansas is to have a complete production package available to producers when southern U.S. rice cultivars are released, including grain and milling yield potential, disease reactions, fertilizer recommendations, and DD50 Program thresholds. Many factors can influence grain yield potential including seeding date, soil fertility, water quality and management, disease pressure, weather events, and cultural management practices. On-farm trials provide information on yield potential and yield response under various environmental and cultural management conditions found in Arkansas.

On-farm trials were conducted during 2008-2012 across the rice-growing region in Arkansas using commercial cultivars and advanced experimental lines. Trials were located in commercial production fields in selected counties during each of the study years. Seeding date of a field was determined by the cooperator and was dependent on weather and field conditions. Seeding of each trial occurred within one to two days of the production field and cultural management of the trial was identical to that of the field throughout the growing season.

As a result of seeding date being dependent on weather and field conditions at each trial location during each study year, the combined dataset can be used to determine if seeding date has any effect on rice grain yield under production field conditions. Seeding dates for the selected cultivars ranged from late March to early June for the five years of the study and are grouped together as ‘weeks of year’ beginning at week 12. Cultivars evaluated for grain yield performance include Cheniere, CL111, CL151, Francis, Jupiter, RiceTec CL XL745, RiceTec XL723, RoyJ, Taggart, and Wells. Linear regression models of each cultivar in this dataset display a strong linear relationship between seeding date and grain yield. Regression lines were similar among all cultivars and indicate that optimum rice grain yields are obtained when rice is seeded earlier in the growing season, regardless of cultivar. Grain yield declined for each cultivar as seeding date was delayed.

Effect of Biochar Amendment on Methane and Nitrous Oxide Emission and Yield from a Rice Paddy from Southwestern Louisiana

Jeong, C., Wang, J.J., and Harrell, D.

Atmospheric methane (CH_4) and nitrous oxide (N_2O) are critical long-lived greenhouse gases (GHGs) contributing to global warming. While agricultural activities release significant amounts of CH_4 and N_2O to the atmosphere, GHGs emissions can potentially be decreased by improved crop management practices. In addition to conventional management implementation, developing novel management strategies to reduce these greenhouse emissions are necessary. Recently, biochar production from pyrolysis of crop residues/straw after harvest as recycling renewable resources had been proposed to increase soil organic carbon and improve soil fertility while reducing GHGs emission. So far, there is little information about the effect of biochar application in rice paddy fields on the reduction of greenhouse gas emissions in southwestern Louisiana.

We conducted a field experiment in rice paddies to examine the influence of biochar amendments on total emissions of CH_4 and N_2O over the whole growing season. Biochar from rice straw was surface broadcast at rate of 0 and 11.2 Mg ha^{-1} and then incorporated to a depth of about 10 cm before planting. In addition, N fertilizer was applied at rates of 0 and 134 kg N ha^{-1} as urea just before permanent flood establishment. The experiment plots were a randomized complete block design and consisted of four replicates. Background CH_4 and N_2O gas emissions were monitored from bare fields prior to flood experimental plots. Emissions from rice paddy were monitored with the closed chamber method at 3- to 4-day intervals throughout the whole rice growing season.

The results showed that biochar amendment significantly reduced total CH_4 and N_2O emissions. Overall CH_4 and N_2O emissions were significantly reduced by 27 and 43%, respectively, by biochar application to rice field. The presented summary of yields was based on one rate of biochar application for one season field trials. Thus, further research is required utilizing several different rates of biochar application in rice.

Arsenic Concentrations in Missouri Rice

Aide, M.T. and Beighley, D.

Rice (CL111) was grown in two soils types using (i) drill-seeded, delayed flood irrigation and (ii) furrow irrigation to assess the agronomic efficiency of the two irrigation systems and their impact on arsenic (As) rice uptake and partitioning among plant organs. The two soil types were a soil of the Sharkey silty clay series and a soil of the Crowley silt loam series. Nitrogen, phosphorus, potassium, sulfur, and arsenic rice tissues concentrations were not significantly different for rice tissues from either the bed or interbed position. For the furrow irrigated rice systems, the rice tissues from the Sharkey series showed normal to slightly elevated nitrogen concentrations throughout the growing season; whereas nitrogen in the rice tissues from the Crowley series showed slightly deficient nitrogen concentrations throughout the growing season. For the furrow irrigated system, arsenic concentrations in vegetative rice tissues from the Sharkey soil series showed approximately 0.4 to 0.2 mg As/kg, whereas arsenic concentrations in vegetative rice tissues averaged 0.25 mg As/kg. For both soils, the As partitioning demonstrated that the leaf tissues possessed the greatest As concentrations, following by smaller As concentrations in the stem and then the paddy rice grain. Brown and polished rice from the delayed-flood system ranged from 0.25 to 0.4 mg As/kg; whereas the brown and polished rice from the furrow irrigated system averaged less than 0.09 mg As/kg. Thus, the furrow irrigated rice had a substantially smaller quantity of As than rice from the delayed flood system.

Soil Arsenic Concentrations in Missouri Soils

Aide, M.T. and Beighley, D.

Twenty-one soil series, some with multiple pedons, were assessed to determine if the arsenic (As) distributions in soil profiles exhibit discrete maxima that correspond to the presence of agrillic horizons. The majority of pedons exhibiting argillic horizon expression show a Fe-oxyhydroxide and As maxima corresponding precisely with the argillic horizon. Pearson correlation coefficients verify the close correspondence of Fe and As. Soil profiles having cambic horizons may also show As and Fe accumulations at soil depths. Some coarse-textured, well-drained to moderately-well drained Entisols and Inceptisols have Fe-oxyhydroxide accumulation in their cambic horizons, promoting As accumulation. Conversely, silty-textured and poorly-drained to somewhat poorly drained Entisols and Inceptisols have C and Cg horizons that show somewhat uniform Fe and As concentrations throughout their soil profiles.

Selected pedons having well-drained to moderately well-drained soil profiles demonstrate that clay fraction Fe and As concentrations are closely correlated and that the As and Fe concentrations are greater than those from the corresponding whole soil. The somewhat poorly-drained Crowley pedon exhibited cohesive masses of Fe and Mn accumulation (sand separate) that had greater arsenic concentrations than those of the clay and silt separates. These pedogenic nodules with enhanced arsenic concentrations reveal alternative pathways involving arsenic transformation.

Development of a Wireless Sensor Network for Monitoring and Managing Water Depth in Production Rice Fields

Chiu, Y. and Reba, M.L.

The inclusion of automation in rice water irrigation and field data measurements may improve management by providing consolidated, meaningful information of irrigation needs of an individual rice field and help a producer make better-informed decisions. Providing water depth levels remotely to producer can help manage water resources as well as related logistics and labor. A rugged, low-cost system to monitor water depth in multiple fields was developed. The key features of the system are wireless data transmission, data-storage, data processing and transmission of compiled data through a user-friendly interface on a mobile device. A prototype wireless sensor network (WSN) system was designed to test feasibility of providing field data while installed in a production size operation. The WSN system consisted of three primary components: field sensor node (FSN), a data processing node (DPN) and a remote data server (RDS). A total of 15 remote FSNs were placed near each monitored rice field. The DPN, located at the epicenter of the FSN installation, collects sensor information wirelessly from each of remote sensor nodes. A remote data server (RDS) archives, processes and outputs alert based on the data collected from the field DPN. The FSN is comprised of a Vegetronix™ VH400 sensor, Synapse®-Wireless RF200 radio module, power supply, solar panel and weatherproof enclosure. The VH400 is a resistance-based sensor, which produces an analog voltage output in proportion to the amount of water the sensing probe is submerged. The sensing probe can respond to a maximum of 100 mm depth in water. The VH400 sensor and RF200 combination transmit information wirelessly to the DPN. The DPN unit is comprised of a cellular modem, microcontroller, microSD card storage module, RF200 radio module, power supply, solar panel, and weatherproof enclosure. The DPN microcontroller communicates to the 15 FSNs through the RF200 module and retrieves the sensor values at timed intervals. The sensor data is compiled into a data string and archived to an onboard microSD storage module and to a RDS through the cellular modem. The RDS is computer server located on Arkansas State University – Jonesboro campus. Using TCP/IP protocols, the data transmitted from the DPN is transferred and archived to a MySQL database residing on the RDS. During regular intervals, stored procedure functions are executed to detect threshold values. Upon detection of the threshold value, an alert is generated and transmitted to a mobile device. For example, when a FSN reported water levels below 50% of the VH400 sensing area a Short Message Service (SMS) text message was generated and transmitted to a designated user indicating water levels had reached a threshold level. A WSN system was developed and installed in a rice production field. The system was able to record and transmit water levels to a remote data server. The water levels, as well as, alert conditions were accessible via mobile devices. Future work will attempt to quantify the benefits and costs of using these systems.

Response of Two Rice Varieties to Midseason Nitrogen Fertilizer Application Timing

Norman, R.J., Frizzell, D.L., Hardke, J.T., Roberts, T.L., Slaton, N.A., Rogers, C.W., and Duren, M.W.

A study was initiated in 2011 on the silt loam soils at the Rice Research and Extension Center (RREC) and Pine Tree Research Station (PTRS) 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.' In 2012, the locations were RREC and the Northeast Research and Extension Center (NEREC) to include a clay soil, and in 2013, all three locations were utilized (i.e., PTRS, NEREC, and RREC). In 2011, the preflood N rates of 50 or 100 kg N/ha were applied and followed by no midseason N or a midseason N rate of 50 kg N/ha applied at beginning internode elongation (BIE), 12.7-mm IE, or 12.7-mm IE + 7 days. In 2012 and 2013, preflood N rates of 50 or 100 kg N/ha were applied and followed by no midseason N or a midseason N application rate of 50 kg N/ha applied at BIE, 12.7-mm IE, 12.7-mm IE + 7 days, or 12.7-mm IE + 14 days. Also, in 2013, a single preflood N application treatment of 135 kg N/ha was added at PTRS and RREC and 168 kg N/ha at NEREC. The treatments were arranged as a randomized complete block factorial design [2 (variety) x 2 (preflood N rate) x 3-4 (midseason N application)] with four replications, as well as a no midseason N application (control; four replications), and in 2013, a single preflood N application treatment (four replications) was added. Analysis of variance was performed on the grain yield data utilizing SAS 9.2 (SAS Institute, Cary, NC). Differences among means were compared using Fisher's protected least significant difference (LSD) procedure at a P=0.05 probability level. Rice variety was treated as a random effect because there was no interaction of rice variety x preflood N rate x midseason N application timing, the interaction of rice variety x midseason N timing was significant in only one out of seven site-years, and because in this presentation, we wish to concentrate on the influence of midseason N application timing on rice grain yield.

In 2011, there was a two-way interaction of preflood N rate x midseason N timing on rice grain yield at PTRS and RREC. Grain yield increased when midseason N was applied at both locations but only at the lower preflood N rate. Rice grain yield increased similarly among the three midseason N application times at the lower preflood N rate. In 2012, there was no two-way interaction of preflood N rate x midseason N timing on grain yield at NEREC and RREC, but there were significant main effects of preflood N rate and midseason N application timing on grain yield at both locations. Grain yield increased when the preflood N rate increased from 50 to 100 kg N/ha at NEREC but not at RREC. Application of midseason N at any of the four application times increased grain yield similarly at NEREC and RREC except that rice grain yield at NEREC increased when midseason N was applied at 12.7 mm IE + 7 days compared to at BIE. In 2013, there was a two-way interaction of preflood N rate x midseason N application timing on grain yield at PTRS and NEREC but not at RREC. However, there was a main effect of midseason N timing on yield at the RREC. At NEREC, all midseason N application times increased yield at both preflood N rates. All midseason N application times increased yield similarly at the lower preflood N rate at the NEREC but not at the higher preflood N rate. At the higher preflood N rate at the NEREC, midseason N increased yield when delayed from BIE to the later application times, but the increase in yield at the latter times was erratic. The grain yield appeared to decrease when the midseason N application was delayed from 12.7-mm IE to 12.7-mm IE + 7 days and then increased again when delayed until 12.7-mm IE + 14 days. At PTRS, all midseason N application times increased yield similarly at the lower preflood N rate except the BIE application timing which did not increase yield. Midseason N applied at any of the four application times at PTRS did not increase grain yield at the higher preflood N rate. At RREC, midseason N increased grain yield when applied at all of the application times except when applied at 12.7-mm IE. A single preflood N application of 135 kg N/ha at PTRS and RREC and 168 kg N/ha at the NEREC resulted in similar or greater grain yields than when N was applied in split applications at preflood and midseason.

The 3-year study indicates that midseason N application timing needs to be reevaluated for 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 3-year study indicate the proper midseason N application timing may also have changed. A single preflood N application added the third year resulted in similar or greater grain yields than the two-way split.

Effect of Water Management on Efficiency of Preflood Nitrogen Applications in a Drill-Seeded, Delayed Flood Rice Production System

Adotey, N., Harrell, D.L., Barron, M., Li, J., Kongchum, M., Leonards, J., Regan, R., and Fluitt, J.

Efficiency of preflood N applications in rice production is greatly influenced by water. Dwindling water sources for irrigation coupled with competing uses have resulted in alternate approaches to the conventional methods of flooding in rice fields. These innovative approaches enhance efficient use of water but may reduce nitrogen use efficiency and yield. Most of these current management systems may result in a greater loss of N as a result of the alternate aerobic and anaerobic soil conditions. Under conventional flooding systems, where anaerobic conditions predominate, N loss is relatively small. Rice varieties and hybrids can also influence nitrogen use efficiency but has been less explored. Hybrids typically have higher NUE compared with inbred varieties and may be able to compensate for potential inefficiencies associated with alternate water management practices. The objective of study was to evaluate the effect of variety/hybrid choice and water management system on nitrogen use efficiency of rice.

The effect of water management on nitrogen use efficiency (NUE) was evaluated under different water management systems in a field study. Four water management practices evaluated were: 1) continuous flooding system, 2) straighthead water management, 3) intermittent flooding system, and 4) semi-aerobic rice management. In continuous flooding system, rice was cultivated under upland conditions until a permanent flood was established at tillering and was maintained until two weeks before harvest. In the straighthead water management practice, plots were drained to a crack two weeks after the initial flood and re-flooded until two weeks before harvesting. Under intermittent flooding system, initial flood was allowed to naturally reside and the flood re-established after residence. This cycle was sustained during the growing season until two weeks before harvest. In semi-aerobic rice management, plots were flush irrigated bi-weekly throughout the growing season. One rice inbred rice variety (Prisidio) and one rice hybrid (CLXL745) were evaluated in the trial. Nitrogen was applied at two rates, 0 and 135 kg ha^{-1} (0 and 120 lb/acre), just before permanent flood establishment. The parameters evaluated were grain yield and nitrogen use efficiency. Rice was harvested at 3 linear row foot from the central drill row at 50% heading. The aboveground dry matter yield was determined by drying samples in 60ºC oven until uniform weights were attained. Dry samples were ground through a cyclone mill with a mesh sieve size of 1 mm. The total N content dry matter was determined using LECO Carbon-Nitrogen analyzer. Nitrogen use efficiency of yield was calculated as NUE = $[(\text{N removed}_{\text{fertilized}} - \text{N removed}_{\text{unfertilized}})/\text{unit of N applied}]*100$.

There was significant interaction between rice variety/hybrid (CLXL745 and Prisidio) and water management system for yield (P=0.0017). The yield of inbred rice was low (ranged from 5,806 to 7,067 kg ha-^{1}) and was not significantly different under differing water management systems. Differences in yields of hybrid rice were observed under water management systems. The yields from continuous flooding were greater than semi-aerobic rice management but similar to the remaining systems. There was no significant interaction between rice variety (CLXL745 and Presidio) and water management practice for NUE. However, there was a significant difference in NUE due to water management (P<0.0017; LSD=15). The NUE for continuous, straighthead, intermittent, and semi-aerobic rice management systems were 67, 57, 48, and 47%, respectively. The NUE of plots treated with continuous flood was significantly higher than straighthead and semi-aerobic but comparable to intermittent. A significant difference in NUE was evident between the inbred rice line and the rice hybrid (P<0.0001; LSD = 11) pooled across all water management practices. The NUE of CLXL745 and Prisidio were 67.6 and 41.9%, respectively. Results from this study show that first, the effect of water management system on rice yield is dependent on variety/hybrid planted. Secondly, nitrogen use is more efficient under continuous flow system in silt loam soil irrespective of the cultivar planted.

Effect of Soil Moisture and Pre-flood Nitrogen Source on Volatilization, NUE, and Yield of Rice Grown on a Crowley Silt Loam Soil

Harrell, D.L., Kongchum, M., Barron, M., Adotey, N., Li, J., Leonards, J., Regan, R., and Fluitt, J.

Soil moisture can play a large role in the efficiency of pre-flood, surface broadcast N fertilizer applications in rice production. Ideally in drill-seeded, delayed flood rice production systems, pre-flood fertilizer N applications should be applied on a dry soil and flooded immediately in order to minimize N losses. Losses of N can occur from ammonia volatilization or from nitrification/denitrification losses. When soils are moist or flooded at the time of pre-flood, N applications increased losses from ammonia volatilization and from nitrification/denitrification are expected. Nonetheless, in commercial rice production, applications of pre-flood N often occur when less than ideal soil moisture conditions exist. However, limited data exist which quantify the extent of the reduction in nitrogen use efficiency (NUE) when applications occur on moist or flooded soils. The objectives of this study were to: 1) first evaluate the NUE and grain yield pre-flood fertilizer N is applied on a dry, moist, and flooded rice soil; and 2) quantify N volatilization losses of pre-flood fertilizer N applications on dry, moist, and flooded rice soils.

Two field yield trials and one field volatilization trial were initiated at the Rice Research Station in Crowley, Louisiana, in 2013. Field yield trials consisted of three soil moisture conditions at pre-flood fertilization: 1) dry, 2) moist, and 3) flooded to approximately 2.54 cm. Three N fertilizer sources were evaluated: 1) urea, 2) NBPT-urea (low rate; LR), and 3) NBPT-urea (high rate; HR). The moist soil condition was established by flooding the soil to 2.54 cm and holding the flood for 24 h and then draining for 24 h before fertilizer N application. N fertilizer was applied at a rate of 134 kg N ha^{-1}. An untreated control where no N fertilizer was applied was included in the trial. The percent NUE was determined by the difference in N uptake from the fertilized plot and the unfertilized plot divided by the N rate and multiplying by 100. The trial was arranged as a split-plot with soil moisture as the whole plot and N source as the sub-plot. All treatments were replicated four times. The trial was duplicated with an early planting drilled-seeded on March 15 and a late planting drill-seeded on May 9. Volatilization was measured in the field over a 15-d period of time after fertilization using semi-open volatilization chambers and an acid trap in the late planted trial only. The same N fertilizer sources and soil moisture conditions were evaluated.

In the early planted trial, when urea was the fertilizer source, grain yields were highest when applied on dry soil (8,242 kg ha^{-1}) as compared with applications on moist (6,908 kg ha^{-1}) or flooded soils (4,877 kg ha^{-1}). When NBPT was used at the low or high rate, grain yields were statically similar when applied on moist or dry soil and ranged from 8,652 to 7,674 kg ha^{-1}, respectively. Rice grain yields were significantly lower for the NBPT-urea low (5,057 kg ha^{-1}) and high (4,875 kg ha^{-1}) rates as compared with applications on moist or dry soil; however, they were not different from each other. NUE was statistically similar regardless of N source when applied on dry soil and ranged from 48 to 59%. NUE was reduced from 58% when applied on dry soil to 22% when applied on moist soil when urea was the fertilizer source. NUE ranged from 6 to 8% across all N sources when applied into a flooded soil. Similar results were observed for the late planted yield trial. Significant differences in NUE were observed between N and soil moisture treatments (P=0.001; LSD=8.6%) for the late planted trial. Volatilization losses for the late planted trial were 26.5% for urea applied on dry soil, 21.8% for urea applied on moist soil, 18.6% for NBPT-urea (HR) applied into the flood, 18.5% for NBPT-urea (LR) applied into the flood, 18% for urea applied into the flood, 8% for NBPT-urea (HR) applied on dry soil, 6.3% for NBPT-urea (LR) applied on dry soil and NBPT-urea (HR) applied on moist soil, and 5.9% for NBPT-urea (LR) applied on moist soil. Mean rice grain yield (4,505 kg ha^{-1}) and mean NUE (2%) was significantly lower when applied into the flood (yield P=0.0001, LSD=491 kg ha^{-1}; NUE P=0.0001, LSD=5%) than applications on moist (6,675 kg ha^{-1}; 23%) and dry (7740 kg ha^{-1}; 40%) soil when pooled across all N fertilizer sources. The data suggest that nitrification-denitrification plays a large role in N loss when pre-flood N fertilizer is applied into a flooded soil.

Can Variable Frequency Drives Reduce Irrigation Costs for Rice Producers?

Henry, C.G., McDougall, W.M., Allen, C., Watkins, K.B., Reba, M.L., Vories, E.D.,
Henggeler, J.C., and Carmen, D.

Variable Frequency Drives (VFDs) allow for variable speed operation of electrical motor drive irrigation pumps and are an emerging technology and are being adapted to pressurized irrigation systems. They can also be an energy savings device, but less is known about their applicability in surface irrigation. Pumping plant performance tests were conducted on several newly installed VFDs on Irrigation Pumps used for rice-soybean rotations in Arkansas. Data from this testing will be used to develop recommendations for utility energy conservation programs.

Newly installed VFD on existing and new irrigation pumping plants were tested at five operational speeds and total dynamic head, flow energy use, and power quality parameters were measured for 11 pumps in northeast Arkansas. Cost of water and relative efficiency compared to the Nebraska pump standards were compared. Recommendations were then made to the user regarding potential savings and optimal performance ranges.

In general, as pump speed was reduced, the cost of water was reduced. However, in some cases at the lowest speed setting (around 1200 rpm), this trend reversed on some pumps, meaning that at a point the pump became more inefficient as it was slowed down. A general recommendation is that pumps should be tested to determine the speed at which this occurs and then program the VFD so that it does not drop below this set point.

During testing on three pumps in particular, the motor size was much larger than required to run the pump by more than 50%. This gross oversizing leads to much lower motor efficiencies than nameplate ratings. Many pumps were mismatched to the pumping conditions putting their operating point outside of the desired efficiency operating envelope.

Relative efficiency ranged from 40 to 81% of the Nebraska Pump standard, indicating a large degree of opportunity for improving overall pump and motor efficiency. For this dataset, the cost of water ($\$/m^3$) using a VFD at the slowest setting compared to operating at full speed ranged between 14 and 150% across the dataset.

VFDs can be an energy savings device and have real potential to reduce irrigation energy costs. However, the cost savings from a VFD can be overshadowed by improper motor sizing, improper pump selection, and deferred maintenance.

Abstracts of Papers on Economics and Marketing
Panel Chair: Michael Salassi

Rice Farming Practices in the Delta Region Using CropScape Data

Shore, F.L. and Cross, B.

The Delta Region of the USDA-NASS was established in 2013 and includes the rice producing states of Arkansas, Louisiana, and Mississippi. Arkansas leads all states in rice production and about 2/3 of National rice acres are typically located in the Delta Region. NASS provides the on-line service Quick Stats to distribute the official crop estimates. Rice is a major food crop for the Nation and the World with detailed tracking in Quick Stats including acres, yields, prices, and production. Another NASS on-line service, CropScape (based on a collection of all available Cropland Data Layer products), provides GIS-ready spatial and temporal acres and pixel estimates. Stacks of pixels from the yearly layers reveal changes in frequency and type of land use. This study uses CropScape products to analyze farmer rotation practices in the states of the Delta Region, 2007-2012.

The pixels in each layer from CropScape were added to give an estimated change. This is available directly from CropScape for any 2-year period. To show rotations over a 6-year period, the annual layers were added, using Imagine® software, in order of increasing years. This was done by coding the pixels to rice or other and then summing using Imagine. Prior to doing the summation, the smart eliminate tool was used to remove fields less than 10 acres. Acres identified as rice but less than 10 acres were assumed to be noise. As with all CropScape products, the pixel estimates should be considered indicative but not official NASS estimates.

Quick Stats identifies 2010 as an important year for rice acres planted in the Delta Region, with each state planting the most acres this year. Unfortunately, prices and yields obtained for rice were lower in 2010 than 2009. CropScape showed planting decisions in 2010, based on National pricing, were better for high intensity farmers (5 of 6 years in rice) than those planting only one year for the period. The high intensity farmers planted less rice in 2010 than in other years of the study, while the low intensity farmers planted more rice in 2010. Overall planting intensity was found to follow the order AR>LA>MS. CropScape was used to directly identify soybeans as the major crop following rice. Rotation every year was found to be 16.5% of total (LA>AR>MS), rotation to rice every 3rd year was 8.6% (AR>MS>LA), rotation out every 3rd year was 2.2% (AR>LA>MS), and rice every year was 1.5% (AR>LA>MS). A total of 85% of rice planting rotations for 2007-2012 were for rice planted 3 years or less: one year 28.3% of total, 2 years 28.7%, and 3 years 28.0%. This infrequent planting of rice by state was MS>LA>AR. Infrequent planting may indicate the value of rice for soil conditioning for subsequent crops.

Comparison of Survey Results and Budget Recommendations for Mississippi Rice Production

Falconer, L. and Walker, T.

The enterprise budgets developed by Mississippi State University (MSU) are prepared to provide general information for several different uses and provide information concerning general levels of cost and returns. This paper compares results from annual surveys of production practices for Mississippi rice producers with rice production recommendations from MSU for the 2012 crop year. This paper focuses on comparisons of total direct expenses, with particular attention paid to plant nutrient and herbicide costs.

The comparisons in this paper are derived from enterprise budgets generated for data collected from individual rice producers and enterprise budgets developed by MSU Research and Extension personnel for the 2012 crop year. Enterprise budgets are developed based on an annual survey of Mississippi rice producers that is carried out by the National Agricultural Statistics Service (NASS) for MSU under a contract with the Mississippi Department of Revenue. For the 2012 crop year, 34 usable surveys were provided. The field operations and input quantities from each survey were input into the Mississippi State University Budget Generator to develop producer costs on a per acre basis from a standard set of input prices.

MSU personnel currently develop budgets for nine different rice production systems within the state. A multidisciplinary approach involving Research and Extension personnel is used to determine production practices and input quantities, and to estimate costs and returns for rice production. The production practices listed in each budget are the result of the combined effort by researchers and extension personnel to represent those practices that producers should use in a specific production system.

The different technologies represented in the MSU rice budgets are based on the type of rice grown (conventional rice, conventional Clearfield rice, hybrid rice and Clearfield hybrid rice), irrigation system (continuous flood or multi-inlet) and levee type (contour levee, straight levee or zero grade). These technologies represent 71% of the cropping systems identified by the NASS survey for 2012.

For conventional variety, continuous flood, contour levee rice (4 observations), the MSU estimated total direct expenses were 9% higher than the survey results $1,577.31 per ha versus $1,430.29 per ha ($638.32 versus $578.82 per acre) based on lower average reported producer costs of fertilizer, $255.6 versus $203.59 per ha ($103.34 versus $82.39 per acre); herbicide, $219.03 versus $173.29 per ha ($88.64 versus $70.13 per acre); and seed costs, $116.76 versus $67.95 per ha ($47.25 versus $27.50 per acre). For conventional variety, continuous flood, straight levee rice (8 observations), the MSU estimated total direct expenses were 6% below the survey results of $1,568.47 per ha ($634.74 per acre). This difference was almost completely due to the difference in fertilizer costs survey results of $315.60 per ha ($127.72 per acre) compared with the budget estimates of $255.36 per ha ($103.34 per acre). For conventional variety, multi-inlet flood irrigation (3 observations), the MSU estimate was 1.1% above the survey results. For Clearfield hybrid straight levee flood irrigated rice, the MSU estimate was 7.7% below the survey results, with the main difference attributed to a difference of $126 per ha ($51 per acre) in fertilizer costs.

This study found that the budgets developed by MSU personnel for the 2012 crop year represent a large percentage of the production systems (71%) that Mississippi rice producers reported using. All budgets developed by MSU personnel were within 10% of the reported total direct costs.

Economic Analysis of Intermittent Flood Irrigation in Arkansas Rice Production

Watkins, K.B., Anders, M.M., and Henry, C.G.

Water is a critical input in rice production and is becoming increasingly more limiting in many parts of eastern Arkansas due to steady depletion of the Mississippi River Valley alluvial aquifer, the main source of agricultural groundwater in the region. Irrigation fuel costs also represent a significant portion of rice production expenses. Intermittent flood irrigation represents a water saving alternative to conventional flood irrigation in rice production. Intermittent flood irrigation refers to application of alternative wetting and drying cycles in rice irrigation during the growing season. If used properly, intermittent flood can result in reduced water use relative to continuous flood. This study compares the costs and returns of intermittent flood versus continuous flood in Arkansas rice production using three years of data from an irrigation management study conducted at the University of Arkansas Rice Research and Extension Center during 2011, 2012, and 2013.

Four irrigation treatments were evaluated in the study: 1) continuous flood (CF); 2) intermittent flood in which water is applied when the field dries to a 40% soil moisture content (IF40); 3) intermittent flood in which water is applied when the field dries to a 60% soil moisture content (IF60), and 4) a combination of IF40 followed by continuous flood (IF40-CF). Two variety types were evaluated in each year: 1) a hybrid variety (XL723 in 2011; XL753 in 2012 and 2013); and a Clearfield-hybrid variety (CLXL745). Measured grain yields and applied water for each irrigation treatment-variety type combination were used to calculate annual net returns above variable and fixed expenses assuming both diesel and electric irrigation power for the years 2011, 2012, and 2013. Three-year average returns were then compared across the 16 management combinations (4 irrigation treatments X 2 variety types X 2 irrigation power sources).

Comparison of returns across diesel and electric irrigation power sources revealed an expected return advantage for electric power relative to diesel power. Irrigation energy costs were 63% lower for electric power relative to diesel power. Average water applied across the three years was greatest for CF (8,087 m^3 ha^{-1}; 32 acre-inches ac^{-1}) followed by IF40-CF (6,031 m^3 ha^{-1}; 24 acre-inches ac^{-1}), IF60 (5,574 m^3 ha^{-1}; 22 acre-inches ac^{-1}), and IF40 (4,527 m^3 ha^{-1}; 18 acre-inches ac^{-1}). Average rice yields were highest for CF and IF40-CF and lowest for IF40 across the two variety types, with hybrids having higher grain yields than Clearfield-hybrids on average across all four irrigation treatments.

When assuming diesel power, average net returns were greatest for IF40-CF followed by CF regardless of the variety type. When assuming electric power, average net returns were greatest for IF40-CF when hybrids were used and greatest for CF when Clearfield-hybrids were used. Average returns were lowest for IF40 regardless of variety type or irrigation power supply. Average returns by power supply, variety type, and by irrigation treatment are listed from highest to lowest return as follows: (1) Electric and hybrids: IF40-CF (\$1,583 ha^{-1}; \$641 ac^{-1}); CF (\$1,547 ha^{-1}; \$626 ac^{-1}); IF60 (\$1,453 ha^{-1}; \$588 ac^{-1}); IF40 (\$1,401 ha^{-1}; \$567 ac^{-1}); (2) Diesel and hybrids: IF40-CF (\$1,388 ha^{-1}; \$562 ac^{-1}); CF (\$1,284 ha^{-1} \$520 ac^{-1}); IF60 (\$1,274 ha^{-1}; \$515 ac^{-1}); IF40 (\$1,256 ha^{-1}; \$508 ac^{-1}); (3) Electric and Clearfield-hybrids: CF (\$1,370 ha^{-1}; \$555 ac^{-1}); IF40-CF (\$1,326 ha^{-1}; \$536 ac^{-1}); IF60 (\$1,244 ha^{-1}; \$504 ac^{-1}); IF40 (\$1,189 ha^{-1}; \$481 ac^{-1}); (4) Diesel and Clearfield-hybrids: IF40-CF (\$1,131 ha^{-1}; \$458 ac^{-1}); CF (\$1,107 ha^{-1}; \$448 ac^{-1}); IF60 (\$1,065 ha^{-1}; \$431 ac^{-1}); IF40 (\$1,045 ha^{-1}; \$423 ac^{-1}). Average net returns were calculated 2013 dollars assuming a rice price of 0.3042 kg^{-1} (\$6.21 bu^{-1}).

Varietal Differences in Impact of Crop Lodging on Rough Rice Milling Yield and Market Price

Salassi, M.E., Deliberto, M.A., Linscombe, S.D., Wilson, Jr., C.E., Walker, T.W., McCauley, G.N., and Blouin, D.C.

Rice crop lodging just prior to harvest can significantly impact the income and expenses associated with the affected area of rice production in a field. Although crop lodging can increase harvest costs and reduce rice harvest rice yield, the most direct results of lodging are seen in the impact on rough rice milling yield and the resulting rough rice market price received for rice grain affected by pre-harvest lodging. To quantify the impacts of rice crop lodging on rough rice milling yield and market price, field experiments were conducted during 2011 and 2012 at four locations: (a.) the Louisiana State University Agricultural Center Rice Research Station in Crowley, LA; (b.) the University of Arkansas Rice Research Station in Stuttgart, AR; (c.) the Mississippi State University Delta Branch Research and Extension Center in Stoneville, MS; and (d.) the Texas A&M AgriLife Rice Research Station in Eagle Lake, TX. Two rice planting dates were evaluated in the study: (1) an early planting date (approximately March 15 for Louisiana and Texas and April 1 for Arkansas and Mississippi) and (2) a later planting date (approximately April 15 for Louisiana and Texas and May 1 for Arkansas and Mississippi). Three rice crop lodging treatments were evaluated: (1) early lodging (approximately 5-7 days prior to field drainage), (2) late lodging (approximately 1 week prior to harvest maturity), and (3) standing (at harvest maturity). Rice varieties evaluated in AR, MS, and TX included CL151, Presidio, Jupiter, Wells, and CLXL745. Trials in LA evaluated CL151, Presidio, Jupiter, Wells, Cheniere, Cocodrie, and LAH10.

Crop lodging was found to be significant for both lodging timing evaluated. The mean head rice (whole grain) milling yield for standing rice over all varieties evaluated in the study was 550.4 g kg^{-1}. Mean head rice milling yields for the early lodged treatment was estimated at 511.5 g kg^{-1} and for the later lodged treatment was estimated at 507.8 g kg^{-1}. Total grain milling yield was reduced slightly, although significant, from 701.6 g kg^{-1} for the standing crop treatment to 691.9 g kg^{-1} and 693.2 g kg^{-1} for the early and later lodged treatments, respectively. Differences in rice crop lodging were not found to be significant regarding the timing of crop lodging. Milling yield differences by variety followed similar patterns, although mean milling yield values differed across rice varieties. Head rice milling yields from early and late lodged CL151 averaged 506.9 g kg^{-1} and 492.8 g kg^{-1} compared to a standing crop milling yield of 540.3 g kg^{-1}. For Cheniere, head rice milling yield from early and late lodged samples averaged 566.1 g kg^{-1} and 577.4 g kg^{-1} compared to mean estimates for standing crop of 618.4 g kg^{-1}. For Presidio, head rice milling yield from early and late lodged samples averaged 506.8 g kg^{-1} and 500.8 g kg^{-1} compared to a mean value of 540.8 g kg^{-1} for the standing crop. Head rice milling yield for early and later lodged Wells averaged 426.3 g kg^{-1} and 430.5 g kg^{-1}, respectively, compared to a standing crop yield of 484.5 g kg^{-1}. Total milling yield differences for all varieties evaluated were small in value but significant in most cases.

Results from this study indicated that crop lodging just prior to harvest does have a significant impact on rice milling yield and rough rice market price. There were no observed differences in milling yield or market price which resulted from the timing the lodging. Lodging was observed to have a greater impact on the whole grain (head rice) milling yield than on the total grain milling yield compared to a non-lodged crop, although reductions in both were significant.

Whole grain rice milling yields over the four varieties were estimated to be reduced by 33.4 to 58.2 g kg^{-1} and total rice grain milling yields were estimated to be reduced by 4.1 to 17.2 g kg^{-1} from lodging, resulting in estimated market price reductions of \$0.00816 kg^{-1} to \$0.01301 kg^{-1}, due to changes in milling yield alone.

Economic Factors Driving USDA's 2013/14 U.S. Domestic Rice Market Baseline Projections

Childs, N.W.

USDA's 2013/14 long-term annual supply and demand baseline results for the U.S. rice industry are presented for both long-grain and combined medium/short-grain rice. An all-rice baseline—an aggregate of the by-class model results—is reported as well. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, stock holdings, and season-average farm prices by class. Underlying economic factors driving these projections for both classes of rice are explained. Because almost half of the total U.S. rice crop is exported annually, expectations regarding the world rice market—including trading prices—affect domestic baseline forecasts as well.

Changing market conditions necessitate annual long-term baseline projections, as market participants and policy makers need updated forecasts for planning, budgeting, and decision making. Each year, USDA develops both a domestic and international 10-year supply and demand baseline for rice. By-class models are developed only for the domestic market.

The baseline effort cuts across multiple commodities, including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding global and domestic population and income growth, interest rates, and exchange rates. The 2013/14 baseline forecasts were developed in November 2013.

Comparison of AFPC Representative Rice Farms Costs of Production to USDA-ERS Regional Estimates

Mazurkiewicz, S.D., Outlaw, J.L., Raulston, J.M., Knapek, G.M., and Anderson, D.P.

The United States Department of Agriculture - Economic Research Service (USDA-ERS) develops and provides annual commodity and production costs and returns for major agricultural commodities in the United States and its major production regions. These commodity crops include, corn, soybeans, wheat, cotton, grain sorghum, rice, peanuts, oats, barley, milk, and livestock operations. The USDA conducts surveys every four to eight years to determine production costs and returns for each of these commodities. The surveys are administered as part of the annual Agricultural Resource Management Survey (ARMS) and are intended to reflect costs experienced by agricultural producers. The 2012 historical rice costs and returns estimates developed by USDA are based on a survey base year of 2006 and have been adjusted annually using price indices and other indicators deemed appropriate by USDA to reflect annual changes between survey base years. Estimates made in the survey years should be regarded as most reliable because they reflect prices and technology used on each commodity without adjustment.

The Agricultural Food and Policy Center (AFPC) at Texas A&M University has developed and maintains 14 representative rice farms in five states. The representative farms are initially developed through a focus group interview process, and follow-up meetings are conducted every two to three years to calibrate the data. Projected prices, policy variables, and rates of change for variable and overhead costs are obtained from annual baselines generated by the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri. Baseline data from FAPRI are used to adjust the representative farms between visits with the producer groups.

Major cost categories used by the AFPC and USDA were standardized to include: seed, fertilizer, chemicals, irrigation, fuel, other variable costs, and overhead. This grouping facilitates comparisons between the two different methods of estimating production costs. Neither method is necessarily correct; they are merely two different perspectives on how to estimate and allocate production costs.

Although cost categories are similar between AFPC and USDA, differences do exist. For example, the USDA reports costs for pumping water for certain states: Arkansas, California, and Missouri. They do not specify costs for purchased irrigation water for the Mississippi River Delta region. AFPC Representative farms in these areas do report costs for water, and, in most cases, pumping costs are included. Both the USDA and AFPC have an entry for purchased irrigation water. The USDA treats taxes differently, combining taxes and insurance, while the AFPC uses a method of splitting out personal property taxes, real estate taxes, and insurance.

This study develops comparisons of estimated costs of production between AFPC representative farms and their corresponding USDA–ERS regional estimates. The USDA regions represented are the Mississippi River Delta, Gulf Coast Region, and California Region. All AFPC farms located in Arkansas were placed in the Mississippi River Delta region for purposes of this study.

On a cost per acre basis, all AFPC representative farms reflect higher production costs than their respective USDA-ERS region. The USDA regional estimates for California are 13.2% lower on average than the four AFPC representative farm estimates. USDA-ERS estimates that the California Region has costs of $3,251.07 per ha ($1,315.67 per acre). The AFPC farms experience costs ranging from approximately $123 to $618 per ha ($50 to $250 per acre) higher. The USDA-ERS assumes Gulf Coast Rice production per acre at relatively low levels compared to AFPC representative farms in the same region, thus leading to the AFPC representative farms in the region exhibiting production costs approximately 37% higher on average than USDA estimates. These differences in costs on a per hundredweight basis are less dramatic. The USDA total cost estimate for the Gulf Coast Region is $2,552.83 per ha ($1,033.10 per acre) while AFPC estimates are much higher, ranging from $2,700.11 to $4,424.89 per ha ($1,092.70 to $1,790.70 per acre). The estimated production cost per acre for the USDA in the Mississippi River Delta Region is $2,119.14 per ha ($857.59 per acre), a figure 25.2% lower than the average costs of production for all AFPC farms in the region.

An Analysis of Price Loss Coverage Calculation Parameters on AFPC Representative Rice Farms

Raulston, J.M., Outlaw, J.L., Knapek, G.M., Anderson, D.P., and Richardson, J.W.

This study examines the economic impact of differences in methodologies for calculating Price Loss Coverage (PLC) payments for rice acres on AFPC representative farms. The study utilizes 500 stochastic outcomes for the all rice price from the preliminary 2014 FAPRI baseline presented in December. A simple regression using historical data was used to estimate a projected medium-grain and long-grain rice price from the all rice price provided in the FAPRI baseline. AFPC representative farm data for 14 representative rice farms were used to obtain historical yields, planted acres, base acres, and farm program yields. Representative farms are focus groups of producers that provide vast knowledge and information through a consensus building, face-to-face interview process. Producers cooperating with the AFPC representative farm project provide all data necessary to model rice production in major production regions of five rice-producing states.

The H.R. 2642 methodology for calculating PLC payments is very similar to the one that actually became law in the 2014 farm bill. Payments in the initial legislation were made based on an average midseason (first five months of a crop marketing year) price. If this price fell below a $0.3086/kg ($14.00/cwt) reference price for long-grain rice or $0.3549/kg ($16.10/cwt) for temperate japonica rice, a payment would trigger. When the midseason price is below the reference price, the payment rate equals the reference price minus the higher of the midseason price or the loan rate. Payments were to be made on planted acres with the restriction that total planted acres for a farm could not exceed base acres, or a proportional reduction would apply. Payments were made on 85 percent of base acres and were subject to a $50,000 per person payment limit (a $75,000 limit applies to loan deficiency payments and marketing loan gains).

The 2014 farm bill maintains a similar structure with a few subtle differences. The reference prices are identical, but the price is compared to the marketing year average price instead of the midseason price. This results in a less frequent payment because prices in the first 5 months of the marketing year are typically lower than the marketing year average. Producers may now elect to maintain their historical base or update/reallocate base acres predicated on their 2009-2012 planting history. The payment fraction remains at 85 percent; however, total Title I payments are now limited to $125,000 per person, allowing more flexibility and potentially greater support if prices fall below reference prices but not to levels below loan rates. Provisions for a one-time payment yield update are common to both pieces of legislation.

Only three out of 14 AFPC representative farms would have preferred the H.R. 2642 proposed methodology for calculating PLC on their rice acres. All three farms (CAR550, CABR1300, and CACR800) are medium-grain temperate japonica growers in California. All 10 AFPC representative farms growing long-grain rice prefer the 2014 farm bill PLC payment calculation. These farms exhibit a strong preference for the 2014 farm bill calculation as they stand to benefit to the tune of $48,079 in increased average annual PLC payments. Seven farms prefer to update farm payment yields but maintain payment acres based on historical base acres. Two farms (ARWR1400 and MOWR4000) have base that matches their planted acres, so these farms are indifferent to maintaining historical base versus reallocating to 2009-2012 planted acres.

Most rice producers would have preferred to retain direct payments provided in the previous farm bill; however, this program was repealed in the most recent piece of agricultural legislation. Although the politically unpopular direct payment program has ended, the Price Loss Coverage (PLC) option is expected to provide an increased level of insulation in situations when prices are on the decline as compared to the previous CCP program. Most rice producers that the AFPC works with will benefit from the ability to maintain payment acres based on historical base. Additionally, 85 percent of the AFPC representative farms will benefit from the opportunity to update farm payment yields for rice.

Analyzing Commodity Programs in the 2014 Farm Bill for Representative Rice Farms

Knapek, G.M., Richardson, J.W., Outlaw, J.L., and Raulston, J.M.

The Agriculture Act of 2014 made significant changes to the farm program safety net. It eliminated the nearly two decade old Direct Payments along with the Counter Cyclical Program (CCP) and the Average Crop Revenue Election (ACRE). The farm bill replaced these programs with two new commodity programs, Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC). Producers will have to choose between PLC and ARC for the 2014 crop. This decision will last for the entirety of the farm bill and is irrevocable. Additionally, there is also a new insurance program, Supplemental Coverage Option (SCO), available to producers starting in 2015 that choose the PLC program. The purpose of this study is to evaluate the farm level economic impacts and risk reduction of various combinations of current farm programs on agricultural producers in major rice production areas of the United States.

This research incorporated a whole farm simulation model with data from four Agricultural and Food Policy Center (AFPC) representative farms. The simulation model utilized a multivariate empirical probability distribution to incorporate price and yield risk into projections for the representative farms used in this study which are located in Texas, Louisiana, and Arkansas. Each of the four representative farms was simulated under four different commodity policy alternatives and two different commodity price alternatives, for a total of eight separate alternatives per farm. The two price paths chosen were the Food and Agricultural Policy Research Institute's (FAPRI) December baseline and a low price projection that represented a five-percent decrease per year from FAPRI's forecast. Output were generated commodity by commodity and for the whole farm. The three commodities grown on the representative farms are rice, soybeans, and wheat.

Results show rice had the highest probability of payment and highest mean payments under PLC versus ARC for both price scenarios. Wheat and soybeans had the highest mean payments and probabilities of payments under ARC. However, the probability of an ARC payment and mean ARC payments for both wheat and soybeans decreases over the life of the farm bill. Furthermore, the combination of PLC and SCO payments was higher than ARC for wheat under baseline prices. For low prices, PLC provided the highest mean payments to wheat.

The results for whole farm show that the 2008 Farm Bill programs are slightly preferred under baseline prices based on the probability of the farm experiencing negative cash. The alternatives of all crops in PLC with SCO and wheat and rice in PLC with SCO with soybeans in ARC showed similar results as the 2008 programs. The all crops in

ARC alternative was clearly least preferred based on ending cash. Under the low price scenario, three out of the four farms preferred to have all their crops in PLC with SCO over the other alternatives. Furthermore, both the all crops in PLC with SCO alternative and wheat and rice in PLC with soybeans in ARC alternative were significantly less likely to experience a cash deficit compared to the 2008 programs under the low price scenario.

Economic Factors Driving USDA's 2013/14 International Rice Baseline Projections

Childs, N.W.

USDA's 2013/14 long-term annual supply and demand baseline results for the global rice market are presented. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, and stock holdings for 31 countries (including the United States) and nine multi-country regions. Aggregated, these 42 models account for total global rice production, supply, and use. Economic factors driving long-term trends in key individual countries and regions are explained, as well as significant changes from the previous baseline. Markets are not segmented by class.

Each year, USDA develops both a domestic and international 10-year supply and demand baseline for rice. The baseline effort stretches across multiple commodities including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding population and income growth for individual countries, interest rates, and exchange rates. The 2013/14 baseline forecasts were developed in November 2013. USDA's annual baseline projections are used by market participants and policy makers for planning, budgeting, and decision making.

Long-Term International Rice Baseline Projections, 2013-2022

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

This paper provides a 10-year projection of the global rice economy, with focus on key exporting and importing countries. Baseline estimates on production, consumption, trade, and prices that are useful in analyzing the impacts of alternative policy, technology, and market scenarios are generated using the Arkansas Global Rice Model (AGRM). AGRM is a non-spatial, multi-country statistical simulation and econometric analytical framework developed and maintained for two decades by the University of Arkansas Global Rice Economics Program (AGREP) in Fayetteville, USA. The model is disaggregated into five world regions: Africa, the Americas, Asia, Europe, and Oceania. There are 45 key countries or regions explicitly included in the model, and all other countries not individually modeled are included in one of the five aggregate rest-of-region (ROR) models. Each country and regional model includes a supply sector, a demand sector, a trade, stocks and price linkage equations. The analysis in this paper is based on the November 2013 baseline.

The rice story revolves around two dominant events which have shaped the dynamics of the global rice market over the last two years--India's official lifting of ban on non-basmati rice exports on September 2011 due to its swelling stocks and Thailand's implementation of paddy pledging program (PPP) in October 2011, a price-floor support policy for Thai farmers which guarantees minimum paddy prices causing Thailand's rice exports to be uncompetitive eventually leading to excessive stocks and the loss of the country's long-standing dominance in global trade. Consequently, India and Vietnam have expanded export volumes substantially—with dampening impact on rice prices. After two years of maintaining status quo, Thailand, with its mounting stocks and increasing controversies on PPP, has recently expressed willingness to release its excess stocks into the marketplace. The international rice baseline projections presented in this report have been prepared against this backdrop.

Over the 11-year baseline period (2012/13 - 2023/24), world rice output grows at 1.08% per year with 0.82% coming from yield gain and 0.26% coming from increased area. Global rice consumption gains 1.04% annually, as population grows at 1.02% and per capita use remains relatively stagnant. Net trade continues to grow at 1.63% per year. International long-grain rice prices are projected to be relatively flat and stable around the $400 level, as growth in rice consumption remains slow and increased production driven by more focused self-sufficiency programs of major consuming countries. The increased output is expected to result from expanded use of higher-yielding varieties and hybrids, and other improved production technologies.

Over the same period, India and China remain as the largest rice economies which combined account for 45.3% of total global rice area harvested, 51.5% of total world milled production, and 50.4% of total world consumption. Indonesia, Bangladesh, Thailand, Vietnam, Myanmar, and the Philippines combined account for 33.7% of world area harvested, 30.0% of global production, and 27.0% of world consumption. The international rice trade is highly concentrated with seven dominant players accounting for 96.1% of global net exports. India, Vietnam, and Thailand combined account for 67.3% of global net exports while Pakistan, Cambodia, the U.S., and Myanmar combined account for 28.8%. Net imports are relatively more distributed, with 10 countries (Nigeria, Iran, Iraq, Indonesia, Bangladesh, Saudi Arabia, Cote d'Ivoire, Malaysia, Senegal, and EU-27) accounting for 46.1% of global total.

Total world rice area is projected to expand by 5.94 million hectares over the 11-year period, with 80.8% combined coming from India, Nigeria, Bangladesh, Myanmar, and Pakistan. China's rice, on the other hand, is projected to contract by 1.22 million hectares due to irrigation constraints and competition from other crops. Vietnam and Japan are projected to lose a combined 405 thousand hectares. World rice output will grow by 60.5 million metric tons (mmt) over the same period, with 61.0% accounted for by Bangladesh, China, Indonesia, India, Cambodia, and the Philippines. Global domestic consumption is projected to grow by 58.3 mmt, with nearly 60% coming from Bangladesh, China, Indonesia, India, Philippines, and Vietnam. Total rice consumption will expand by 9.3 mmt in Africa and by 2.0 mmt in the Middle East.

Net exports are projected to expand by 5.9 mmt over the same period, with increases expected for Cambodia, Myanmar, Pakistan, and Thailand but declines for India and the U.S. On the other hand, the bulk of the growth in net imports over the same period will come from Africa, at 5.3 mmt.

Potential Welfare Impacts of Thailand's Paddy Pledging Program on Major Players in the Global Rice Market, 2013-2022

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

In October 2011, following an election promise to improve the Thai farmers' income, Thailand's new Prime Minister implemented a paddy price-floor support policy called Paddy Pledging Program (PPP) which guarantees minimum prices for paddy rice—which initially were 30-50 percent higher than world market prices—causing a surge in Thai rice domestic prices. Consequently, Thailand's rice export volumes in 2011 declined by 44%, losing its long-standing dominance in global trade.

The PPP is both theoretically interesting and controversial. It has caused uncertainties in the global rice market—as it has created an abnormally large rice stockpile in the country. Due to mounting program-related problems and controversies, the country is expected to release the excess Thai rice into the international market--most likely sooner than later. While theoretically, this action has the potential of causing significant distortions in domestic and international markets—its impact has not been adequately assessed and quantified. This study is an attempt to contribute to a better understanding of the intricacies of this program and its potential consequences on the global rice economy using a global rice model. Two release scenarios for Thai's excess rice stocks, 50% and 100%, are used in the analysis.

The major potential impacts of the release of excess Thai rice stocks in 2013 are on price, consumption and trade; and lagged response on area harvested and production thereafter. The deterministic analysis shows the average impact of a one-time shock on the model. At 50% Thai excess stocks release, global rice net trade expands by 11.5% with a consequent decline of 16% in the long-grain international reference price. The impacts nearly doubled under the 100% stocks release scenario, with global rice net trade expanding by 23.1%--resulting in nearly 28% decline in the long-grain international reference price. Vietnam's exports suffer the most declines, i.e., at 13.3 and 26.2% under the two scenarios, respectively. As rice trade increases, total global rice consumption expands by 1.3% in 2013 under the 50% scenario and by 2.5% under the 100% scenario, with a combined 60% accounted for by China, Indonesia, Philippines, and Vietnam. The decline in rice price could encourage usage shift from wheat to rice, as rice and wheat are substitute staples in countries like China and Indonesia. On average, global rice consumption gains by nearly1.4 mmt per year for the 50% scenario and 2.8 mmt per year for the 100% scenario over the 10-year period.

The 50 and 100% scenarios cause global rice production in 2014 to decline by 3.8 mmt and 7.1 mmt, respectively, about 74% of which is accounted for by China, Bangladesh, Indonesia, Pakistan, and the U.S. The potential global impact of the release of Thai's excess rice stocks could partially be neutralized by China's ability to manage its big rice stockpile, i.e. withdraw stocks as needed, in order to mitigate the negative effects of the country's decreased production and expanded consumption.

Understanding the welfare implications of the scenarios adds value to the analysis. Results show that, in general, the rice producers are worse off and rice consumers are better off under both scenarios. Rice producers in China are faced with the highest potential loss, followed by Thai and Indonesian rice producers. U.S. and Indian rice producers have relatively low losses. The producers' losses result from a combination of lower prices and lower production. Rice consumers, on the other hand, have substantial gains under the scenarios due to lower prices, with the Chinese gaining the most benefit. Indonesian and Thai rice consumers will also benefit considerably. Combining the effects on both producers and consumers, the net welfare changes show that only Thailand has considerable annual loss; while losses for China's producers are compensated by the gains of Chinese consumers, resulting in nearly awash net welfare change. The same is true for India. The Philippines and Indonesia, on the other hand, could potentially earn net benefits from the scenarios.

Thus, while the abrupt release of excess Thai rice stocks into the global market is probably not the most desirable course of action by the Thai government, results of this study show that the net impacts on rice prices, trade, production, consumption appear to be manageable. While rice producers will experience losses, consumers will benefit considerably; and the net welfare changes are relatively moderate.

Abstracts of Posters on Economics and Marketing
Panel Chair: Michael Salassi

Economic Effect of 2013 Farm Bill Commodity Title Provisions on Louisiana Rice Production

Deliberto, M.A. and Salassi, M.E.

The commodity title of the Agricultural Act of 2014, signed by the President on February 7, 2014, represents major change to farm price and income support policies that were contained in the 2008 farm bill. This preliminary research examines program mechanics and evaluates the economic effect that these programs have on a rice producer's income at the state level in 2014. Under the 2014 Act, new price and income programs were designed to fit current commodity production, although regional production differences were noted. During farm bill negotiations, the House unveiled a Price Loss Coverage (PLC) and a Revenue Loss Coverage (RLC) plan. The Senate passed legislation for an Agriculture Risk Coverage (ARC) and an Adverse Market Program (AMP) in their talks. In the H.R.2642 conference report, agreed to on February 4, 2014, the conferees elected to keep the PLC and ARC programs in the commodity title. For producers participating in the PLC program, program yield can be updated. These two programs, along with the marketing loan program- largely unchanged from 2008 law, will be key elements of the new farm safety net. The tables that immediately follow illustrate the operational mechanics of the PLC and ARC programs for county-level rice production in Acadia Parish, LA. Multiple price scenarios are presented for the 2014 crop year. Information was interpreted from the legislative language of the conference report and is subject to USDA FSA implementation.

During the lengthy farm bill policy debate, several commodity support programs were proposed, leading observers to ask what would these program look like at the county level if a farm bill was enacted in 2013. Therefore, in addition to the PLC program, the House-proposed Revenue Loss Coverage Plan (RLC) is presented for comparison to the ARC program. The Senate-proposed Adverse Market Payment Program (AMP) is also presented in comparison to the PLC program contained in the conference report. These program estimates are reflective of rice production conditions in Acadia Parish, Louisiana. The program parameters were obtained from earlier proposals (H.R.1947 and S.954) and applied to the anticipated 2013 price level.

Influence of Planting Date on Crop Lodging Impacts on Rough Rice Milling Yield

Salassi, M.E., Deliberto, M.A., Linscombe, S.D., Wilson Jr., C.E., Walker, T.W., McCauley, G.N., and Blouin, D.C.

Lodging of a rice plant just prior to harvest can significantly impact the quality of the harvested crop yield as well as the market returns received for sale of the crop. The purpose of this study was to quantify the level and significance of lodging on the milling yield and market price of rough rice. A two-year study was conducted in the major rice-growing regions of Arkansas, Louisiana, Mississippi, and Texas to evaluate the impact of early and late lodging prior to harvest.

The general objective of this study was to estimate the impact of lodging on rough rice milling yield and market price. More specifically, the study objectives were to attempt to quantify the impacts of rice crop lodging prior to harvest on the rough rice milling yield and, using these observed changes in rice milling yield, to estimate the impact of crop lodging on the resulting rough rice market price received. The focus of the research results presented here is to highlight and compare the potential influence of rice planting date on crop lodging impact.

Field experiments were conducted during 2011 and 2012 at four locations: (a.) the Louisiana State University Agricultural Center Rice Research Station in Crowley, LA; (b.) the University of Arkansas Rice Research Station in Stuttgart, AR' (c.) the Mississippi State University Delta Branch Research and Extension Center in Stoneville, MS; and (d.) the Texas A&M AgriLife Rice Research Station in Eagle Lake, TX. Three lodging treatments were evaluated in this study: early lodging, late lodging, and standing (no lodging). Two planting dates (early and late) were evaluated in the study. Rice varieties evaluated in AR, MS. and TX included CL151, Presidio, Jupiter, Wells, and CLXL745. Trials in LA evaluated CL151, Presidio, Jupiter, Wells, Cheniere, Cocodrie. and LAH10.

Least squares means for head rice yield and total rice yields were estimated. Rough rice milling yield for the early planting date averaged 518.7/695.6 g kg^{-1} over all varieties and locations, while milling yields for the later planting date averaged 527.7/695.5 g kg^{-1}. Statistical analysis indicated that these two mean milling yields were not statistically different. Impacts of early and later crop lodging on milling yields were similar for both planting date trials. Lodging of rice plants just prior to field drainage (early lodging) and just after field drainage (late lodging) had similar impacts on rough rice milling yield, with a greater reduction in head rice yield than total rice yield. Least squares means differences by lodging treatment and planting date were also estimated. Head rice head was estimated to be reduced from impacts of early lodging by 38.8 g kg^{-1} and from later lodging by 42.6 g kg^{-1} across all planting dates. Reductions in head rice yield for early and late planted rice were similar: 39.5 and 55.0 g kg^{-1} for early planted rice and 38.1 and 30.1 g kg^{-1} for late planted rice. Differences in total rice milling yield were similar, in the range of 7.8 to 10.8 g kg^{-1}.

Impacts of rice milling yield on rough rice market price were estimated over a range of typical milling yield values. These price estimates are based on a general market price level of \$0.30865 kg^{-1} for a standard average milling yield, using price differences for head rice and second heads/brokens for the 2012 crop year. Using these market price relationships, every one pound increase in head rice milling yield increases market price by \$0.00198 kg^{-1} and every one pound increase in total rice milling yield increases market price by \$0.00287 kg^{-1}. This market price reduction due to the impacts of rice crop lodging is in addition to any other impacts of lodging including price decreases due to lower rice grades, reduction in recovery of rice yield during harvest, and additional harvest costs associated with harvesting lodged rice.

Potential Adjustment of Louisiana Rice Crop Rental Rates under Proposed 2014 Farm Bill Provisions

Salassi, M.E. and Deliberto, M.A.

With the repeal of farm program fixed direct payments, which were a part of the expiring 2008 farm bill, it is anticipated that rental arrangements for rice production could likely adjust, to some extent, to reflect the loss of this revenue source. The Agricultural Act of 2014 replaces the direct and counter-cyclical payment programs with the choice of either a price-based or revenue-based crop income support program. Farm program payments to rice are expected to be lower under either of these two new program options and, as a result, have a much lower influence on gross returns per acre from rice production. Any adjustments to rice share crop rental arrangements would likely focus more on market returns from crop sales.

With the decrease in expected farm program income support under the new farm bill and the increase in rice production costs per acre which has occurred over the past few years, net economic returns from rice production would be expected to become more variable. The table below illustrates the impact on grower and landlord net returns for a small adjustment to a crop share rental arrangement over a range of rough rice market prices. Mean net returns results are based on a simulation of 1,000 combinations of random rough rice prices and yields. This simulation analysis includes participation in the Price Loss Coverage Program of the 2014 farm bill. This program has a \$0.30865 kg^{-1} (\$14.00 $cwt.^{-1}$) reference price for rice, with payments paid on 85% of base acres with an updated rice program yield.

An equitable crop share lease allocates returns from crop production to the grower and landlord in a manner comparable to the prorated share of inputs contributed by each party to the rice production enterprise. As the net return estimates in the table below illustrate, changes to the fixed crop share percentages still allow for varying crop proceed share ratios as market price changes. With the increase in production costs per acre which has occurred over the past few years, flexible crop share leasing arrangements could become more prevalent. Flexible leases allow for the percentage shares of crop proceeds received by each party to vary, often related to the market price level, although yield triggers are also common. With the reduction in federal farm program payments likely for rice over the new farm bill, flexible type crop share arrangement may distribute crop proceeds in a more equitable manner.

In an effort to provide a decision aid to assist rice growers and landlords in evaluating alternative rental arrangements for rice, a spreadsheet model was developed which has the capability to compare grower and landlord net returns for a wide variety of potential rice rental arrangements. The Rice Rental Arrangement Net Return Evaluation Model is a spreadsheet-based decision tool developed in the fall of 2013 to assist Louisiana rice producers in evaluating the impacts of alternative crop land rental arrangements on projected net returns above specified rice production costs from the perspective of both the rice producer and the land owner. With changes in the recently passed U.S. farm program for major commodities, the level of farm program benefits could change substantially from previous benefits under prior farm bills. This could be especially significant for rice, with the loss of direct payments which were in place under the 2008 farm bill and had been a major component of the farm bill commodity title since 1996. The purpose of this decision aid is to assist rice producers and landowners in evaluating alternative rice rental arrangements and to estimate the impact on expected net market returns above specified rice production expenses for both the tenant rice producer and the land owner. This decision aid can evaluate cash and crop share leases for rice production. Rice crop production costs can be entered along with the portion of each cost paid by the land owner and/or tenant. An expected rice market price and expected rough rice yield are also data values entered into the model. These price and yield values are then used as the midpoints of a rice price and yield range over which net returns above specified production expenses are calculated.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Joan King

Effect of Enzyme Activity on the Starch Structure and Processing Quality of Selected Rice Varieties

Bryant, R., Yeater, K., Wang, Y.-J., Counce, P., and McClung, A.

Although most commercialized long-grain rice varieties have intermediate amylose content (~22%), high amylose (>25%) varieties are important for the canning and parboiling industry. Research has shown that high amylose rice varieties that have the best processing quality have high setback and low breakdown paste viscosity as measured by the Rapid Visco Analyzer (RVA). Genetic markers have been developed that are associated with the granule bound starch synthase gene (GBSS) and can be used to generally categorize rice varieties for amylose content and starch paste viscosity profiles, thus predicting processing quality. However, our research has demonstrated that high amylose rice cultivars with the same genetic haplotype for GBSS may differ in RVA profiles. Moreover, various environmental parameters such as high nighttime temperatures, in particular, have been shown to be related to lower head rice yield, higher chalk percentages, lower amylose contents, and poor processing quality. This phenomenon is believed to be caused by the changes in the activity of the starch synthesizing enzymes during grainfill (starting at R6 growth stage). This study was conducted to determine how intermediate and high amylose rice varieties respond to different growing environments for factors associated with processing quality and to what degree this may be explained by changes in starch enzyme activity and starch structure.

Ten rice varieties were grown in the field in Stuttgart, AR, during 2010 and 2012 using a randomized complete block design with two replications and two planting dates, about 1 month apart. Intermediate amylose varieties included Cypress, Francis, and LaGrue and the high amylose varieties included Rondo, Shu 121, Teqing, Zhe 733, Dixiebelle, Sabine, and Bowman. Grains were harvested at the R6 growth stage and the activity of seven starch synthesizing enzymes [sucrose synthase (SS), uridine 5'-diphosphatase (UDGP), adenosine 5'-diphosphatase glucose pyrophosphorylase (ADGP), granule-bound starch synthase (GBSS), soluble starch synthase (SSS), branching enzyme (BE), and debranching enzyme (DB)] were determined. At maturity (R8), grain was harvested, dried to 12% moisture, and milled. Apparent amylose content, protein content, DSC, RVA, and chain-length distributions of amylopectin were determined. A two-way ANOVA was performed with the plant date, variety, and their interaction treated as fixed effects. The interaction source of variation was not significant for any parameter measured.

The delayed planting date was found to decrease gelatinization temperature, increase protein content, and increase UDGP activity. Varieties were significantly different for amylose and protein contents, gelatinization temperature, and RVA parameters. Rondo and Shu 121 had significantly higher final RVA paste viscosity and a higher proportion of short chains (db 6-12) in the amylopectin assay than all other varieties. Rondo and Shu 121 were also characterized as having the lowest gelatinization temperature. The other high amylose varieties (Dixiebelle, Sabine, Bowman, Teqing, and Zhe 733) had significantly greater final RVA paste viscosities as compared to the intermediate amylose cultivars (Cypress, LaGrue, and Francis). There was a significant varietal difference in DB activity, however, no significant difference was found among the cultivars for the activity of any of the other enzymes. Dixiebelle had significantly greater DB activity than Zhe 733, Rondo, Bowman, and Teqing.

These initial results indicate that factors associated with processing quality and starch enzyme activity were quite stable across the two planting dates that were one month apart. Varieties with the same genetic haplotype for several genetic markers associated with GBSS were also consistent for measures associated with processing quality. Differences were observed between intermediate and high amylose varieties for factors associated with processing quality however these differences were not related to six of the seven starch enzymes activities that were analyzed. Debranching enzyme, which determines the degree of branching of the amylopectin molecule, was the only enzyme to significantly differ among the varieties. The data will be further explored using various modeling approaches to better understand the relationship of enzyme activities, starch structure, and processing quality.

Sensory and Analytical Comparison of Commercially Available Aromatic Rice Cultivars

Bett-Garber, K.L., McClung, A.M., Bryant R.J., Grimm, C.C., and Lea, J.M.

There continues to be an increasing demand for aromatic rice in the USA with basmati and jasmine rice making up the majority of imports. Because these varieties are photosensitive, they cannot be grown directly in the USA. US rice breeders have endeavored to develop rice cultivars with the quality characteristics that would be competitive with imports while having the agronomic traits that make them economically viable to grow in the US. Characteristics of basmati rice include a very slender long grain which cooks dry and flaky and has a strong aroma whereas Jasmine rice typically has a long grain with a soft cooked texture and strong aroma. Research was conducted to determine how the aromatic profile and sensory characteristics differed among US aromatic varieties that were developed for the basmati and jasmine markets. In an initial study of seven aromatic cultivars and two no-aromatic, some 15 volatile compounds were found to be distinctive of aromatics in addition to 2-acetyl-1-pyrroline (2AP) which is known to have a strong popcorn/buttery aroma. However, no characteristic volatile profile was found unique to basmati or to jasmine rice varieties. The objective of this study was to determine if varieties derived from basmati or from jasmine origin differed in flavors, volatiles, or physical traits.

Eight cultivars, four of basmati origin (Aromatic se2, Sierra, Dellmati, and Dellrose) and four of jasmine origin (JES, Jasmine 85, Jazzman, and Charleston Gold) were produced in Stuttgart, AR, and Beaumont, TX, in 2009 using an RCB design with two replications. Samples were harvested, dried to 12% moisture, and rough rice was stored in zip-close bags at 4C for approximately five months. The samples were then milled and cooked using 1.7 parts water: 1 part rice ratio. Samples were evaluated using descriptive flavor analysis along with amylose, protein, and lipid contents, RVA profile, alkali spreading value, volatile profile, and color. The jasmine-type rice cultivars were more intense in grainy/starchy and animal/brothy/meaty flavors than the basmati type rice cultivars. Jasmine 85 had the highest intensity of grainy/starchy while Dellmati had the lowest. The other six rice cultivars were not significantly different. Dairy, beany, and bitter flavor were significantly different between cultivars but were not different between basmati and jasmine types. Production location significantly impacted water-like metallic, sweet, bitter, sour and astringent flavors. Basmati group had greater apparent amylose contents (AAC) than the jasmine group, but Sierra had higher AAC than all other cultivars. Although protein content was not different between the basmati and jasmine groups, it was significantly different between cultivars. Production location significantly affected apparent amylose and protein contents. Alkali spreading values were greater in the jasmine group, indicating low gelatinization temperature. RVA peak viscosity was greater in the jasmine group, while RVA final viscosity was greater in the basmati group. Except for Charleston Gold, the jasmine type cultivars had significantly greater RVA peak viscosity than the basmati cultivars. Using the Hunter-LAB color system, the basmati group had greater L-values than the jasmine cultivars signifying whiter rice, as well as greater rice whiteness meter values. Jasmine cultivars had greater Hue angle (more green and less yellow) than basmati type cultivars. Basmati cultivars had greater chroma (less gray) than Jasmine cultivars. Of 29 aromatic compounds monitored using SPME/GC-MS, 14 were significantly lower in the jasmine group than in the basmati group and the other 15 aroma compounds were not significantly different. Aromatic se2 had relatively greater amounts of Ethyl-hexanol and, Nonanal, compounds associated with lipid oxidation. Although relatively greater overall in the basmati group, 2-Heptanone and 6-Methyl-5-hepten-2-one, volatiles associated with lipid oxidation were highest in the Jazzman cultivar. 2-acetyl-1-pyrroline was greater on average in the basmati group than in the jasmine group and was higher in Dellrose than in any other cultivar. Basmati and jasmine types of rice differed for 14 volatile compounds, a few flavor components, color, and grain chemistry factors associated with cooked rice texture.

Varieties within these groups differed from imported samples of basmati and jasmine indicating that domestic aromatics may not meet expectations of replacing imported aromatic rice. Identifying the flavor compounds and grain chemistry factors that need to be targeted for increase or decrease by breeders during development of new varieties to be similar to imports is where this work is headed.

Effect of Rice Bran Extracts on Glucose Uptake in 3T3-L1 Adipocytes

Boue, S.M., Chen, M.H., Daigle, K., and McClung, A.M.

Rice bran contains several bioactive components that have been linked to the promotion of human health. Brown rice bran contains lipophilic components that include the tocotrienols and γ-oryzanol. Pigmented or colored rice bran contains different phenolic compounds including anthocyanins (purple rice) and proanthocyanidins (red rice). Some of these bioactive compounds individually have been shown to promote glucose uptake and aid in glucose homeostasis in animal studies. However, only recently has rice bran been examined for its potential to aid in glucose management. The objectives of this study were to: 1) evaluate glucose uptake using 3T3-L1 cells; 2) determine active bran components; and 3) determine mechanism of action.

The three rice bran varieties used in this study were Cocodrie (brown), IAC 600 (purple), and IITA 119 (red). Bran samples were extracted with 70% ethanol, dried, and reconstituted in DMSO (100 mg/mL). Rice bran extracts were applied to mature 3T3-L1 adipocytes 16 h before glucose uptake determination using [3H]-2-deoxy-D-glucose. Adipocyte RNA isolation and RT-PCR were completed using TaqMan probes (GLUT1 and GLUT4).

Both IITA and IAC bran extracts significantly stimulated glucose uptake. Also, IITA fractions from a Sephadex LH-20 column stimulated glucose uptake. Overall, the two pigmented rice bran extracts in this study exhibited strong stimulatory effects on glucose uptake.

Increasing Dietary Rice Bran Consumption for Colorectal Cancer Prevention and Control

Borresen, E.C., Gundlach, K.D., Weir, T.L., Wdowik, M., Sheflin, A., Rao, S., Brown, R., Marschke, Jr., R.F., Dickson, E., Malia, J.O., Bazan, M., and Ryan, E.P.

Emerging evidence supports dietary fiber from whole grains and legumes is associated with increased longevity and protection against colorectal cancer. Nutritional metabolomics is a rapidly growing tool that can advance our understanding of spatial and temporal variation in host metabolic responses to diverse dietary exposures and disease conditions. This presentation will focus on interim data analysis from an ongoing, placebo controlled, randomized dietary intervention trial titled BENEFIT: Beans/Bran(rice) Enriching Nutritional Eating for Intestinal health Trial (NCT01929122). A primary outcome measure of this study is to evaluate changes in the stool microbiome and metabolome of healthy adults and colon cancer survivors following increased consumption of rice bran when compared to control. Rice bran, the outer covering of the rice grain, has been shown to regulate blood lipids and modulate immunity in humans. Yet, little is known regarding metabolic changes important for cancer control and prevention. Changes in the global and targeted metabolite profiles, namely methanol-soluble compounds detected in rice bran, as well as those metabolites found in blood, urine, and stool of humans consuming 30 g rice bran/day for 4 weeks will be described. Metabolite variation was semi-quantified using both gas chromatography and ultraperformance liquid chromatography-mass spectrometry (GC/UPLC-MS). We conclude that metabolomics is a novel multi-purposed tool for investigating the variance in the small molecule profiles of foods themselves and the dietary responses after consumption. We put forth that an integrated systems biology approach using metabolomics may identify dietary biomarkers of intake that merit validation prior to utility in population based studies, and stool biomarkers of dietary efficacy for protection against cancer. As a result of the global accessibility, affordability, and availability of rice bran, we anticipate that future studies will be able to assess the public health impact potential for rice bran to exhibit "phytochemical teamwork” strategies to prevent and control colorectal cancer.

Influence of Harvester and Weather Conditions on Field Loss and Milling Quality of Rough Rice

Khir, R., Atungulu, G.G., and Pan, Z.

Rice loss in the field during harvesting presents a direct economic loss to growers. This research studied the impact of harvester header, harvester type, and weather conditions on field loss and milling quality of rough rice. Appropriate harvesting conditions are suggested for mitigating rice loss and milling quality.

U.S. Cultivar Grain Quality as Assessed Using Objective and Subjective Methods

McClung, A.M., Yeater, K., Jodari, F, Linscombe, S., Walker, T., Ottis, B., Wilson, L.T., and Moldenhauer, K.

For decades, USA rice was considered to have excellent milling quality, grain appearance, and cooking quality as compared to much of the rice in world trade. This was largely due to a concerted effort by breeders to eliminate genotypes that did not possess grain quality characteristics that were considered acceptable by the USA rice industry. Since the 1950s, breeders have relied upon grain quality evaluations performed by the USDA ARS which assessed various parameters associated with cooking and processing quality. In addition, southern US public breeders collaborate in the Uniform Regional Rice Nursery which is a multi-state test of promising breeding lines for agronomic, pest resistance, and grain quality traits. The outcome has been the development of rice varieties by public researchers that have consistent grain quality which meet industry standards and can be sold at a premium in the global market. Although the USA exports almost 50% of its crop, over the last decade, there have been increasing concerns that US produced rice is declining in quality and competitiveness in the world market. As a result, the USA Rice Federation partnered with breeding programs and commercial rice mills to critically assess currently produced US rice cultivars for quality and to compare these with high quality international samples of rice.

A series of three studies were conducted, each using sets of US rice cultivars and imported samples that were evaluated by both subjective and objective methods. The US rice samples were all milled to the same degree, subdivided, and sent to analytical labs and industrial mills for assessment in a blind test. The imported samples were commercially milled overseas. Subjective scoring using a 1 to 5 scale was conducted by staff at private mills and included grain uniformity, bran streaks, chalk, and kernel color. The objective tests included image analysis for chalk, kernel length and width, and bran streaks, as well as caliper measurement of grain thickness. The first study consisted of 18 US rice cultivars produced in various environments and one sample from Vietnam. Mills evaluated the samples for eight visual grain traits. From this study, the traits luster, creamy, and clear were dropped from further analysis because they were deemed not very informative. The second study included nine US varieties, some grown in multiple locations during 2011 and imports from Brazil and Thailand, for a total of 25 samples. Major differences in quality among the varieties and among the locations where they were grown were observed. The third study was conducted in 2012 and included 17 US varieties, three hybrids, and imported samples from Thailand and Uruguay. The US cultivars were grown in unreplicated trials at six locations and at two planting dates (1 month apart) providing a total of 226 samples for evaluation. In addition, a repeated check sample of milled CL111 was included 13 times to assess consistency in the various measurements. Several of the findings from the previous studies were confirmed in this more extensive study.

The results demonstrated that rice mills differ greatly in how they judge rice samples and they are not highly consistent in their evaluations. This indicates that developing clear, uniform standards for evaluating samples that all mills would use, may be a better way to communicate with breeders and other researchers about rice grain quality issues. Two image analysis systems were used, Winseedle and S21, which gave similar results for grain dimension traits, although the S21 system was more precise. Although they were highly correlated (r=0.64), these two methods produced very different measures of grain chalk. Samples averaged 38% chalk with the S21 system and 3.8% chalk with the Winseedle, however, the Winseedle method was more repeatable. In addition, the subjective measures of chalk by the mills were more highly correlated with the Winseedle system (r=0.59) than the S21 system (r=0.35). The delayed planting date resulted in earlier maturity, shorter grainfill period, larger grain size, lower milling quality, greater chalk, and overall lower scores by the mills. The cultivars with the best quality scores by the mills were the two imported samples and L206, Presidio, Cheniere, and Bowman. These also had the lowest levels of chalk as measured using the Winseedle method. The cultivars with the poorest scores by mills and the highest levels of chalk were CL151, XL723, CLXL729, CLXL745, and CL111. The cultivars L206, Presidio, Cheniere, CL151, and CL111 had been evaluated in the previous studies and all were consistent with the third study's rankings except for CL111 which was more variable in quality depending on the location grown. In all three studies, the imported samples were ranked moderate to high for quality, however there were US varieties that had better quality. This demonstrates that the USA has germplasm that can deliver excellent grain quality and can be incorporated into new high yielding cultivars.

Comparison of 2-Acetyl-1-Pyrroline Levels in Brown and Milled Rice

Grimm, C.C., Ahrent, D.K., Lloyd, S.W., and Moldenhauer, K.A.K.

The most important aroma compound in aromatic rice is 2-Acetyl-1-Pyrroline (2AP). The concentration levels of 2AP in aromatic rice can vary depending upon variety, growing conditions, processing, and storage conditions. 2AP concentration is one of the key determinants of quality when developing new lines. The scientific literature has mixed results in the relative concentrations of 2AP found in brown and milled rice. This research was undertaken to determine if 2AP concentrations varied between brown and milled rice.

As part of a larger nitrogen study, each year over a 3-year period (2010, 2011, 2012), 2-acetyl-1-pyrroline concentrations were determined for brown and milled rice from seven aromatic and one non aromatic variety: Dellrose, Jasmine 85, Jazzman, JES, Sierra, STG03F5-02-085, Jazzman 2, and the non-aromatic rice; Wells. Jazzmen II was only grown during 2011 and 2012. Each variety was raised under six different growing regimes at the University of Arkansas facility in Stuttgart, AR. Each growing regime was replicated in triplicate to make a total of (8 x 6 x 3) 144 samples. Samples were subdivided and half of the rice milled to produce 144 brown and 144 milled samples. Aliquots of ~ 10 g were then shipped to the USDA's Southern Regional Research Laboratory. Samples were frozen until analyzed. Rice kernels were floured in a coffee grinder and 0.3 g of ground rice was placed in a 2 ml vial, to which 500 µl of a 459 ng/µl solution of trimethylpyridine (TMP) in $MeCl_2$ was added. The TMP served as the internal standard. The sample vials were heated to 85°C for an extraction period of 2.5 hr. A 2-µl injection was then made, and the sample analyzed by GC/MS. Individual samples were run in triplicate. A calibration curve of 2AP at six different concentrations was developed and used for quantitative analysis.

Relative standard deviations (RSD) within a single plot (N = 3) ranged from 2%-6%. Samples taken from replicated plots showed large differences in 2AP concentrations differing, in some cases, by several 100 ppb. These differences could result from slight variations in growing conditions, handling and processing, or non-homogeneous sampling. In the comparison of sample from the same plot, from 2010 and 2012, 2AP concentrations in brown rice were 10% and 4% higher, respectively, than in milled rice. For 2011, a substantial difference was observed of over 300 ppb between the averaged values pooled from all varieties. This dramatic difference for the 2011 crop year was observed in all seven of the aromatic rice samples. This difference is roughly divided between a lower average amount of 2AP in brown rice and a higher amount in milled rice.

Economics of Integrated Pest Management in Rice Processing Facilities

Niu, L., Adam, B.D., Campbell, J., and Arthur, F.

Methyl bromide is a commonly used fumigant for controlling insects in food processing facilities. Because of its increasing cost and declining availability since its designation as an ozone depleter, integrated pest management (IPM) is an increasingly attractive alternative. IPM may reduce insecticide resistance, improve worker safety, and reduce environmental concerns and consumer concerns about pesticide residuals. However, little is known about the costs and efficacy of IPM in food processing facilities. Here, we consider several IPM and traditional fumigation approaches. The goal is to determine the least cost combination of insect control methods that will achieve the desired level of insect control in rice processing facilities. The costs include treatment cost, shutdown time cost, and the cost of failing to control insects.

The data are collected from several rice mills in Arkansas, Texas, and Louisiana. Cost of traps and their installation in strategic locations within a facility and the costs of monitoring those traps and counting insects, costs of surface pesticide treatments, sanitation, aeration, sealing structure, aerosols, and space sprays are key parts of the data. Economic engineering costs of these tools are estimated for several intensities of insect management. Red flour beetle is the target insect because of the significant damage it causes in rice.

Costs of failing to control insects may vary by location within the processing facility; for example, insects in locations closer to processing stages near the final product may cause greater costs than insects near earlier stages of processing. A Geographic Information Systems (GIS) model that considers the proximity of insects to sensitive areas and the costs of infestation in those areas will be used to measure the costs of failing to control insects for each of several insect control methods. Insect activity contours are paired with economic data to model economic pressure and measure cost of failing to control insects.

An IPM approach such as that modeled here may have higher costs of implementation and require significant expertise in evaluating trap counts. However, while whole-plant methyl bromide fumigations are often effective, they typically involve significant shutdown costs in the form of lost revenue. Little information exists on costs of IPM in processing facilities. The results provide critical information for managers in determining the kinds and intensities of insect control methods they will need. The GIS approach should prove very helpful in similar applications in other processing industries, because of the heterogeneous nature of insect growth environments, along with the high costs of insect infestation in especially sensitive areas within processing facilities.

Improving Drying Efficiency, Milling Quality, Stabilization, and Safety of Rough Rice using Infrared Radiation Heating

Pan, Z., Khir, R., Wang, B., Wang, T., Ding, C., and Atungulu, G.

Infrared (IR) drying as a novel technology has a promising potential to achieve a high drying rate, energy saving, and improvement in the quality of dried rice. Our consecutive researches investigated the feasibility of simultaneous drying, disinfestations, disinfection, and stabilization of rough rice using infrared radiation heating. Our results revealed that IR heating has a great promise to improve the drying efficiency and milling quality, achieve effective disinfestations and disinfection of rough rice, and effective stabilization for rice bran and improve its utilization without affecting the quality of rice bran oil. Also, IR heating can be used as an effective method to improve the storage stability of brown rice. Moreover, we have systematically investigated and proved the technical feasibility of using IR heating as energy efficient technology for rice drying. The results provided guidance for determining appropriate conditions of infrared heating, tempering, and cooling treatments to achieve high drying efficiency, quality, and effective disinfestations, disinfection, and stabilization of rough rice.

Integrated Pest Management Programs in Rice Mills

McKay, T., Adam, B., Arthur, F.H., Beuzelin, J., Campbell, J.F., Reagan, T.E.,
Starkus, L., Wilson, L.T. and Yang, Y.

Red flour beetle, *Tribolium castaneum* Herbst, is the primary pest in rice mills, and it is the most frequently targeted pest for methyl bromide fumigation under the continuing use exemption. We will present an overview of a multi-institutional project where we have been researching how integrated pest management (IPM) programs for rice mills might be improved. Due to the impending complete phase-out of methyl bromide, revised IPM plans specific for rice mills will be critical to maintain product quality and economic viability. Specific objectives will be discussed and are described below.

Since June 2012, we have been examining the spatial and temporal distributions of red flour beetles (RFB) in four rice mills in northeast Arkansas. We have been focusing on collecting RFB using pheromone-based Dome traps baited with kairomone. Monitoring has been conducted inside the mills, with emphasis placed on areas near potential routes of entry into the mill. Monitoring has also being conducted outside of the mills, including around storage bins, rice receiving areas, by-products storage, and shipping. We have also been collecting rice spillage accumulations around the facilities to determine what insects exploit these spillage accumulations. Monitoring is scheduled to be conducted over the course of two years at each site.

To better predict RFB population dynamics, we are assessing the survival and development of the RFB on different types of rice and rice by-products present in mills and will develop predictive models based on this information. The results of this study will provide information on where RFB populations are more likely to build up, which should allow mill personnel to better target and prioritize monitoring and control efforts. We have also been examining the residual efficacy of cyfluthrin applied to concrete surfaces inside mills and the impact of spillage accumulation and cleaning activities on this residual efficacy.

The overall goal of this project is to develop a pest control alternative to methyl bromide fumigation through integration of the prediction models, focused monitoring, targeted pesticide treatments and sanitation, and economic analysis. Because each mill is unique in terms of their structures, surrounding environments, mill operations, and pest management actions, implementation of a pest control alternative must be tailored to each specific mill. We therefore have been adapting the web-based Post-Harvest Grain Management Program (http://beaumont.tamu.edu/GrainManagement/) for RFB control in rice mills to allow mill personnel to design an IPM program specifically for their rice mill.

Development of an Integrated Post-Harvest Grain Pest Management Program

Yang, Y., Wilson, L.T., and Wang, J.

Red flour beetle, *Tribolium castaneum* Herbst, is a major pest in rice mills. The objectives of this study are 1) Develop an integrated red flour beetle management system integrating population prediction, targeted surface pesticide treatment and sanitation, focused monitoring, and economic analysis and 2) Identify the best combination of measures (surface treatment, sanitation, monitoring) to achieve optimal red flour beetle control. The integrated system is based on our existing Post-Harvest Grain Management Program (http://beaumont.tamu.edu/GrainManagement), which is designed to develop strategies to optimize the control of lesser grain borer, *Rhyzopertha dominica* (Fabricius), and rice weevil, *Sitophilus oryzae* (L.), the two primary pests in storage rice.

Major components of the red flour beetle population model include: 1) Development and survival of the red flour beetle as affected by temperature and relative humidity; 2) Adult reproduction as affected by temperature, relative humidity, adult age, and population density; 3) Adult and larval cannibalism as affected by adult and larval density; 4) Adult dispersal as affected by population density and environment conditions; and 5) Effects of different control measures on population survival (fumigation, sanitation). These components have been integrated into a generic distributed-delay population model that simulates variations in developmental time, survivorship, and management-induced mortality for individual stages. The population model is integrated with the rice mill component in the Post-Harvest Management Program and tied to the control economics to simulate red flour beetle population dynamics with different management options and identify optimal control strategies.

Stored-Product Insect Exploitation of Rice Spillage Accumulations

Campbell, J.F., Buckman, K.A., Starkus, L., and McKay, T.

Accumulations of rice and rice fractions can occur outside rice storage and milling facilities and removal of this material is an important part of a facilities sanitation program, but the role these outside accumulations play in facilitating stored-product insect infestations is not well understood. We conducted a study to evaluate which insect species are found exploiting rice spillage accumulations outside, how long does it take for a spillage accumulation to become infested, if stored-product insects use spillage accumulations primarily as temporary harborage for adults or it they are also used for oviposition and progeny development, and if there is seasonal and spatial variation in spillage exploitation. At two rice mills in Arkansas, brown rice was placed outside in containers (i.e., refuges) for 1-, 2-, 3-, or 4-week periods between May and October of 2012. After returning the refuges to the laboratory, the number of each species or species group present was counted and the rice was then held to determine if progeny development occurred within the spillage. In addition, outside accumulations of rice or rice fractions present at each mill were collected and processed as described above for the refuges. A diverse community of stored-product insects were found to colonize rice accumulations, with sap beetles (Nitidulidae), hairy fungus beetles (*Typhaea stercorea*), lesser grain borer (*Rhyzopertha dominica*), and flat or rusty grain beetles (*Cryptolestes* spp.) being among the most commonly recovered species. Progeny production within the rice by these major species was also observed. Variation among mills, locations at a mill, time of year, and length of time refuges were placed outside was observed for both total number of individuals and number of species collected. These findings highlight the potentially important role that outside food accumulations may play in stored-product insect population dynamics and immigration into food facilities. Better understanding of these processes can lead to more effectively targeted post-harvest pest management programs.

Red Flour Beetle Development on Rice Fractions

Arthur, F.H., McKay, T., Campbell, J.F., and Starkus. L.A.

Insect pests can be found within various components of rice mills, and composition and diversity will change depending on location. One of the predominant pests in the milling component of mills is the red flour beetle, *Triboilum castaneum* Herbst. This species can persist on a wide variety of food products, including rice fractions generated during the milling process. Therefore, development of the beetle on these fractions needs to be examined for their possible impact on control programs. The red four beetle, which does not develop well on whole grains or rough rice, can readily feed and infest brown rice. Development from neonate to adult was examined initially on nine different rice fractions. They failed to develop on ground rice hulls, paddy dust, and rough rice, and five fractions were chosen for further study. These were milled whole kernels, milled whole kernels, brown rice, rice flour, and rice bran. Tests were conducted at 22, 27, and 32°C. Time required to develop to the pupal and adult stage varied with temperature, and development was greatly slowed down at 22°C compared to 27 and 32°C. Results indicate that some rice fractions produced as part of normal milling operations can support development of the red flour beetle, hence monitoring could be targeted in those sites where these fractions are produced.

Efficacy of Cyfluthrin for Control of Red Flour Beetles (*Tribolium castaneum*) in Rice Mills

Starkus, L.A., McKay, T., Arthur, F.H., and Campbell, J.F.

The red flour beetle, *Tribolium castaneum* Herbst, is the primary pest in rice mills. Cyfluthrin (Tempo©) is a commonly used residual treatment for the control of red flour beetle. Cyfluthrin has been shown to give residual control of the red flour beetle on a concrete surface for up to 8 weeks post-application, but residual efficacy has not been measured under the conditions found within a mill. The objective of this study was to determine the residual efficacy of cyfluthrin applied to concrete surfaces and the impact of the accumulation of food and dust residues and subsequent cleaning activities (i.e., weathering) on efficacy. Petri dishes filled with concrete were treated with the label rate of cyfluthrin and placed in two mills. Half of the treated dishes were covered with duct tape to prevent weathering and half were left exposed to residue accumulation and periodic cleaning that occur during normal milling operations. Dishes were removed at 2, 4, 6, and 8 weeks post-treatment and returned to the lab for bioassays. Adult red flour beetles were placed on the surface in the dishes and knockdown and mortality were assessed at different time points after removal. Levels of adult insect knockdown and mortality were lower on the surfaces exposed to residues and cleaning with good residual efficacy observed out to 8 weeks. It was also found that the residue materials absorbed the cyfluthrin and insects that came in contact with the residue had increased knockdown and mortality compared to controls. This information is important for pest management in rice mills since it can be used to determine optimal frequency for treatments.

Solar Irradiance Differences which Accompany Different Planting Dates Lead to Higher Grain Yields for Earlier Planted Rice

Counce, P.A., Hardke, J.T., Wilson, C.E., Siebenmorgen, T.J., Nalley, L.L., Frizzell, D.L., and Watkins, K.B.

In studies conducted in Louisiana and Arkansas, earlier planting and emergence lead to higher rice grain yields. Rice yield has also been positively related to the hours of sunlight 10 days before and after heading. Tropical rice yield is positively related to irradiance for the entire length of the growing season. We analyzed historic Stuttgart, Arkansas, temperature archives coupled with relevant rice development data to determine a few pertinent relationships, namely: (1) probable rice seedling establishment as soil temperatures begin to increase in late winter; (2) historic DD50 accumulations relative to the dates of heading for current cultivars and hybrids; and (3) hours of sunlight available to the crop from emergence to heading from the earliest normal crop establishment to the latest successful rice crop. Then, we tested (1) whether hours of sunlight at heading was higher with earlier planting in Arkansas; (2) whether yield was positively related to incident radiation 10 days before and after heading; and (3) whether yield was positively related to hours of sunlight for the 10 days prior to and after heading. We then evaluated whether the positive relationship of seedling emergence to yield was attributable to greater irradiance and hours of sunlight.

We examined long-term weather archives from Stuttgart including soil temperatures, DD50 accumulations and hours of sunlight available to the rice crop. Soil temperatures rarely rise above 50 F (10°C) prior to March. While germination can occur at even 0 to 5°F, it requires disproportionately more time. Earlier planting, even if the crop survives oscillating soil temperatures, is compensated by disproportionately longer germination and emergence dates. Consequently, rice planted in early March or before normally emerges 20 to 30 days later. Moreover, most current cultivars and hybrids require 1222 DD10 (2200 DD50 units) to reach heading (R3) and 1222 DD10 units are rarely accumulated prior to the summer solstice at Stuttgart. Finally, the earlier the crop is established, the closer the heading date will be to the summer solstice leading more sunlight available to the crop at heading. From early March onward, the earlier the crop is established, the greater the total hours of sunlight potentially available to the crop between emergence and heading. Rice emerging on March 20 has 50% more hours of sunlight potentially available to the crop prior to heading than rice emerging on June 10. The actual radiation received depends on the meteorological conditions, mainly cloudiness and rainfall, for a given year.

We examined the relationship of rice grain yields to incident radiation and hours of sunlight. We found significant positive relationships between grain yield and (1) incident radiation for the 10 days before and after R1 (panicle differentiation) and (2) for the 10 days before and after heading (R3). Since incident radiation data are often unavailable, we also calculated hours of sunlight available at heading. In all years, the relationships of yield to hours of sunlight at R3 were significant and positive with R^2 ranging from 0.22 to 0.67. This different relationship in each year is partially related to different incident radiation amounts and the range of date of emergence dates in the studies each year.

Assuming an adequate crop stand (plant population density) is established and adequate crop leaf area is available prior to R1, the potential yield is partially set at R1 by increased numbers of potential florets. Light (irradiance) at beginning anthesis (R4) normally limits floret pollination and fertilization. Irradiance at R3 – R5 (the interval when most florets are fertilized) is positively related to the percentage of grains fertilized. Furthermore, the greater the number of grains fertilized, the more grains are filled per unit area. And, the number of grains per unit area is directly related to grain yield. Consequently, the earlier we can obtain emergence in Arkansas, the greater the potential yield. The earlier planting dates result in greater irradiance (prior to and after heading) and higher grain yields. In all years in this Arkansas study, the relationship of grain yield to emergence date was negative; the relationship of grain yield to hours of sunlight at R3 was positive; and most of the increase in yield from earlier emergence is directly due to more hours of sunlight at R3. The earlier we plant rice in Arkansas, the greater our potential yield will likely be due largely to greater available hours of sunlight and solar radiation.

Earlier Planting Dates for Arkansas Rice Increased Likelihood of High Nighttime Air Temperatures during Grain Filling

Counce, P.A., Siebenmorgen, T.J., Watkins, K.B., Nalley, L.L., Hardke, J., Wilson, C.E., and Frizzell, D.L.

In planting date studies in Louisiana and Arkansas, earlier planting and emergence have led to higher rice grain yields. Some have suggested that earlier planting or adjusting planting rates could also improve head rice yield (HRY) by potentially avoiding high nighttime air temperatures (NTAT). First, we examine long-term Stuttgart, Arkansas, weather data to examine this question. The question is: "can we plant early enough to avoid the likelihood of high NTAT?" We need to examine the likelihood of avoiding high NTAT by earlier planting. Secondly, we examine the data to see if HRY is increased by earlier planting dates.

There are several facts which deserve consideration regarding the Arkansas soil and air temperature conditions and rice development. Soil temperatures in Arkansas rarely allow seedlings to emerge prior to late March. Most currently available rice cultivars and hybrids require a minimum 1222 DD10 units (2200 DD50) to reach R3. Rarely are 1222 DD10 units accumulated prior to the summer solstice (the one exception we identified was 2012 when 1222 units were accumulated between March 1 and 5 days prior to the summer solstice). The critical crop growth stage for yield is R3 to R5, but the critical growth stages for HRY are R6, R7, and R8. Of the three critical reproductive growth stages for determining HRY, R8 is the most critical. Approximately 18 days or 158 DD10 units (285 DD50) are required for the crop to develop from R3 to R8. The hottest part of the year begins normally 20 to 30 days after summer solstice. Given that R3 is rarely reached as early as solstice, the earlier the rice emerges, the more likely R8 will be to the hottest nights of the year. Planting early can only increase, not decrease, the likelihood of high NTAT. In Arkansas, with current cultivars and hybrids, we can't escape the high NTAT period of the year by planting earlier. We can escape the effects of high NTAT by planting 50 to 70 days later than the optimum planting date with a yield reduction of 2500 to 5000 kg ha^{-1} (50 to 100 bushels/acre). A decrease in yield of that magnitude would unacceptably decrease total return. While the highest night temperatures can be avoided by planting later, a higher head rice yield may not result. To understand this, further considerations are needed.

The relationship of HRY to planting date was negative, and the relationship of HRY to hours of sunlight at R8 (the most sensitive period for grain filling with respect to sensitivity to high NTAT) was positive in only one of three years (the coolest). In the other two years examined, there was no relationship between HRY to emergence date or of HRY to hours of sunlight at R8. When temperatures are moderate (relative to HRY sensitivity to high NTAT), the greater sunlight availability will improve HRY but more hours of sunlight or higher irradiance cannot overcome the relatively greater negative impact of extremely high NTAT.

In Arkansas and elsewhere in the mid-south, early planting is critical to achieving maximum grain yield. Such early planting necessarily results the critical crop growth stage for rice grain filling (R8) being in the hottest days and nights of the year. In years with moderate NTAT, the earliest planting will likely result in the highest quality rice as well. But in years with quality limiting high NTAT, quality was not related to date of planting. In terms of actual quality results, however, the quality is more often unrelated to the emergence date. Also, due to the sporadic nature of NTAT temperatures during the normal hottest period, it is impossible to predict when quality limiting NTAT may occur during the R8 to harvest interval from 20 to 40 days after heading. Planting early in Arkansas won't reduce the occurrence of high NTAT during R8 but instead will likely increase their likelihood. For rice farmers at present, the only management tool for effectively reducing the likelihood of high NTAT negatively impacting rice quality is cultivar selection. The medium-grain cultivars Jupiter and Bengal are relatively resistant to high NTAT. There are no commercially available long-grain rice cultivars which are resistant to high NTAT effects on rice quality. With these constraints, the best long-term solution, we suggest, is to identify genes which confer resistance of quality (HRY and chalk) to high NTAT. These genes, in turn, could be incorporated into mid-south rice cultivars by conventional breeding augmented by effective molecular markers for resistance to high NTAT. Long-grain cultivars resistant to high NTAT would benefit individual growers and the industry as a whole.

Rapid Throughput Methods for Detection of Arsenic Species in Rice Tissues

Tarpley, L.

Methods for high-throughput, inexpensive quantitation of inorganic arsenic in rice tissues are needed. An industry-wide collaborative effort with an accelerated basis to address the arsenic in rice issue will create a very high demand for arsenic (As)-analysis resources, especially in support of production practice and breeding/variety development-research, and potentially for industry to respond to government data requests. Gold-plate methods for analysis of As species should be instrumentation-based, however, alternative analysis methods exist and can be used to support sample-analysis needs of the collaborative research effort, and, potentially, for preliminary screening of industry-generated samples. Specifically, biochemical-based methods can provide high sensitivity, high specificity, and high throughput in analysis of inorganic and organic arsenic (As). Such methods have been used before for metal-speciation analyses. Although sensitivities of some types of biochemical-based methods are theoretically unlimited, practical limitations exist. The practical limits are within the desired ranges of detectability as expressed by the U.S. government. For biochemical-based methods, specificity and extraction are the biggest concerns but are addressable. An estimated throughput for routine analyses of inorganic As species of 200-300 samples/week with a sample cost of $10-$20 can be achieved with the use of relatively inexpensive laboratory equipment. The U.S. rice industry should consider the use of biochemical-based assays to meet near-term demand for arsenic-analysis resources.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2016 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 2016 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 36th RTWG meeting must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the proceedings.

1. An electronic file is requiredand should be submitted to the respective panel chairs 2 ½ months prior to the 36th RTWG meeting in 2016, or earlier as stated in the Call for Papers issued by the 36th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2016 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:

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2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
   a. Include a statement of rationale for the study.
   b. Briefly outline methods used.
   c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 36th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 36th 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 36th 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 2016 PANEL CHAIRS

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Dale Bumpes National Rice Research Center	Fax: (870) 673-7581
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Texas AgriLife Research	Fax: (409) 752-5560
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Beaumont, TX 77713	Email: f-dou@aesrg.tamu.edu

Weed Control and Growth Regulation:

Muthukumar Bagavathiannan	Phone: (479) 387-1674
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Fayetteville, AR 72704	Email: muthu@uark.edu

IN MEMORY OF

Mark A. Bohning

Mark Bohning was a Plant Germplasm Program Specialist with the USDA-ARS National Germplasm Resources Laboratory in Beltsville, Maryland. He worked on a variety of projects to support the U.S. National Plant Germplasm System (NPGS). He was the primary liaison between ARS and the 42 Crop Germplasm Committees (CGC) and travelled to many CGC meetings over the years. He participated in a number of Rice CGC meetings over his career, several of these held in conjunction with RTWG. He also helped assign Plant Introduction numbers for the NPGS and was always willing to help locations upload data into Germplasm Resources Information Network (GRIN), generate reports for ARS, and generally help users understand the system. Few ARS employees knew the history, and had breadth of knowledge, of the NPGS and GRIN as well as Mark as he was a part of the program that helped it develop and evolve. He began working for ARS in 1980 while he was still an undergraduate student at the University of Maryland. He received his B.S. and M.S. degrees in Horticulture from the University of Maryland in 1982 and 1985, respectively. He spent his entire career at USDA ARS facility in Beltsville, MD, and almost all of it in National Germplasm Resources Laboratory.

IN MEMORY OF

Charles Milton "Chuck" Rush

Charles Milton "Chuck" Rush passed away on August 10, 2013. Chuck was born in Goodyear, AZ. He grew up on a dairy and cotton farm. He received his bachelor's and master's degrees in Plant Pathology from the University of Arizona and his PhD degree in the Department of Plant Pathology at North Carolina State University. He then came to Louisiana in 1970 as assistant professor with responsibility for rice pathology in the Department of Plant Pathology & Crop Physiology, Louisiana State University, and the Louisiana State University Agricultural Center, Baton Rouge.

Chuck dedicated over 39 years to education, research, and service to the Louisiana and U.S. rice industry. As a professor at Louisiana State University, he taught and mentored 13 MS and 14 PhD students from many different countries. His program pioneered the development of quantitative rating scales for rice diseases in the southern United States, and his work in this area enabled breeders to develop and improve varieties with partial and complete disease resistance. He reported eight new diseases in Louisiana rice. His extensive fungicide testing programs were critical for labeling new fungicides for the severe foliar diseases that affected rice in the Gulf South and throughout the world. He was involved in the labeling of Benlate 50WP, the first foliar fungicide labeled for rice in the U.S. He and his students elucidated the importance of leaf surface interactions between the host and pathogen in resistance of rice to *Rhizoctonia solani*, the cause of sheath blight. They demonstrated the importance of epicuticular wax thickness on sheath blight resistance and the effects of cultural practices on wax formation. They conducted the first studies to show that the effect of flooding in controlling leaf blast was related to a change in the plant's resistance rather than to the effects of leaf-wetness period. They also developed information on variation within rice pathogens, including classifying the races of *Cercospora oryzae*, the cause of narrow brown leaf spot. Recently, Chuck, his students, and colleagues successfully identified *Burkholderia glumae* and *B. gladioli* as the causal agents of the perennial rice panicle blight disease in United States. Chuck was the first scientist to succeed in regenerating rice plants from anthers using a U.S. rice cultivar (Labelle). He was instrumental in the establishment of the anther culture laboratory at the International Rice Research Institute in the Philippines during his sabbatical leave from 1979 to 1980. He also developed a highly efficient somaculture technique with which thousands of somaclones were regenerated from U.S. cultivars, including two sheath blight-resistant Labelle somaclones, LSBR-5 and LSBR-33. By crossing elite long-grain cultivars with newly identified resistance sources, over 300 lines showing sheath blight resistance and high yield potential were developed and turned over to various breeding programs. One of the lines, MCR00661, has been adopted by the USDA-CSREES Rice Cap project as a sheath blight-resistant parent for the development of molecular markers. Later and at the time he developed the Blanca Isabel purple rice variety which is being commercialized, he became a registered rice breeder.

During his professional and academic career, he published over 300 refereed journal articles, book chapters, and research reports. He served the Rice Technical Working Group (RTWG) as a member of the Awards Committee, Germplasm Advisory Committee, and Local Arrangements Committee, and as a panel moderator. His numerous outstanding honors include: the Distinguished Academy Scientist Award by the Louisiana Academy of Sciences in 1989; the RTWG Distinguished Rice Research and Education Award in 1994; the Louisiana Agricultural Experiment Station Doyle Chambers Award for Outstanding Research Contributions in 1995; the Outstanding Plant Pathologist in the Southern Division of the American Phytopathological Society in 1997; the RTWG Distinguished Rice Research and Education Team Award in 2002, and the RTWG Distinguished Service Award in 2008.

Chuck was a man of great determination. He was very passionate about plant pathology and mentoring students, and he loved to share his science opinion and more with his colleagues and friends. He was a devoted husband and father who will be terribly missed. He is survived by his loving wife of 30 years, Blanca Isabel Rush; mother, Charlotte Tamillo; three daughters, Carrie Rush, Ana M. Boone and Claudia I. Rush; three sons, Michael C. Rush, Tomás A. Rush and Jesus "Chucho" Retana; sister, Cheri Echard; brother, Robert Rush and wife Irene; uncle, Ted Wootten; and one grandchild, Jacob Rush.

GUIDELINES FOR RTWG AWARDS

1.0 The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

1.1 The Distinguished Rice Research and/or Education Award

1.1a Individual category – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research, (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress and promise technical advances in the rice industry.

1.1b. Team category – Same as the individual category, except that one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

1.2 The Distinguished Service Award - Awards to be made to designated individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2.0 The Awards Committee shall consist of the Executive Committee.

3.0 The duties of the Awards Committee are as follows:

3.1 To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee Members cannot nominate or write letters of support for an individual or team for the RTWG awards.

3.2 To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority vote. The Awards Committee Chair (same as the Executive Committee Chair) can only vote in case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

3.3 The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting.

3.4 The Awards Committee shall select appropriate certificates for presentation to the recipients of the Awards.

4.0 Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three (3) recommendation letters. Fifteen (15) complete copies of each nomination must be submitted. A one-page summary of accomplishments should also be included with each nomination. This summary will be published in the RTWG Proceedings for each award participant.

4.1 Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

4.2 A member of an organization, described in 4.1, may nominate or co-nominate two persons.

4.3 Nominations are to be sent to the Awards Committee for appropriate committee consideration.

4.4 The deadline for receipt of nominations shall be three months preceding the biennial meeting.

4.5 Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

Past RTWG Award Recipients

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients
1972	D.F. Houston	L.B. Ellis	None
Davis, CA	R.D. Lewis	H.M. Beachell	
	N.E. Jodon	C.R. Adair	
	E.M. Cralley	W.C. Dachtler	
1974	J.G. Atkins	R.A. Bieber	None
Fayetteville, AR	N.S. Evatt	J.T. Hogan	
	M.D. Miller	B.F. Oliver	
	T. Wassermand		
1976	D.H. Bowman	T.H. Johnston	None
Lake Charles, LA	R.F. Chandler	M.C. Kik	
	J.N. Efferson	X. McNeal	
	J.P. Gaines		
1978	J.W. Sorenson, Jr.	D.T. Mullins	R.K. Webster
College Station, TX	R. Stelly		
1980	M.L. Peterson	W.R. Morrison	B.D. Webb
Davis, CA	L.E. Crane	F.T. Wratten	

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Arkansas 'Get the Red Out' Team	
1982	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	H.R. Caffey	B.R. Jackson	None	
Biloxi, MS	O.R. Kunze			
1992	C.N. Bollich	A.A. Grigarick	J.W. Stansel	
Little Rock, AR	B.D. Webb	C.M. Wick		
1994	S.H. Crawford	K. Grubenman	M.C. Rush	
New Orleans, LA	J.V. Halick	R.N. Sharp		
	R.J. Smith			

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1996 San Antonio, TX	P. Seilhan	K. Tipton	D.M. Brandon	
1998 Reno, NV	G. Templeton	B. Wells	S.D. Linscombe	
	S.-T. Tseng			
			Advances in Rice Nutrition Team	
2000	D.M. Brandon	R.K. Webster	P.K. Bollich	C.E. Wilson
Biloxi, MS	J.W. Stansel		R.J. Norman	
			Bacterial Panicle Blight Discovery Team	
2002	F.L. Baldwin	M.A. Marchetti	M.C. Rush	D.E. Groth
Little Rock, AR	R.H. Dilday	J.F. Robinson		A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
	P.K. Bollich	J.A. Musick	F.N. Lee	M.A. Marchetti
2004	A.D. Klosterboer	J.E. Street	A.K. Moldenhauer	
New Orleans, LA	F.N. Lee	J.F. Williams	Individual	
	W.H. Brown	S.L. Wright	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	
2012	E. Champagne	G. McCauley	D. Harrell	N. Slaton
Hot Springs, AR	J. Hill		G. McCauley	B. Tubaña
			R. Norman	T. Walker
			T. Roberts	C. Wilson
			J. Ross	
			Individual	
			A. McClung	

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Rice Entomology Team	
			J. Bernhardt	M. Stout
2014	R. Fjellstrom	J. Oster	G. Lorenz	J. Gore
New Orleans, TX			L. Espino	M. Way
			L. Godfrey	
			Individual	
			J. Saichuk	

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
35th	2014	New Orleans, Louisiana	C.E. Wilson, Jr.	E.P. Webster	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.

<u>Rice Technical Working Group</u>

Manual of Operating Procedures

2014

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 at least biennially to review results and to develop proposals and suggested plans for future work. It is understood that the actual activities in research and extension will be determined by the respective administrative authorities and subject to legal and fund authorizations of the respective agencies.

Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (chair and secretary), subject to consultation with the remainder of the Executive Committee.

The Executive Committee shall consist of 15 members:

Officers (2):

Chair -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

Secretary/Program Chair -- (normally moves up to Chair).

Geographic Representatives (7):

One active rice worker in state or federal agencies from each of the major rice states -- Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas.

These Geographic Representatives will be responsible for keeping all governmental rice workers and administrators in their respective geographic areas informed of the activities of the RTWG.

Immediate Past Chair -- provides guidance to incoming chair to facilitate 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)

<u>Old Business</u>

i) The Chair opens the meeting
ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

<u>New Business</u>

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)

<u>Old Business</u>

i) The Chair opens meeting
ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. Opening General Session and Business Meetings

The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

a. Opening General Session and Opening Business Meeting (begins the 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, 2014	Secure Hotel
May 1, 2015	Pre-RTWG planning meeting
June 15, 2015	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 2015	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 2015	First call for papers and a call for award nominations
Sept. 15, 2015	Second call for papers (Reminder; e-mail only)
Oct. 15, 2015	Titles and interpretive summaries due
Dec. 1, 2015	Abstracts due
Dec. 1, 2015	Award nominations due to Chair
Dec. 1, 2015	Registration and housing packet sent
Jan. 3, 2016	Reminder for registration and hotel (e-mail only)
Jan. 29, 2016	Last day for hotel reservations
Jan. 30, 2016	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 2016	Registration due without late fee
Mar. 1, 2016	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. Woodin 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. The Distinguished Rice Research and/or Education Award

i) 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 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) Team category – 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. The Distinguished Service Award - 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.

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