Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Seventh Rice Technical Working Group

Long Beach, California: February 19 – 22, 2018

Edited by: Michael Salassi, Bruce Linquist and Lee Tarpley

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

**Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station**

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PROCEEDINGS ... THIRTY-SEVENTH 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 2018 Meeting

The 37th RTWG meeting was hosted by California and held at the Westin Long Beach Hotel in Long Beach, California, from February 19 - 22, 2018. The Executive Committee, which coordinated the plans for the meeting, included Lee Tarpley, Chair; Bruce Linquist, Secretary; and Eric Webster, Immediate Past Chair. Geographic Representatives were Xueyan Sha (Arkansas), Luis Espino (California), Matthew VanWeelden (Florida), Herry Utomo (Louisiana), Bobby Golden (Mississippi), Michael Aide (Missouri), Ted Wilson (Texas), and Pat Clay (Industry). Administrative Advisors were Eric Young (Experiment Station), Rogers Leonard (Extension Service), and Anna McClung (USDA-ARS). Publication Coordinator was Michael Salassi (Louisiana). The Industry Representative was Pat Clay (California). Website coordinator was Eric Webster. The Local Arrangements Coordinators for California were Luis Espino (Chair), Bruce Linquist, Whitney Brim-DeForest, Randall (Cass) Mutters, Kassim Al-Khatib, Kent McKenzie, Michelle Lienfelder-Miles, and Lauren McNees.

Location and Time of the 2020 Meeting

The 2020 RTWG Meeting Location Committee recommended that the 38th RTWG meeting be held by the host state Mississippi. The meeting will be held on March 2-5, 2020, at Perdido Beach Resort, Orange Beach, Alabama.

2018 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. Mo Way. The team award was presented to the advance irrigation management practices team of Merle Anders, Michelle Reba, Benjamin Runkle, Chris Henry, Joe Massey, Jarrod Hardke, Arlene Adviento-Borbe, Bruce Linquist, Steve Linscombe and Dustin Harrell.

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. Merle Anders, Dr. Randall "Cass" Mutters, Dr. Steve Linscombe, Dr. Johnny Saichuk, Dr. Terry Siebenmorgen, and Dr. Ted Wilson.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 37th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2018 proceedings. The 2018 proceedings was edited by Michael Salassi, Bruce Linquist (Secretary), and Lee Tarpley (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 38th RTWG (2020 meeting) proceedings are included in these proceedings.

Committees for 2020

Executive:

Chair:	Bruce Linquist	California
Secretary:	Jason Bond	Mississippi

Geographical Representatives:

Jarrod Hardke	Arkansas
Whitney Brim-DeForest	California
Matthew VanWeelden	Florida
Manoch Kongchum	Louisiana
Bobby Golden	Mississippi
Gene Stevens	Missouri
Ted Wilson	Texas
Mallory Everett	Industry-Valent USA

Immediate Past Chair:

Lee Tarpley	Texas

Administrative Advisors:

Eric Young	Experiment Station
Rogers Leonard	Extension Service
Anna McClung	USDA-ARS

Publication Coordinator:

Michael Salassi	Louisiana

Web Page Coordinator:

Eric Webster	Louisiana

Industry Representative:

Mallory Everett	Valent USA

2020 Local Arrangements:

Bobby Golden (Chair)	Mississippi
Kenner Patton (Vice Chair)	Mississippi
Jason Bond	Mississippi
Lindsey Bell	Mississippi

Nominations:

Chuck Wilson (Chair)	Arkansas
Whitney Brim-DeForest	California
Matthew VanWeelden	Florida
Blake Wilson	Louisiana
Jeff Gore	Mississippi
Jim Heiser	Missouri
Fugen Dou	Texas
Mallory Everett	Industry-Valent USA

Rice Crop Germplasm:

Georgia Eizenga, Chair	USDA-ARS
James Correll	Arkansas
Adam Famoso	Louisiana
Teresa deLeon	California
Karen Moldenhauer	Arkansas
Edilberto Redoña	Mississippi
Paul Sanchez	California
Xueyan Sha	Arkansas
Qiming Shao	Crop Protection Services
Rodante Tabien	Texas
Ex Officio:	
Harold Bockleman	USDA-ARS
Jack Okamuro	USDA-ARS
Anna McClung	USDA-ARS
Martha Malapi-Wight	USDA-APHIS
National Germplasm Resources Laboratory:	
Gary Kinard	USDA-ARS

Rice Variety Acreage:

Dustin Harrell, Chair	Louisiana
Jarrod Hardke	Arkansas
Kent McKenzie	California
Bobby Golden	Mississippi
Christian DeGuzman	Missouri
Ted Wilson	Texas
Matthew VanWeelden	Florida

2020 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:	
Edilberto Redoña	Mississippi
Economics and Marketing:	
Larry Falconer	Mississippi
Plant Protection:	
Jeff Gore	Mississippi
Processing and Storage:	
Zhongli Pan	California
Rice Culture:	
Bobby Golden	Mississippi
Rice Weed Control and Growth Regulation:	
Whitney Brim-Deforest	California

RESOLUTIONS
37th RTWG – 2018

The 37th meeting of the RTWG, held in Long Beach, California, February 19-22, 2018, 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 37th meeting.

1. Lee Tarpley, RTWG Chair, and all other members of the Executive Committee who organized and conducted this very successful meeting. We recognize Bruce Linquist 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 Westin Long Beach Hotel, Long Beach, California, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements Committee chaired by Luis Espino, California, for the site selection and overseeing arrangements. To the faculty and staff of the Division of Agriculture and Natural Resources, University of California, Davis, for their time and assistance in conducting all aspects of pre- and on-site registration and other conference planning and operational details.

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

5. The Panel Chairs, Randall (Cass) Mutters, Lanier Nalley, Zhongli Pan, Luis Espino, Kassim Al-Khatib, and Thomas Tai, and moderators for planning, arranging, and supervising the technical sessions. The Symposia Chairs and Co-chairs, Ben Runkle and Anna McClung, for planning, arranging and supervising these special sessions.

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

7. The Symposia, General Session, and Industry Luncheon speakers for sharing their knowledge and wisdom.

8. Michael Salassi, LSU Department of Agricultural Economics and Agribusiness, and Darlene Regan, LSU Rice Research Station, for editing and publishing the RTWG proceedings.

9. We gratefully recognize our many sponsors that made the 37th Rice Technical Working Group meeting possible.

2018 RTWG Conference Sponsorship

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Distinguished Rice Research and/or Education Award

Michael Orrin "Mo" Way

Dr. Mo Way is an inspiring researcher and an educator par excellence. In his 35 long dedicated years as a scientist, he has devoted his research career in entomology, majority of those years in rice entomology. He mentored dozens of college students and young scientists, and served as an inspiration to young students to pursue a career in science. Dr. Way is a strong advocate of Integrated Pest Management (IPM) as vital in achieving sustainability in rice production. He developed the IPM program for rice water weevil, rice stink bug and chinch bug, saving millions of dollars in production costs. He keeps an eye not only on prevailing pests but also to new and potential pests. Thus, he was the first to discover rice seed midge, rice leaf miner, Mexican rice borer, and South American rice miner in U.S. rice production areas, and rice panicle mites in the greenhouse. Very recently, he found the exotic Delpachid (*Tagosodes orizicolus*) in Texas. He also warned rice growers on the Golden Apple snail, an invasive major pest in Asian rice. In all cases, Dr. Way monitored these newly discovered pests to avoid and prevent spread, and pioneered several basic studies in most of them. During the outbreak of fall armyworm and water weevil, he applied for crisis exemptions and extensions for chemicals controlling these two pests, again saving millions of dollars in to U.S. rice producers. With strong partnership with USEPA, TDA, USA Rice and agrichemical companies, he was instrumental in getting labels for more than a dozen insecticides and a bird repellant for use in rice. His requests for these labels were all supported by his data, indicating the value and efficacy of the product. Economics of use is always part of his recommendation so that the producers can make the right decision in using the product. His works largely reduced the pesticide load in the rice agroecosystem, an average of about 10 fold.

During his career, he received millions of dollars in research funds. In the last seven years, he received $4 million from several check-offs, private companies and university/state/national competitive grants. He authored or co-authored over 300 research/extension publications, including 85 refereed journal papers and seven book chapters. He writes monthly in Rice Farming and Rice Advocate and acts as editor or co-editor and section author of the Texas Rice Production Guidelines. In recognition of his numerous achievements, he received eight individual awards and six team awards, including two team awards from RTWG. He is an active member of several scientific organizations, chair or vice chair of committees and convener of national and international meetings, workshops or conventions. As an internationally well known rice entomologist, Dr. Way was invited as speaker in numerous international meetings and resource speaker in scientific gatherings, as consultant and/or as visiting scientist. He visited Mexico, Korea, Costa Rica, Nicaragua, Cuba, Brazil and Australia in various capacities. Guiding the youth and college students has been part of his long career. He was the major, co-major advisor or committee member of 3 M.S. and 11 Ph.D. students and mentor or host to 2 Postdocs, 2 visiting scientists, and 1 foreign student. Dr. Way is also very much involved in Future Farmers of America, Science Summer Camp, Science Teachers Workshop and the Texas Rice Festival. For his contribution to the rice industry in the area of rice entomology, the Thirty-Seventh Rice Technical Working Group is proud to award Mo Way as the recipient of the 2018 Rice Technical Working Group Distinguished Rice Research/Education Individual Award.

Distinguished Rice Research and/or Education Team Award

Merle Anders, Michelle Reba, Benjamin Runkle, Chris Henry, Joe Massey, Jarrod Hardke, Arlene Adviento-Borbe, Bruce Linquist, Steve Linscombe, and Dustin Harrell

Until recently, the only way most farmers thought of growing rice was by maintaining the field constantly flooded. This practice is easy to manage and has many advantages including good weed control, reduced blast, and efficient use of N fertilizer, which lead to the high yields possible in most of the rice growing states within the U.S. However, maintaining a constant flood also has drawbacks. These drawbacks include high water use, high methane emissions, and increased availability of some heavy metals that can result in high concentrations in rice grains relative to other cereal crops. Introducing aerobic periods during the growing season (often referred to as alternate wetting and drying or AWD) has been shown to reduce CH4 emissions and water use in Asia; however, this was usually accompanied by yield loss.

This team, with members crossing disciplinary boundaries and geographic regions, and including those with both research and extension appointments began research in 2010 on AWD. Results from numerous field trials indicate that with AWD, rice yields can be maintained or more efficiently grown while also reducing water use by up to 30%, CH4 emissions by 50 to 90% with minimal increases in N2O, and As and MeHg grain concentrations by over 50%, relative to continuous flooding. These are achieved with no changes to N fertilizer or weed management. Using the right varieties, there is no increase in blast. These benefits are all well documented in numerous publications. Members of this team have pushed the bar even further by growing rice under completely aerobic conditions (referred to as furrow irrigated rice or row rice) which has all of the above mentioned benefits but can reduce water use even more. While these practices were tested on small plots, adoption at the field level possesses additional challenges. First, many growers are uncomfortable growing rice in anything but a flooded field. Second, fields are often large and heterogeneous. Researchers developed irrigation practices that allow the fields to be reflooded quicker and more uniformly using polytubing. These findings, along with extension efforts by university personnel and partnerships with the USDA-NRCS Rice Stewardship Program have fostered adoption of these practices.

In 2017, over 150,000 acres were enrolled in the NRCS RCPP-Ducks Unlimited program that featured AWD flood management. Apart from the interest these practices have generated among rice growers, this research has attracted the interest of a number of organizations. For example, the USA Rice Sustainability Committee has used information generated by this research extensively in promoting sustainable production practices. The White River Irrigation District, through multiple Conservation Innovation Grants has been able to promote this practice within their district. In addition, these practices have also caught the attention of private companies such as Mars Inc., Walmart, Unilever and Kellogg's that are interested in promoting sustainable rice production practices. RiceTec also includes AWD practices under their guidelines to help growers maximize sustainability efforts through their "Smart Rice" program. The American Carbon Registry also developed a protocol – "Voluntary Emission Reductions in Rice Management Systems" which allows growers to receive carbon credits for various management practices including AWD as it leads to reductions in CH4 emissions. In 2017, this program was officially completed and seven farmers from California, Arkansas and Mississippi participated – generating the first ever carbon credits from rice which were sold to Microsoft. Recently, Field to Market: The Alliance for Sustainable Agriculture partnered with team members to improve the Rice Fieldprint platform which allows producers to benchmark their farms sustainability performance. Using US data, GHG emissions and major factors controlling GHG emissions were quantified, allowing Field to Market to develop a tool that will allow producers to evaluate the carbon footprint of rice at a field scale based on soil, variety and field management practices – including AWD water management. The adoption of these irrigation management practices by rice producers across all of the southern rice producing states is remarkable given the complexity of these changes at the farm level and is a true testament to the quality of research from this team and the extension efforts made. For their contribution to the rice industry in the area of advancing irrigation management practices to achieve sustainable intensification outcomces, the Thirty-Seventh Rice Technical Working Group is proud to award Merle Anders, Michelle Reba, Benjamin Runkle, Chris Henry, Joe Massey, Jarrod Harke, Arlene Adviento-Borbe, Bruce Linquist, Steve Linscombe, and Dustin Harrell as the recipients of the 2018 Rice Technical Working Group Distinguished Rice Research and/or Education Team Award.

Distinguished Service Award

Merle Anders

Dr. Anders is an Arkansas rice agronomist, who has influenced rice research and production in the United States and internationally. Dr. Anders' service as an agronomist spans 46 years, and 2018 marks his 20th year in rice.

Merle was born and raised on an Iowa corn farm, and graduated from Iowa State University in 1968. He was drafted into the United States Army, and after serving his country and [we think] hitchhiking across Australia, in 1972, he surfaced in the Kingdom of Tonga. There he worked for 8 years as an agronomist, and ultimately as a trainer of Peace Corps volunteers.

By 1980, Merle knew every coconut palm on the island by name, so he moved to an agronomist position in Papua, New Guinea on a World Bank project. There he worked for 3 years before returning to the States to pursue graduate studies at the University of Hawaii. He completed his M.S. and Ph.D. degrees in Agronomy before taking a position in India at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics).

After nine years in the deserts of India, Merle resurfaced in the U.S. once more, this time as a Rice Systems Agronomist with the University of Arkansas. Merle brought his international experience and perspective on crop production to rice - most notably in water conservation. His early work in furrow irrigated rice, zero grade, and continuous no-till rice was pivotal in developing the recent advances in rice sustainability, which paved the way toward conservation production practices like alternate wetting and drying (AWD). Additional progressive approaches have reduced greenhouse gas emissions, reduced arsenic content in rice grain, and improved carbon sequestration in soils, all while maintaining full yield potential. It is a rare accomplishment for a researcher to have an impact on so many aspects of the rice industry.

Currently, Dr. Anders is active as a consultant and collaborator with many organizations tied to the U.S. rice industry. These include the American Carbon Exchange, Ducks Unlimited, Mars, RiceTec, Unilever, USDA ARS, Walmart and others that are affiliated with the NRCS RCPP program, which is the largest water conservation program in Arkansas. These programs assist rice producers in implementing sustainable practices and also provide an opportunity to sell carbon credits derived from the use of conservation practices. Over the past 20 years Dr. Anders has been influential in moving rice production to the forefront of sustainably produced crops. For his contribution to the rice industry as a rice systems agronomist, the Thirty-Seventh Rice Technical Working Group is proud to award Merle Anders as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Distinguished Service Award

Steven D. Linscombe

Steve Linscombe has been working as a rice scientist at the LSU AgCenter for 35 years. His service started in 1982, when he served as statewide extension rice agronomist for the Louisiana Cooperative Extension Service. Since 1988, he has led the LSU AgCenter rice variety development efforts. His research in rice variety development has provided significant benefits for rice producers and processors in the mid-south rice production region and around the world. He is directly responsible for the development of new superior conventional long- and medium-grain types, as well as Clearfield long and medium grains. In addition, four years ago he began a project to incorporate the Provisia herbicide resistance trait into adapted varieties for production in the southern U.S. rice growing region. As a PI, he has received in excess of $20 million in grant funding. He is also senior or co-author on more than 350 publications of which 67 are referred. Three of his articles were chosen as the article of the year for the LSU AgCenter publication - Louisiana Agriculture. Since 2001, he has served as the director of the LSU AgCenter Southwest Region. Since 2003, he has also served as the director of the H. Rouse Caffey Rice Research Station.

During his tenure, there have been 33 new improved rice varieties developed and released from the LSU AgCenter's rice breeding program. He was directly responsible for the development of 25 of them. The varieties developed by this program have dominated the southern U.S. rice acreage over the last 20 years. This has been aided by greatly expanding the productivity of the winter nursery facility in Puerto Rico, vastly improving the agronomic productivity of the breeding nurseries and seed increases grown at this location.

Steve's distinguished long-term contributions include pioneering accomplishments. These include the first variety developed and released especially for planting in waterfowl habitat called Mossy Oak Waterfowl Forage. He also developed the first true short grain for Louisiana production and the first crawfish forage variety. He conducted the world's first field test of Golden Rice in 2004. In 2001, the first Clearfield varieties for use with the Clearfield system for red rice control were released. The program has since developed nine additional Clearfield varieties. Well over 90% of the Clearfield inbred acres in the United States have been seeded to varieties developed by this program. Steve currently holds nine U.S. patents from his research efforts.

Additional areas of research specialization include planting date studies, the impact of various factors on milling quality and grain fissuring, herbicide tolerance of different genotypes, the impact of lodging on milling quality and factors impacting pollen flow, variety by environment impacts on rice quality, and genotype by variety interactions. The rice breeding program also has had cooperative research endeavors with numerous other research centers in the United States, Asia, South America and Europe. These efforts are of great benefit to southern U.S. rice producers because of the additional germplasm and research expertise that they make available to the AgCenter's program. He has developed very close working relationships with many of the major U.S. rice mills and end-users of rice. For his contribution to the rice industry in the area of rice variety development, the Thirty-Seventh Rice Technical Working Group is proud to award Steve Linscombe as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Distinguished Service Award

Randall "Cass" Mutters

Cass Mutters received a BS in Agronomy from Colorado State University in 1979, an MS in Soil Fertility from Clemson University in 1981, and a Ph.D. in Plant Physiology from UC Riverside, in 1988. Cass worked for the University of California Cooperative Extension as Rice Farming Systems Advisor in Butte County from 1994 until his retirement in 2017. As an advisor, Cass conducted an applied research and outreach program directed towards rice growers, pest control advisers, and others in the rice industry with the objective of improving productivity while maintaining environmental quality.

Cass' work has been visionary and transformative, always thinking ahead of the curve. He is recognized nationally and internationally as a rice research and extension expert. His achievements during his career have been many. To name a few, Cass developed the Leaf Color Chart to determine mid-season rice nitrogen needs. This has been adopted not only in California but also in many other rice production areas of the world. He quantified the effects of cold water on rice growth and yield, providing the California rice industry information needed to mitigate cold water damage. He developed guidelines to drain fields in preparation for harvest that allow growers to save water while maintaining yield and grain quality. In collaboration with the Rice Experiment Station breeders, Cass refined harvesting guidelines for new rice varieties, allowing growers more harvest flexibility and reduced drying costs. He is co-author of the Rice Quality Handbook, the most important publication in California dealing with post-harvest management of rice and used widely by rice storage managers. He was also part of the team that developed the first agricultural carbon offset protocol, approved by environmental groups and regulatory agencies in the United States.

Cass has collaborated with others working in California rice. He has played a major role in projects testing new rice varieties, developing nitrogen management guidelines, refining rice water use estimates, and developing strategies to manage herbicide-resistant weeds. As part of his outreach program, he developed the Rice Quality and Rice Production Workshops, which have trained more than a 1,000 growers and other rice industry representatives since their inception in the early 2000s. Through his efforts, he has helped the California rice industry adapt to new challenges and remain viable and competitive.

Cass also served the rice industry by participating in many committees of state and national significance, such as the Rice Certification Act, California Air Resources Board Technical Advisory Committee, and the Rice Technical Working Group Executive Committee. In 2008 and 2010, he served as Secretary and then Chair for the 32nd and 33rd Rice Technical Working Group Meetings.

Cass' research and outreach have always addressed the needs of rice growers in California. He is an outstanding educator both in formal settings and in the field. He has mentored numerous students and academics. For all of his contributions to the rice industry, the Thirty-Seventh Rice Technical Working Group is proud to award Cass Mutters as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Distinguished Service Award

Johnny Saichuk

Dr. Johnny Saichuk was the LSU AgCenter rice extension specialist where he 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 was the RTWG Rice Variety Acreage Committee chairman for many years, providing important information on rice acreage and varietal distribution. Dr. Saichuk also has a long history of working closely with industry and regulatory partners to help make new and more effective pest management tools available for stakeholders. Dr. Saichuk collected and conveyed data to partners, highlighting the benefits and disadvantages of the new tools at the field level to procure product registrations for numerous herbicide, insecticide and fungicide products. Dr. Saichuk received the RTWG Distinguished Rice Research and Education Award in 2014.

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 some areas. He worked to save Furadan 3G for rice water weevil control and simultaneously investigated alternative tactics such as timing of pyrethroid application. 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 concern.

Dr. Saichuk routinely made 125 plus visits annually to inspect and conduct research/extension programs. He developed The Rice Research Verification Program. This signature outreach program has been on-going since 1997 with a total of 135 fields comprising 5,000 acres in 19 Louisiana parishes. Dr. Saichuk set up experiments and observational studies in these fields across Louisiana and monitored them on a weekly basis. He reported results in real-time to help growers make critical pest management and other agronomic decisions. Participating growers learned about the problems, solutions and novel or recommended practices applied in the verification fields. Rice producers not directly participating in the Program also benefited through observation and communication with Dr. Saichuk; thus, extending the impact of the program.

Dr. Saichuk created Field Notes, which was a weekly electronic publication emphasizing current rice production topics in Louisiana. This publication has a multi-state, multi-discipline readership and includes high quality photographs of current subjects 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. For all of his contributions to the rice industry, the Thirty-Seventh Rice Technical Working Group is proud to award Johnny Saichuk as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Distinguished Service Award

Terry Siebenmorgen

Terry Siebenmorgen is the Distinguished Professor and Coordinator, University of Arkansas Rice Processing Program University of Arkansas, Fayetteville, Arkansas. He received a B.S. degree in Agricultural Engineering from the University of Arkansas in 1979, an M.S. degree in Agricultural Engineering from Purdue University in 1981, and a Ph.D. degree in Engineering from the University of Nebraska in 1984.

Dr. Terry Siebenmorgen's research and outreach program focused on rice processing and rice quality. The scope of his program ranges from preharvest property characterization, through drying, storage, milling, and end-use quality evaluation. Terry and his collaborators have, over the past 30+ years, greatly improved our understanding of the development, composition and processing behavior of rice. Some of his most impactful research includes: the application of the glass transition theory to rice drying, the establishment of optimum rice harvest moisture content, the understanding of residual milled rice breakage, and the establishment of laboratory milling procedures.

The University of Arkansas Rice Processing Program, administered by the U of A Division of Agriculture and directed by Dr. Siebenmorgen, was formed in the early 1990s to provide a center for rice processing research that would serve the U.S. rice industry. The Program has, from its inception, been very industry interactive, regularly seeking direction and feedback from company sponsors. The Program is funded in large part by annual contributions from sponsoring companies which range from driers and millers, to processors and equipment suppliers.

In an on-going effort to provide current research information to sponsoring companies, the Rice Processing Program annually hosts the *Industry Alliance Meeting*. Held in May on the U of A campus, the Industry Alliance Meeting comprises research presentations by faculty and students, as well as timely presentations by invited industry speakers. The Industry Alliance meeting is typically attended by more than 100 individuals who represent a strong cross-section of the rice industry, with 2018 marking the 25th anniversary of the meeting.

Comments on Dr. Siebenmorgen's contribution to the rice industry from colleagues include the following quotes: "Dr. Siebenmorgen is recognized in the US Rice industry as the leader in post-harvest rice research;" "Dr. Siebenmorgen has invested his career in providing practical research to develop real solutions to some of the rice processing industry's greatest opportunities. A mentor to dozens of students who have come through his program and a true friend to many colleagues around the world;" "Forming the Rice Industry Alliance was a stroke of genius. Holding the Alliance together and keeping it relevant over time is evidence of remarkable leadership." For all of his contributions to the rice industry, the Thirty-Seventh Rice Technical Working Group is proud to award Terry Siebenmorgen as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Distinguished Service Award

Lloyd T. (Ted) Wilson

Dr. Wilson has been working on rice research and serving the rice industry for nearly two decades, since his appointment as Jack B. Wendt Endowed Chair in Rice Research in 2001. He has served in key positions in the rice industry, helping the growth, development, and promotion of rice as a major commodity not only in Texas but also in the Southern Rice Belt and California.

As Director of Texas A&M AgriLife Research Center in Beaumont, he guided the recruitment of new and young faculty to invigorate the research and other rice related activities. His vision and commitment have promoted the center's excellence. His approach to research management has led to the establishment of partnerships with scientists from around the United States and the world. Under his leadership, Beaumont faculties deliver a high level of service to the Texas rice industry while conducting and expanding their programs. Under his stewardship, the Center increased its annual rate of peer-reviewed publications by 287% and Center funding by 38%. The Center scientists have received more than $39 million in research funds, sourced from 39 federal competitive grants, as well as others. The Center ranked first in average number of citations per scientists among the 13 Texas A&M AgriLife Research Centers. He also initiated new projects and programs at the Center. The most recent being a hybrid rice breeding program with over $2 million in funding in the first 5-years, and two additional 5-year funding agreements anticipated.

Dr. Wilson's rice research has focused on the ecology and management of sugarcane borer and Mexican rice borer; post-harvest rice grain management; quantifying the effects of putative climate changes on crop performance, developing a physiological basis for phenotypic trait selection; expanding the Texas Rice Crop Survey; improving the Rice Development Advisor (RiceDevA); and maintaining the largest climatic database by a land grant university (over 28,000 stations worldwide). His highly integrated approach to agricultural research provides opportunities for cross-disciplinary collaboration in rice breeding, system analysis/modeling, post-harvest research and regional management of invasive arthropod species of rice and sugarcane. He has collaborated with scientists around the world including those at Milan University, Wageningen University, USDA-ARS, LSU, IRRI and CIRAD. He has published roughly 800 scientific papers, including 255 peer-reviewed. His papers have been cited over 6,000 times, which ranks 2nd highest of the 87 Texas A&M off-campus research faculties. Dr. Wilson's grant support is broad-based representing local, state, national, and international funding. He has authored or co-authored 170 funded grants, totaling roughly $29 million.

Dr. Wilson has served on numerous industry/state/national/international committees involving agricultural production and management, majority of them on rice. He is the current Co-Chair of the International Agricultural Model Inter-comparison and Improvement Project for Rice (AgMIP Rice) and Chair of the Texas Rice Research Foundation Scientific Advisory Committee. He served as mentor to students, post-docs and visiting scientists. He was an instructor for 21 courses and delivered lectures at UC Davis, Queensland University, OSU, LSU, and in Caracas, Venezuela. He was Chair or committee member to 43 MS and PhD students, and guided the training of 16 post-docs and visiting scientists. For all of his contributions to the rice industry, the Thirty-Seventh Rice Technical Working Group is proud to award Ted Wilson as the recipient of the 2018 Rice Technical Working Group Distinguished Service Award.

Minutes of the 37th RTWG Meeting

Opening Executive Committee Meeting

In Attendance: Lee Tarpley, Chair, Texas; Bruce Linquist, Secretary, California; Eric Webster, Past Chair, Louisiana; Xueyan Sha, Geographic Representative, Arkansas; Luis Espino, Geographic Representative, California; Matthew VanWeelden, Geographic Representative, Florida; Herry Utomo, Geographic Representative, Louisiana; Bobby Golden, Geographic Representative, Mississippi; Ted Wilson, Geographic Representative, Texas; Pat Clay, Industry Representative; Eric Young, Administrative Advisor Anna McClung, Administrative Advisor; Mike Salassi, Publication Coordinator, Louisiana; Jason Bond, Mississippi

1. Tarpley called meeting to order at 7:00 am.

2. Tarpley presented details about the previous RTWG meeting held at the Moody Gardens Hotel Spa in Galveston, TX.

3. Tarpley stated that the minutes from the 2016 RTWG meeting are already printed in the printed proceedings. Linquist motioned to dismiss reading the minutes. Golden seconded. All in favor.

Golden motioned to accept the minutes as printed in the proceedings. Linquist seconded. All in favor.

Wilson motioned to accept agenda to proceed. Golden seconded. All in favor.

4. Linquist discussed the program and layout of the Conference Hotel. He mentioned there will be 126 technical presentations, 67 posters, and 2 symposia. Funds from sponsorships were high - over $66,000. Linquist described the program and went over the keynote speakers.

Regarding the student competition, Linquist commented that the goal is to showcase students, because they are key to keep RTWG going into the future. This year oral presentations were included in the student competition. Response was good, with 22 oral presentations and 15 posters entered. All oral presentations fell under three panels, with roughly similar number of presentations in each panel. The student competition will take place after the keynote speakers, when there is no other activities scheduled in order to maximize participation. For each oral presentation, there is a first and second price, $300 and 200, respectively; three first prizes and three second prizes in total. The posters are all competing amongst one another, and there will be a first, second, and third place. Awards will be given during awards luncheon. Enough volunteers were recruited for judges. Each student competition session has between four and six judges. Whitney Brim-DeForest and Michelle Leinfelder-Miles organized the student competition.

Guidelines for the student competition were given to participants, but there might be some differences between disciplines. McClung expressed that judges should take the differences among disciplines into consideration in their judging.

This year, evaluation forms will be available to participants to give feedback regarding the meeting to benefit organization of upcoming RTWGs. Results will be shared at the closing executive committee meeting.

Tarpley asked to revisit the student competition and evaluate it at the closing executive committee meeting.

Linquist stated that attendance for the current RTWG is close to 300, which was the objective.

6. Award recipients were announced by Tarpley.

7. Necrology report: Espino presented Larry Godfrey, Webster and Salassi presented Joseph (Joe) Musick. Webster and Salassi will prepare a report to be read during the opening ceremony.

8. Tarpley presented the draft proposal for the next five years of the SERA018 project. The writing team consists of Bruce Linquist, Chuck Wilson, and Steve Linscombe. The proposal was very similar to the previous proposal. There was a request from one of the panels to change their name to Breeding, Genetics and Genomics. This is noted in the proposal. Also, the executive committee as was included as a standing committee

Objective 1 was modified to be more representative of the research being conducted. After a short discussion, Wilson suggested: “To provide opportunities…exchange information on rice marketing and economics, crop physiology, agronomic and pest management, breeding, genetics, and other aspects of rice culture and value.”

Linquist mentioned that there is nothing on the objectives regarding students. He mentioned that other professional society meetings are not a good venue to present rice information because there is not much interest in rice. Wilson suggested including a new objective with the following wording: “Develop new knowledge, implement solutions to producer and industry needs, and train the future leaders in rice research and extension.”

Tarpley suggested continuing the discussion by email regarding these changes. Espino will send the suggestions to Tarpley to circulate to the group.

Wilson asked about the prioritization of research, extension, and education areas. This is done at the business meeting at the end of each technical panel. The group discussed how this process has evolved over time, with panel recommendations getting longer and longer. The group suggested developing a short list of recommendations for the next five years. These would be useful to ARS area directors, NIFA, and research and extension directors. Tarpley suggested putting together a small team to work to make a list of priorities after the panels have made their recommendations at the end of their business meeting. This list will be presented electronically to the executive committee before it goes to the public.

Webster suggested that the business meeting should be held at the beginning of each panel meeting, rather than at the end, to improve attendance and input. The committee discussed what the best way to improve participation was. Linquist and McClung suggested mentioning the SERA project during the opening session so that attendants are prepared to discuss priorities. McClung suggested that each panel chair should identify a team of three people to develop the list of priorities.

The new SERA project starts October 1. There will be a call for participation, so people need to sign up. The call is sent by email and then forwarded to participants, in this Young should send the call to the executive committee so they can forward to others. Bruce will be main contact.

Tarpley suggested that at each panel business meeting chairs should identify two priorities and two or three people to follow up. It should be brought up in the panel chairs meeting.

9. Discussion regarding the permanent website. Tarpley described that for each meeting, states have worked on their own registration websites and not the permanent website. Texas has covered the costs of the permanent website, and now California should cover them. Costs are $800/year. Updates are done by request, and the cost of this is $400/year. Right now the website is down, and a payment is needed to fix it.

Wilson asked the question whether a permanent website is needed. The committee discussed the value of having a permanent website to host the proceedings and maybe pictures of award winners. For the biennial meeting, a permanent website may not be necessary. Tarpley stopped the discussion and tabled the rest of the agenda for the closing executive meeting, which will start at 8:00 am.

Jason Bond gave an update for the next RTWG to be hosted by Mississippi. The tentative dates are March 2-5, 2020, at Perdido Beach Resort, Orange Beach, Alabama. Flying to Pensacola and then 30-minute drive. Bobby Golden will be local arrangements chair.

Meeting was adjourned at 8:30 am.

Opening Business Meeting

Chairman Lee Tarpley called the meeting to order at 8:00 a.m. on February 20, 2018, at the Westin Long Beach Hotel in Long Beach, California.

Chairman Lee Tarpley introduced Eric Young (NCSU) who is serving as the the Administrative Advisor representing Experiment Stations of the major rice-growing states and is helping the RTWG through the transition into a new SERA project. Attendees were encouraged to register as members of the SERA-18 RTWG Project.

Secretary Bruce Linquist was asked to read the minutes from the last RTWG meeting. Motion was made and approved to dispense with the reading of the minutes.

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

Jason Bond announced that the 38th RTWG meeting will be held at the Perdido Beach Resort in Orange Beach, Alabama on March 2-5, 2020.

Jason Bond, chair of the Nominations Committee, recommended the following individuals for leadership for the 38th RTWG:

Bruce Linquist – Chair
Jason Bond – Secretary
Lee Tarpley – Immediate Past Chair

<u>Geographical Representatives:</u>
Jarrod Hardke – Arkansas
Whitney Brim-DeForest – California
Matthew VanWeelden – Florida
Manoch Kongchum – Louisiana
Bobby Golden – Mississippi
Gene Stevens – Missouri
Ted Wilson – Texas
Mallory Everett – Industry (Valent USA)

Nominations Committee:
Charles Wilson, Jr. – Arkansas (Chair)
Whitney Brim DeForest – California
Matthew VanWeelden – Florida
Blake Wilson – Louisiana
Jeff Gore – Mississippi
Jim Heiser – Missouri
Fugen Dou – Texas
Mallory Everett – Industry (Valent USA)

Chairman Lee Tarpley called for a motion to accept the nominations from the Nominations Committee. The motion was made, seconded and approved.

Secretary Bruce Linquist announced the sponsors for each level: Bald Eagle Sponsors: California Rice Commission, BASF Corporation; Peregrine Falcon Sponsors: California Rice Research Board, Dow AgroSciences, Gowan USA, LLC, Horizon Ag LLC, Netafim USA, Rice Research Trust; Sandhill Crane Sponsors: RiceCo LLC, RiceTec, Valent U.S.A. LLC; Pintail Duck Sponsors: American Commodity Company, FMC Agricultural Solutions, Nichino America, Inc., Syngenta, Wilber-Ellis: Tule Goose Sponsors: Almaco, Amvac, Farmers' Rice Cooperative, Oro-Agri, Simplot, Sipcam Agro, SunWest Foods, Inc.; Other Sponsors: California Family Foods. Appreciation was also given to all those aiding in organizing the meeting.

Secretary Bruce Linquist announced the general schedule, including changes to the program, of the 37th RTWG meeting.

Meeting was adjourned

Closing Executive Committee Meeting

In Attendance: Lee Tarpley, Chair, Texas; Bruce Linquist, Secretary, California; Xueyan Sha, Geographic Representative, Arkansas; Luis Espino, Geographic Representative, California; Matthew VanWeelden, Geographic Representative, Florida; Bobby Golden, Geographic Representative, Mississippi; Ted Wilson, Geographic Representative, Texas; Anna McClung, Administrative Advisor; and Jason Bond, Mississippi

1. Tarpley called meeting to order at 8:00 a.m.

2. Linquist updated the group on highlights of the meeting. There were 285 registrations, which was on target with the budget. Evaluations will be processed and recommendations passed on to organizers of next meeting. There were some problems with the submission of titles and summaries; participants expected to receive a receipt notice, but it was not sent. A confirmation e-mail should be sent once a summary is received to confirm it has been received.

Linquist gave some updates regarding the conference evaluations. The conference program received a lower score, but it was still a good score. University affiliated participants were the most positive about the conference, industry the least. The Economics and Quality Panel had the lowest ranking, probably because they did not have any posters.

Wilson commented that the student contest should be continued and expanded. Linquist mentioned that having the student contest changed the panels. For example, the Weeds panel had fewer presentations because many were given during the student contest oral presentations.

McClung voiced a concern. Having the student competition may cause a concentration of the scientific talks given by the main scientists, reducing the number of talks given by them. Discussion followed on the subject, with the conclusion that organizers should make sure to emphasize both students' and scientists' presentations.

Wilson mentioned that perhaps it would be a good idea to create a panel dealing with plant physiology. Currently, the Rice Culture and Plant Breeding and Genetics panels take some of the presentations dealing with plant physiology. However, it is not certain if there would be enough presentations dealing with plant physiology to fill a full panel session. McClung suggested also having a panel that includes presentations on integrated research, and Wilson expressed support for this idea. Golden brought the concern that it might be difficult to have enough presentations to fill an integrated research panel session. Linquist suggested using the symposia to address this subject. McClung suggested that the panel chairs may decide to put a synthesis panel if there were enough related presentations submitted. Wilson gave his experience on the organization of symposia during the last RTWG meeting in Galveston. Tarpley shared that the symposia created excitement and helped to have higher attendance a day before the regular program started, and increased international attendance.

Bond stated that, for the next RTWG meeting, Mississippi will have a call for symposia and that they are planning on a county agent training session, with invitation to private consultants.

VanWeelden expressed that maybe bringing vendors to the conference may help to increase interest in the meeting. During discussion, it was concluded that RTWG is not very appropriate for this type of event.

3. Tarpley proposed to continue the discussion about the draft proposal for the next five years of the SERA 18 project. The wording of objective 1 was changed to: "To provide opportunities to exchange information on rice marketing and economics, crop physiology, agronomic and pest management, breeding, and genetics." The second new objective regarding future leaders was discussed. Tarpley proposed to adopt it.

Tarpley brought another aspect of the SERA 18 project, the need to include five-year impacts. Discussion ensued regarding the impacts that could be included, from collaborative research groups to research ideas. Tarpley will request impacts from the executive committee by email.

Another aspect of the SERA 18 project is a change of the list of officers, inclusion of more recent published proceedings, and what industry groups to include. Tarpley suggested changing the list of industry representatives to be: 1) chemical, 2) seed, 3) milling, 4) processing, 5) producers, 6) consultants, or 7) manufacturers. Wilson moved to approve this change, Linquist seconded, and all were in favor.

Wilson brought up the issue of who approves the project and that approvals should be directed to the right administrators. Tarpley will find out if the approval routing can be changed.

4. Prioritization of research needs. Tarpley mentioned that some panels had a difficult time prioritizing needs. A group from each panel is required to aid in the prioritization. Tarpley proposed forming a subcommittee of the executive committee to work on the synthesis of priorities. These priorities will be distributed to area directors and research and extension leaders among the states. The tentative date when this is needed is August 1. The subcommittee to work on this will consist of Tarpley, Linquist, Bond, McClung, Wilson, and Espino. A final draft will be circulated to all members of the executive committee for input. A motion to approve the subcommittee was made by Linquist, seconded by VanWeelden, and approved by all.

5. Tarpley brought up the issue of what "majority" when voting for award recepients means. It was approved by all to change the proceedings from "simple majority" to "simple majority (highest number of votes)" to avoid confusions.

6. Discussion regarding the permanent website. The current permanent website vendor, Aristotle, is not working. The website name was bought for a significant amount, and payment is needed to bring the website back. However, no one was sure who owns the name. LSU might be able to host a website. It was agreed not to work with Aristotle anymore, and Tarpley would check the contract to see how to proceed. The group agreed that the proceedings should be scanned, and made searchable. However, first LSU should be asked if they have done any scanning before proceeding.

6. McClung voiced the concern that there was a significant delay in the publication of the last RTWG meeting proceedings. Tarpley explained that Texas did grammar corrections, and so did LSU. This took longer than expected and delayed publication. For the current RTWG, abstracts are already ready for publication.

7. Meeting was adjourned at 10:00 am.

Closing Business Meeting

Chairman Lee Tarpley called the meeting to order at 10:00 a.m. on February 22, 2018, at the Westin Long Beach Hotel in Long Beach, California. He extended his gratitude to California for hosting the 37th RTWG, and to Michael Salassi for his efforts at publishing the proceedings.

Committee reports presented included: Rice Variety Acreage Committee by Dustin Harrell (Chair), Rice Germplasm Committee by Georgia Eizenga (Chair), Industry Committee by Lee Tarpley for Pat Clay (Chair), and Executive Committee by Lee Tarpley (Chair). Motions to accept the committee reports were approved.

Chairman Lee Tarpley called upon Secretary Bruce Linquist to read the resolutions. A motion to accept the resolutions was approved.

Chairman Lee Tarpley thanked the RTWG for the opportunity to serve as Secretary and Chair. Chairman Tarpley extended his gratitude to Secretary Bruce Linquist and California for hosting the 37th RTWG. He then passed the gavel to Bruce Linquist, incoming Chair. He presented a plaque that illustrates the history of the RTWG leadership since 1950 to Bruce Linquist.

Incoming Chair Bruce Linquist presented a plaque to Lee Tarpley in recognition of his service to the RTWG. He then expressed thanks to those from California who were instrumental in making the 37th RTWG a success.

Incoming Chair Bruce Linquist called for a motion to adjourn the 37th RTWG meeting. 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 2020 RTWG Executive Committee and Nominations Committee:

Executive Committee:

Bruce Linquist	Chair
Jason Bond	Secretary
Lee Tarpley	Immediate Past Chair

Geographical Representatives:

Arkansas	Jarrod Hardke
California	Whitney Brim-DeForest
Florida	Matthew VanWeelden
Louisiana	Manoch Kongchum
Mississippi	Bobby Golden
Missouri	Gene Stevens
Texas	Ted Wilson
Industry	Mallory Everett

Nominations Committee:

Arkansas	Charles Wilson, Jr., Chair
California	Whitney Brim-DeForest
Florida	Matthew VanWeelden
Louisiana	Blake Wilson
Mississippi	Jeff Gore
Missouri	Jim Heiser
Texas	Fugen Dou
Industry	Mallory Everett

Rice Crop Germplasm Committee

The 38th meeting of the Rice Crop Germplasm Committee was held on Monday, February 19, 2018, in Long Beach, CA, in conjunction with biennial 2018 Rice Technical Working Group meeting. Members in attendance were Georgia Eizenga (Chair), Harold Bockelman, Adam Famoso, Anna McClung, Jack Okamuro, Ed Redoña, Paul Sanchez, Xueyan Sha, Qiming Shao and Rodante (Dante) Tabien. Members participating via conference call were Gary Kinard, Martha Malapi-Wight and Karen Moldenhauer. Members not present were Peter Bretting and Jim Correll. Guests in attendance were Cynthia Andaya, Virgilio C. Andaya, Christian deGuzman, Teresa deLeon, Yulin Jia, David Gealy, Joe Kepiro and Eric Young. The meeting was called to order. The minutes of the 37th Rice Crop Germplasm Committee held on January 24, 2017, in Crowley, LA, were approved by a motion from Karen Moldenhauer, seconded by Adam Famoso, and supported by the other committee members.

Jack Okamuro gave the report of the USDA/ARS Office of National Programs for Peter Bretting, on the status, prospects and challenges of the National Plant Germplasm System (NPGS) which highlighted key challenges of managing and expanding the NPGS to meet the increased demand for germplasm and associated information, training a new generation of plant genetic resource (PGR) managers with at least 1/3 being eligible to retire in the next five years, developing conservation methods for clonal germplasm, managing accessions with genetically engineered traits and acquiring additional crop wild relatives. A USDA/NIFA grant was secured to develop a PGR management training curriculum which could be delivered through distance learning. The development of a strategic plan envisioning what the NPGS would look like in 20 years was discussed.

Gary Kinard, USDA/ARS National Germplasm Resources Lab, reported that as of 2018 there were 587,205 active accessions listed in the Germplasm Resources Information Network (GRIN) which represent 15,720 species and 2,533 genera. The collection grows 1-2% per year. The GRIN-Global interface has been in place for two years and continues to be upgraded and improved. Currently, there is a need to adapt GRIN-Global to the smaller platforms including tablets and smart phones. The crop wild relatives page in GRIN-Global was redone and the problems addressed. John Wiersema, curator for GRIN-Taxonomy will retire this year and Melanie Schori will continue these responsibilities. Proposals for the Plant Exploration and Exchange Program for FY2019 are due July 20, 2018, to Karen Williams.

The implications of the United States being party to the International Treaty and distribution of germplasm both domestically and internationally were discussed. GRIN-Global will need some restructuring to deal with distributions based on the International Treaty. Currently, accessions obtained with an SMTA (standard material transfer agreement) are distributed with a SMTA. Also, there is a decision to include just 64 crops under the SMTA or the entire collection. Neither China nor Russia have ratified this treaty.

Eizenga briefly reviewed the Crop Germplasm Committee (CGC) chairs webinar organized by Kinard on Jan. 25, 2018. Presentations were made by Peter Bretting, Stephanie Greene (seed curator), Karen Williams, John Wiersema, Melanie Schori, and Hannes Dempewolf from the Crop Trust, which includes the International Rice Research Institute (IRRI) and the other CGIAR centers.

Harold Bockelman, Curator of the Small Grains Collection, reported currently there are 19,081 accessions in the *Oryza* collection with 18,825 being *O. sativa* accessions. Eight *O. sativa* accessions were added to the collection this past year. A list of the 34 descriptors currently being used for rice in GRIN-Global was presented for discussion. Interest was expressed in updating the pedigree information feature which was originally developed by Ed Byrd but did not carry over from GRIN to GRIN-Global.

Martha Malapi-Wight, USDA/APHIS Plant Germplasm Quarantine Program (PGQP) reported that 87 accessions were imported from IRRI of which 79 were released from quarantine and shipped to the importer. The PGQP is implementing next generation sequencing (NGS) technologies for plant pest diagnostics. An Illumina NextSeq Platform was purchased, Dr. Bishwo Adhikari, a bioinformatics scientist, was hired, and Malapi-Wight has been attending workshops on NGS technologies for plant pest diagnosis.

Anna McClung, USDA/ARS Dale Bumpers National Rice Research Center (DBNRRC) reported on the Genetic Stocks-*Oryza* (GSOR), which as part of the NPGS, included in GRIN-Global, and distributed from the DBNRRC. Since GSOR was initiated in 2004, 85,000 accessions have been distributed with over 9,000 in 2016 and 8,500 in 2017, thus GSOR is fulfilling the purpose for which it was established. Many of these distributions have been the Diversity Panels especially the Rice Diversity Panel 1 (RDP1), followed by the Rice Mini-Core (RMC) and Katy mutant population. Of the 1,333 accessions included in the RDP2, 1,291 are currently being distributed through GSOR and 42 are currently in quarantine grow-out in Fayetteville, AR, after being re-imported from IRRI. The *Tropical Japonica* Core (TRJ core) collection, consisting of about 700 accessions, should be available for distribution in 2021.

McClung made a presentation explaining the routine genotyping of the rice collection with 23 SSR markers which is now included as part of the rejuvenation process. Nearly 2,000 accessions have been genotyped to date. Based on current results, approximately 25% of the collection appears to be redundant. Due to two key vacancies, this routine rejuvenation will not be done in 2018.

There was a brief discussion of adding descriptors to GRIN based on molecular markers for blast genes and grain quality including aroma. Other suggested descriptors were arsenic accumulation and reduced water usage. A motion was made by Moldenhauer to have McClung, Bockelman and Eizenga suggest possible descriptors to add to GRIN for the committee to review, seconded by Sha and supported by the committee members. Suggestions were made by the group to acquire the needed information for the rice crop vulnerability report, which Bockelman and Eizenga could use to complete the revised report template developed by Peter Bretting.

Several committee members' terms will be completed in 2018, thus Eizenga presented the following recommendations to the committee after contacting these members. Recommendations were to reappoint Jim Correll, Georgia Eizenga, Ed Redoña, Qiming Shao, and Dante Tabien for another six-year term on the committee and Eizenga as committee chair for a second two-year term. Teresa deLeon was recommended to complete the term of Farman Jodari who retired in 2017. A motion to approve these recommendations was made by Karen Moldenhauer, seconded by Anna McClung and supported by committee members present.

Paul Sanchez made the motion to adjourn, Dante Tabien seconded the motion, and the motion was supported by all members.

Rice Crop Germplasm Committee members as of February 24, 2018, with year term ends in parentheses:

Dr. Georgia Eizenga, Chair (2024)
USDA-ARS georgia.eizenga@ars.usda.gov

Dr. James Correll (2024)
Arkansas jcorrell@uark.edu

Dr. Adam Famoso (2022)
Louisiana afamoso@agcenter.lsu.edu

Dr. Teresa deLeon (2020)
California tdeleon@crrf.org

Dr. Karen Moldenhauer (2022)
Arkansas kmolden@uark.edu

Dr. Ediliberto Redoña (2024)
Mississippi ed.redona@msstate.edu

Dr. Paul Sanchez (2022)
California plsanchez@crrg.org

Dr. Xueyan Sha (2020)
Arkansas xsha@uark.edu

Dr. Qiming Shao (2024)
Crop Protection Service qiming.shao@cpsagu.com

Dr. Rodante Tabien (2024)
Texas retabien@ag.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. Martha Malapi-Wright, Ex-officio
USDA-APHIS martha.malapi-rwight@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

Submitted by
Georgia Eizenga

Publication Coordinator/Panel Chair Committee

Publication Coordinator Michael Salassi communicated by email with the panel chairs before the 2018 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. All changes in operating procedures will be incorporated into the RTWG guidelines for preparation of abstracts in the 2020 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 meeting of the Rice Technical Working Group (RTWG) Acreage Committee was called to order by Dustin Harrell at 8:30 a.m.

In attendance were committee members: Jarrod Hardke, University of Arkansas; Kent McKenzie of California Cooperative Rice Research Foundation; Dustin Harrell of Louisiana State University Agricultural Center; Bobby Golden of Mississippi State University; Christian DeGuzman of Southeast Missouir State; Ted Wilson of Texas A&M Agrilife; and Matthew Van Weelden of University of Flordia. Guests in attendance were: Lanier Nally, Hanlin Du, Joe Kepiro, Vern Vierra, and Anna McClung.

Harrell distributed and presented the minutes of the 2016 Acreage Committee meeting and asked for a motion to accept. Kent McKenzie moved and Christian DeGuzman seconded a motion to accept the minutes with the following corrections: The affiliations of Kent McKenzie and Donn Beigley should be the California Cooperative Rice Research Foundation and Southeast Missouri State, respectively. The motion carried.

The California report was presented by Kent McKenzie. He reported that the California estimates are based on foundation seed sales. In 2016, approximately 441,000 acres were planted to Calrose, 35,000 to short grain and 8,000 to long grain. Total acres planted were 521,000. In 2017, 445,000 total acres were planted. Approximately 360,000 were medium grain, 32,300 short grain, and 6,300 long grain. New varieties, M-210 and a Calrose medium grain and a Calrose Jasmine are expected to be available in 2018.

The Texas report was presented by Ted Wilson. Texas planted rice acres for 2016 and 2017 were approximately 191,000 and 170,000, respectively. Acres were predicted to increase by 15,000 in 2018. The top planted varieties were XL723 (31%), Presidio (20%), and CLXL745 (12%). Cheniere and Presidio showed high grain quality. A new Foundation release is Bernard. Bernard shows high grain quality and a 12% yield increase over Presidio.

The Arkansas report was given by Jarrod Hardke. Rice acres for 2015 and 2016 were estimated at 1.3 and 1.5 million acres respectively. A 27% decline in acres was observed in 2017 with an estimated 1.1 million acres planted. Top planted varieties over the past few years included CLXL745, Roy J, XP753, Diamond and CL153. Medium grains typically made up around 8% with Jupiter being the bulk of those acres. 2018 rice acres were estimated to be around 1.5 million acres. Approximately 50% of Arkansas acres are planted with Clearfield varieties and hybrids. Approximately 45% are planted to hybrids.

The Missouri report was given by Christian DeGuzman. Rice consultants provided variety information on varieties in 2017. Rice acres in 2016 and 2017 were estimated at 236,000 and 231,000, respectively. Approximately 98% were long grain varieties and 2% medium grain. Top planted varieties and hybrids included XP753, CLXL745, CL153, CL111, CL172, CL163, Diamond, RoyJ, LaKast, Wells and Jupiter.

The Mississippi report was given by Bobby Golden. The 2016 rice acres were approximately 196,000 up from 150,000 in 2015. Hybrids made up 54% with XP7523 and CLXL745 making up the largest acres. Rice acres in 2017 were approximately 114,000 which was noted to be the smallest rice acreage in Mississippi since the allotment program. Hybrids made up 50% of the acres and rice varieties and hybrids with the Clearfield technology made up 63%. Long grains made up 99% of the acres. 2018 acres were estimated to increase to 150,000. A new Clearfield long grain, currently identified as RU1504083, is expected to be released in the future. It has a 25% yield increase over CL163.

The Florida report was given by Matthew Van Weelden. Crop consultants with the Florida Crystals provided the estimates. 2016 and 2017 acres were 21,848 and 28,370, respectively. Taggart (26%), Mermentau (25%), Cheniere (18%), and LaKast (11%) made up the bulk of the acres in 2016. Roy J (29%), Rex (23%), La Kast (15%), and Diamond (9%) made up the majority of the acres in 2017.

Dustin Harrell gave the report for Louisiana. Acres in Louisiana for 2016 and 2017 were approximately 432,000 and 391,000, respectively. Long grains made up about 94% while medium grains made up approximately 5% in 2016. The top grown varieties and hybrids in 2016 included CL111 (36%), Cheniere (13%), CLXL745 (12.5%), Mermentau (10%), XP753 (6%), CLXL 729 (5%), and CL161 (4.6%). The top grown varieties and hybrids in 2017 included CL111 (25%), Cheniere (11%), CL153 (13%), Mermentau (10%), CLXL745 (10%), XP753 (5.5%), and CL151 (4.5%).

In other business, organic rice acres in each state were estimated by each state representative. California was estimated at 20,000 to 30,000 acres, Texas at 20,000 acres, Arkansas at 10,000, Louisiana at <3,000 with only two growers, and Mississippi at 500 acres. No other states reported any organic acres.

There being no further business, a motion was made to adjourn by Kent McKenzie and seconded by Jarrod Hardke. The motion passed and the meeting was adjourned at 11:50 p.m.

Submitted by
Dustin Harrell

Industry Committee

The Rice Technical Working Group Industry Committee again held a successful luncheon at the 37th RTWG meetings in Long Beach, California, on Tuesday, February 20, 2018. 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 2018 Industry luncheon met all of these goals. The luncheon was attended by approximately 250 guests who heard Mr. Jim Morris, Communications Manager for the California Rice Commission. Jim spoke about the importance of using various outlets to get our message as a rice industry to the public, opinion leaders, legislatures and the media. The story of rice is a good one and we need to adapt to and use current avenues of communication (social media) to reach a broad audience.

The Industry Committee would like to thank Dr. Lee Tarpley and Dr. Bruce Linquist for their assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 38th RTWG meetings hosted by Mississippi in 2020.

Submitted by
Pat Clay

2016 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2015 Acreage	2016 Acreage	MEDIUM GRAIN		LONG GRAIN									
			Jupiter	Others[2]	CL111	CL151	LaKast	Mermentau	CLXL729	CLXL745	CLXL756	XP753	Roy J	Others[2]
Arkansas	86,669	90,193	3,299	451	1,735	8,896	5,868	3	1,182	30,599	2,206	21,481	9,780	4,693
Ashley	9,105	8,923	705	0	0	0	0	0	740	2,684	2,388	0	2,406	0
Chicot	27,057	35,524	0	0	3,414	746	549	3,610	5,011	9,531	4,983	2,507	738	4,434
Clay	69,905	82,535	6,144	986	3,018	26,617	21,797	0	0	13,511	0	3,790	2,946	3,724
Craighead	66,874	70,876	10,222	0	0	17,484	0	0	0	6,503	0	18,105	18,562	0
Crittenden	43,842	63,483	1,561	1,881	0	2,752	449	0	3,577	10,339	816	12,175	26,067	3,867
Cross	84,001	99,540	7,582	0	3,052	14,843	15,363	357	687	8,496	516	12,424	29,845	6,375
Desha	17,226	21,509	2,440	813	0	0	1,333	0	312	4,874	1,248	3,459	3,224	3,805
Drew	9,550	13,590	0	0	0	0	0	0	1,224	4,438	3,949	0	3,979	0
Faulkner	511	3,552	0	0	0	355	0	0	0	1,243	0	1,066	533	355
Greene	66,208	80,237	2,647	72	790	29,692	0	0	0	32,352	0	8,496	132	6,056
Independence	9,974	10,805	255	0	0	1,125	0	4,584	0	3,577	0	0	1,264	0
Jackson	82,216	113,446	9,687	7,013	3,116	15,937	12,816	0	701	23,842	1,019	9,643	24,454	5,219
Jefferson	64,767	75,313	696	0	0	3,731	23,477	0	2,985	17,162	0	13,431	5,969	7,862
Lafayette	3,546	4,751	0	0	0	950	0	0	0	1,900	0	1,900	0	0
Lawrence	91,554	104,971	2,946	12,819	1,595	17,448	2,361	2,214	0	27,219	1,239	20,938	3,490	12,703
Lee	21,744	25,228	1,136	0	328	5,591	5,184	131	0	328	0	131	12,102	296
Lincoln	21,016	22,872	0	0	434	434	0	0	434	2,818	5,203	13,550	0	0
Lonoke	80,916	90,233	1,210	187	1,034	5,065	0	0	8,580	35,430	0	18,270	10,488	9,968
Mississippi	47,953	64,018	1,053	0	0	0	0	67	0	32,150	0	23,862	6,751	134
Monroe	48,728	52,591	2,160	0	0	1,180	6,419	0	6,631	5,878	0	10,285	18,042	1,995
Phillips	16,094	32,151	279	0	400	400	5,005	7,728	801	801	0	1,301	14,635	801
Poinsett	110,824	121,335	21,760	979	1,336	29,780	3,972	2,444	0	12,666	0	7,456	29,409	11,533
Pope	2,186	2,798	0	0	0	0	878	0	713	713	0	0	0	494
Prairie	61,743	64,137	7,655	741	2,632	2,777	2,464	1,742	5,644	22,381	0	4,965	8,014	5,120
Pulaski	3,799	3,920	0	0	0	392	0	0	0	1,960	0	784	784	0
Randolph	30,009	33,646	8,945	0	967	2,441	2,296	0	2,900	7,372	0	8,725	0	0
St. Francis	37,462	42,451	57	2,854	20	5,901	3,193	544	1,457	755	5	1,246	26,404	15
White	10,073	9,569	1,150	0	0	0	0	0	1,172	2,695	0	2,999	761	792
Woodruff	50,874	61,186	2,720	492	836	6,180	7,051	709	9,493	12,441	0	5,800	15,465	0
Others[3]	2,746	8,187	0	0	0	736	0	190	0	2,475	0	2,607	910	1,268
Unaccounted[4]	5,596	7,433												7,433
2016 Total		1,521,000	96,309	29,288	24,706	201,452	120,476	24,323	54,244	339,136	23,570	231,398	277,155	98,942
2016 Percent		100.00%	6.33%	1.93%	1.62%	13.24%	7.92%	1.60%	3.57%	22.30%	1.55%	15.21%	18.22%	6.51%
2015 Total	1,286,000		184,910	51,076	48,751	159,837	64,460	53,015	40,804	256,492	n/a	186,673	168,677	71,304
2015 Percent	100.00%		14.38%	3.97%	3.79%	12.43%	5.01%	4.12%	3.17%	19.94%	n/a	14.52%	13.12%	5.54%

[1] - Harvested acreage. Source: USDA-NASS, 2017. [2] - Other varieties: AB647, Antonio, Catahoula, Cheniere, Cocodrie, CL152, CL153, CL163, CL172, CL271, CL272, Caffey, Della-2, Diamond, Francis, Jazzman-2, Presidio, Rex, RT XL723, RT XL760, RT XP754, Spring, Taggart, Titan, and Wells. [3] - Other counties: Clark, Conway, Franklin, Hot Spring, Little River, Miller, Perry, and Yell.
[4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2017 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2016 Acreage	2017 Acreage	MEDIUM GRAIN			LONG GRAIN								
			Jupiter	Titan	Others[2]	CL151	CL153	CL172	Diamond	CLXL729	CLXL745	CLXL756	XP753	Others[2]
Arkansas	90,193	66,009	1,324	2,276	1,523	1,384	3,296	892	7,453	1,266	20,296	15,345	225	10,729
Ashley	8,923	4,092	0	0	0	0	0	0	0	0	4,092	0	0	0
Chicot	35,524	20,441	0	0	717	1,639	3,421	0	0	0	6,190	3,721	0	4,752
Clark	2,102	2,181	0	0	0	0	0	0	0	0	0	0	0	2,181
Clay	82,535	63,882	8,121	445	756	11,447	15,380	553	3,377	1,107	9,826	5,820	6	7,111
Craighead	70,876	56,526	6,687	0	1,933	3,624	9,421	10,392	0	0	12,537	10,777	0	1,196
Crittenden	63,483	41,026	6,040	610	0	0	273	0	2,102	1,990	5,174	13,900	9,290	1,823
Cross	99,540	61,513	7,588	4,880	406	5,357	3,977	3,947	6,151	407	5,231	9,202	4,416	10,017
Desha	21,509	9,162	0	0	171	0	29	392	20	0	695	2,160	2,198	3,496
Drew	13,590	8,138	0	0	0	0	0	2,594	0	0	3,039	357	0	2,149
Greene	80,237	67,214	2,310	0	0	6,071	14,914	0	7,237	108	17,601	5,939	0	13,035
Independence	10,805	7,274	1,245	0	0	641	321	0	641	0	2,245	577	641	962
Jackson	113,446	77,199	11,534	6,090	1,380	8,237	4,330	0	12,203	0	7,996	12,025	5,456	8,055
Jefferson	75,313	55,105	452	0	0	0	2,494	0	0	613	14,511	16,463	12,100	8,472
Lafayette	4,751	4,798	0	0	0	0	720	720	0	0	0	960	0	2,399
Lawrence	104,971	88,301	10,196	1,945	1,650	11,553	15,161	11,807	11,463	0	668	2,021	0	21,854
Lee	25,228	7,345	0	820	0	0	0	0	2,803	0	0	1,693	1,997	0
Lincoln	22,872	15,068	0	0	0	0	0	0	0	0	5,910	9,157	0	0
Lonoke	90,233	79,670	2,991	0	0	562	1,773	0	5,144	4,682	19,534	21,819	4,070	19,758
Mississippi	64,018	48,965	0	0	1,574	5,687	3,808	0	24	0	13,840	22,236	0	1,904
Monroe	52,591	37,228	1,751	1,883	275	0	784	1,075	7,158	1,232	4,641	4,735	3,084	10,608
Phillips	32,151	13,473	641	0	0	855	0	0	998	0	0	3,564	5,133	2,281
Poinsett	121,335	91,741	24,674	1,708	2,437	8,274	10,319	333	15,013	0	12,503	2,884	7,709	5,957
Pope	2,798	2,525	0	0	0	0	0	0	0	0	746	0	0	1,779
Prairie	64,137	54,434	5,528	2,368	210	701	3,090	1,640	2,891	5,354	16,398	6,199	751	9,281
Pulaski	3,920	4,917	0	0	0	0	0	0	2,399	0	0	0	0	2,499
Randolph	33,646	28,066	0	7,922	0	5,630	0	0	657	1,783	5,629	3,978	0	2,467
St. Francis	42,451	25,981	1,634	2,278	0	0	7	0	836	0	8,867	4,509	2,676	5,173
White	9,569	6,013	1,211	0	0	0	0	0	656	273	1,087	362	333	2,090
Woodruff	61,186	46,473	4,407	389	0	2,924	4,954	5,563	5,135	11,704	3,827	958	2,254	4,357
Others[3]	9,638	5,981	0	0	0	697	0	155	119	0	1,931	517	1,111	1,450
Unaccounted[4]	7,433	3,262												2,018
2017 Total		1,104,000	98,333	33,615	13,032	75,283	98,473	40,062	94,480	30,520	205,015	181,879	63,453	169,855
2017 Percent		100.00%	8.91%	3.04%	1.18%	6.82%	8.92%	3.63%	8.56%	2.76%	18.57%	16.47%	5.75%	15.39%
2016 Total	1,521,000		96,309	1,037	28,840	201,452	1,118	2,758	2,727	54,244	339,136	231,398	277,155	284,825
2016 Percent	100.00%		6.33%	0.07%	1.90%	13.24%	0.07%	0.18%	0.18%	3.57%	22.30%	15.21%	18.22%	18.73%

[1] - Harvested acreage. Source: USDA-NASS, 2018. [2] - Other varieties: LaKast, RT CLXP756, Wells, CL111, RT XL760, Taggart, Cheniere, RT 7311 CL, Francis, RT XL723, RT Gemini 214 CL, CL272, RT XP754, CL163, Mermentau, Jazzman-2, Rex, AB647, Caffey, Della-2, Bengal, Antonio, Catahoula, Thad, Spring, Presidio, and Jazzman. [3] - Other counties: Conway, Faulkner, Franklin, Hot Springs, Little River, Miller, Perry, and Yell. [4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2016 & 2017 CALIFORNIA RICE ACREAGE BY VARIETY SUMMARY

Variety	2016			2017		
	Seed Acres[1]	Percentage	Estimated Acres[2]	Seed Acres[1]	Percentage	Estimated Acres[2]
M-104	250	1.3%	5719	103	0.5%	1967
M-105	1849	9.6%	66403	2336	12.4%	44613
M-202	819	4.2%	18736	0	0.0%	trace
M-205	2086	10.8%	47721	2061	10.9%	39361
M-206	9102	47.2%	235023	8425	44.7%	160902
M-208	299	1.6%	6840	96	0.5%	1833
M-209	3408	17.7%	27065	4467	23.7%	85311
M-401	1316	6.8%	30106	1219	6.5%	23281
M-402	148	0.8%	3386	143	0.8%	2731
Medium Grain	19277	100.0%	441000	18850	100.0%	360000
S-102	758	41.3%	14731	189	14.4%	4664
Calhikari-201	87	4.7%	1691	85	6.5%	2097
Calhikari-202	137	7.5%	2662	95	7.3%	2344
Calmochi-101	755	41.1%	14673	883	67.5%	21788
Calmochi-203	100	5.4%	1943	57	4.4%	1406
Calamylow-201	0	0.0%	75	0	0.0%	trace
Short Grain	1837	100.0%	35700	1309	100.0%	32300
L-206	123	19.8%	1602	67	17.3%	1090
L-207	124	19.9%	1615	9	2.4%	151
A-201	153	24.6%	1992	205	52.9%	3335
A-301	45	7.2%	586	0	0.0%	trace
Calmati-202	49	7.9%	638	0	0.0%	trace
A-202	128	20.6%	1667	106	27.4%	1724
Long Grain	622	100.0%	8100	387	100.0%	6300
NASS CA Acres						
Medium		90.6%	490000		89.9%	400000
Short		7.8%	42000		8.5%	38000
Long		1.7%	9000		1.6%	7000
Total		100.0%	541000		100.0%	445000

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

[2] Acreage estimated based on seed production of these varieties assuming they account for 90% of the medium and long grains and 85% of the short grain California planted acres reported by NASS.

Subtotals may not match due to new releases that are in the early stages of seed production. The remaining percentage are assumed to be planted to proprietary, Japanese short grains, or older CCRRF varieties not in seed production.

2016 LOUISIANA RICE ACREAGE SUMMARY
All Classes

Parish	2015 Total	2016 Total	Long Grain	Medium Grain	Special Purpose	Percent of State Total (by Parish)
Acadia	81,847	83,598	81,279	2,119	200	19
Allen	13,628	15,646	15,238	308	100	4
Avoyelles	12,096	13,666	13,617	49	0	3
Beauregard	1,039	554	554	0	0	0
Calcasieu	12,673	12,291	12,291	0	0	3
Caldwell	567	1,142	1,142	0	0	0
Cameron	11,314	11,415	11,277	0	138	3
Catahoula	1,319	3,646	3,646	0	0	1
Concordia	7,244	12,134	12,134	0	0	3
East Carroll	2,035	2,085	1,419	270	396	0
Evangeline	40,701	43,970	41,334	2,636	0	10
Franklin	2,949	4,203	4,056	0	147	1
Iberia	1,033	859	859	0	0	0
Iberville	0	113	113	0	0	0
Jefferson Davis	75,669	81,013	75,444	5,368	200	19
Lafayette	762	931	638	293	0	0
Madison	6,338	8,239	6,227	2,012	0	2
Morehouse	31,532	27,504	21,826	5,678	0	6
Natchitoches	3,481	3,466	3,466	0	0	1
Ouachita	7,569	6,136	3,380	1,941	815	1
Pointe Coupee	1,397	1,678	1,678	0	0	0
Rapides	8,560	9,832	9,741	91	0	2
Red River	416	406	406	0	0	0
Richland	5,308	4,768	3,864	0	904	1
St. Landry	23,968	24,051	23,182	869	0	6
St. Martin	3,502	4,041	4,041	0	0	1
St. Mary	0	216	216	0	0	0
Tensas	3,427	4,342	4,342	0	0	1
Vermilion	49,901	48,857	48,578	279	0	11
West Baton Rouge	508	580	580	0	0	0
West Carroll	1,521	787	787	0	0	0
Total Acreage	412,303	432,168	407,355	21,913	2,900	100
Percent of Total	100	100	94.26	5.07	0.67	100

2016 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Long Grain

Parish	2016 Total	Long Grain	Variety														Hybrid			
			Aura	Catahoula	Cheniere	Cocodrie	LaKast	Mermentau	Presidio	Roy J	CL111	CL151	CL152	CL153	CL163	CL172	CLXL729	CLXL745	XP753	Hybrid NS[1]
Acadia	83,598	81,279	350	150	7,541	1,562	0	17,784	300	0	34,926	6,121	875	0	0	0	3,215	4,706	3,749	0
Allen	15,646	15,238	0	0	565	0	0	1,985	0	0	6,743	700	235	0	0	0	1,485	2,310	1,215	0
Avoyelles	13,666	13,617	0	136	3,348	159	0	285	0	0	3,419	0	0	70	0	0	0	3,111	130	2,959
Beauregard	554	554	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	344	185	0
Calcasieu	12,291	12,291	0	0	1,069	220	0	1,389	0	0	4,612	1,768	0	0	123	0	0	2,950	160	0
Caldwell	1,142	1,142	0	0	0	0	0	0	0	0	1,142	0	0	0	0	0	0	0	0	0
Cameron	11,415	11,277	609	0	0	0	0	2,762	0	0	1,695	0	0	0	0	0	474	5,569	0	168
Catahoula	3,646	3,646	0	0	1,654	0	0	0	0	0	0	47	0	0	0	0	0	761	0	1,184
Concordia	12,134	12,134	0	0	650	0	0	0	0	0	670	320	0	0	0	0	1,250	6,270	1,620	1,354
East Carroll	2,085	1,420	0	0	313	0	0	0	0	0	521	0	0	0	0	0	0	586	0	0
Evangeline	43,970	41,334	0	0	4,960	1,000	0	4,546	0	0	16,534	2,066	0	0	0	0	9,735	1,243	1,250	0
Franklin	4,203	4,056	0	0	702	0	0	0	0	0	0	0	0	0	158	0	0	3,072	0	124
Iberia	859	859	0	0	540	0	0	64	0	0	0	0	115	0	0	0	0	140	0	0
Iberville	113	113	0	0	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	81,013	75,444	0	100	4,000	1,500	0	7,000	200	0	30,982	5,890	850	0	2,422	0	3,500	10,000	8,500	500
Lafayette	931	638	0	0	0	0	0	125	0	0	345	92	0	0	0	0	0	76	0	0
Madison	8,239	6,227	0	0	3,113	0	0	0	0	0	312	0	0	0	0	0	0	1,557	1,245	0
Morehouse	27,504	21,826	0	0	5,893	0	380	0	0	0	8,512	524	0	0	710	0	0	4,934	873	0
Natchitoches	3,466	3,466	0	0	1,925	0	0	0	0	0	1,541	0	0	0	0	0	0	0	0	0
Ouachita	6,136	3,380	0	0	460	0	240	0	0	1,035	1,225	0	0	0	420	0	0	0	0	0
Pointe Coupee	1,678	1,678	0	0	0	471	0	0	0	0	0	0	0	0	0	0	0	402	805	0
Rapides	9,832	9,741	0	100	5,604	300	0	0	0	0	3,737	0	0	0	0	0	0	0	0	0
Red River	406	406	0	0	300	0	0	0	0	0	106	0	0	0	0	0	0	0	0	0
Richland	4,768	3,864	0	0	641	0	0	0	0	0	585	0	890	0	882	0	0	866	0	0
St. Landry	24,051	23,182	0	0	4,900	0	0	1,141	93	0	9,085	487	3,538	0	0	98	195	1,994	1,651	0
St. Martin	4,041	4,041	0	0	239	140	0	0	0	0	300	144	660	0	0	0	0	0	2,558	0
St. Mary	216	216	0	0	111	0	0	105	0	0	0	0	0	0	0	0	0	0	0	0
Tensas	4,342	4,342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,257	1,845	240
Vermilion	48,857	48,578	0	334	8,275	161	0	6,929	0	300	28,564	1,795	947	0	0	0	694	263	316	0
West Baton Rouge	580	580	0	0	480	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
West Carroll	787	787	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	787	0	0
Total	432,188	407,355	959	820	57,396	5,513	620	44,140	593	1,335	155,556	19,954	8,110	70	4,715	98	20,548	54,297	26,102	6,529
Percent (of Long Grain)		100	0.24	0.20	14.09	1.35	0.15	10.84	0.15	0.33	38.19	4.90	1.99	0.02	1.16	0.02	5.04	13.33	6.41	1.60
Percent (of all acres)		94.26	0.22	0.19	13.28	1.28	0.14	10.21	0.14	0.31	35.99	4.62	1.88	0.02	1.09	0.02	4.75	12.56	6.04	1.51
Total									299,879									107,476		
Percent (of Long Grain)									73.62									26.38		
Percent (of all acres)									69.39									24.87		

[1] Hybrid NS includes hybrid seed rice production not specified, RT silver, XP754, Express, XL723, CLXL756, and XP760.

2016 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Medium Grain

Parish	2016 Total	Medium Grain	Variety		
			Caffey	Jupiter	CL272
Acadia	83,598	2,119	274	1,745	100
Allen	15,646	308	35	273	0
Avoyelles	13,666	49	0	49	0
Beauregard	554	0	0	0	0
Calcasieu	12,291	0	0	0	0
Caldwell	1,142	0	0	0	0
Cameron	11,415	0	0	0	0
Catahoula	3,646	0	0	0	0
Concordia	12,134	0	0	0	0
East Carroll	2,085	270	0	270	0
Evangeline	43,970	2,636	132	2,504	0
Franklin	4,203	0	0	0	0
Iberia	859	0	0	0	0
Iberville	113	0	0	0	0
Jefferson Davis	81,013	5,368	520	4,698	150
Lafayette	931	293	0	293	0
Madison	8,239	2,012	0	2,012	0
Morehouse	27,504	5,678	0	5,678	0
Natchitoches	3,466	0	0	0	0
Ouachita	6,136	1,941	0	1,941	0
Pointe Coupee	1,678	0	0	0	0
Rapides	9,832	91	0	91	0
Red River	406	0			
Richland	4,768	0	0	0	0
St. Landry	24,051	869	0	869	0
St. Martin	4,041	0	0	0	0
St. Mary	216	0	0	0	0
Tensas	4,342	0	0	0	0
Vermilion	48,857	279	66	143	70
West Baton Rouge	580	0	0	0	0
West Carroll	787	0	0	0	0
Total	432,168	21,913	1,027	20,566	320
Percent (of medium grain)		100	4.69	93.85	1.46
Percent (of all acres)		5.07	0.24	4.76	0.07

2016 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Special Purpose

Parish	2016 Total	Special Purpose	Variety			
			Della-2	Hidalgo	Jazzman-2	Sabine
Acadia	83,598	200	0	0	200	0
Allen	15,646	100	50	0	50	0
Avoyelles	13,666	0	0	0	0	0
Beauregard	554	0	0	0	0	0
Calcasieu	12,291	0	0	0	0	0
Caldwell	1,142	0	0	0	0	0
Cameron	11,415	138	0	0	138	0
Catahoula	3,646	0	0	0	0	0
Concordia	12,134	0	0	0	0	0
East Carroll	2,085	396	0	0	0	396
Evangeline	43,970	0	0	0	0	0
Franklin	4,203	147	0	0	147	0
Iberia	859	0	0	0	0	0
Iberville	113	0	0	0	0	0
Jefferson Davis	81,013	200	0	0	200	0
Lafayette	931	0	0	0	0	0
Madison	8,239	0	0	0	0	0
Morehouse	27,504	0	0	0	0	0
Natchitoches	3,466	0	0	0	0	0
Ouachita	6,136	815	0	0	0	815
Pointe Coupee	1,678	0	0	0	0	0
Rapides	9,832	0	0	0	0	0
Red River	406	0	0	0	0	0
Richland	4,768	904	0	321	170	413
St. Landry	24,051	0	0	0	0	0
St. Martin	4,041	0	0	0	0	0
St. Mary	216	0	0	0	0	0
Tensas	4,342	0	0	0	0	0
Vermilion	48,857	0	0	0	0	0
West Baton Rouge	580	0	0	0	0	0
West Carroll	787	0	0	0	0	0
Total	432,168	2,900	50	321	905	1,624
Percent (of Special Purpose)		100	1.72	11.07	31.21	56.00
Percent (of all acres)		0.67	0.01	0.07	0.21	0.38

2016 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Clearfield

Parish	2016 Total	Clearfield	Variety							Hybrid			
			CL111	CL151	CL152	CL153	CL163	CL172	CL272	CLXL729	CLXL745	CLXL756	RT Silver
Acadia	83,598	49,943	34,926	6,121	875	0	0	0	100	3,215	4,706	0	0
Allen	15,646	11,473	6,743	700	235	0	0	0	0	1,485	2,310	0	0
Avoyelles	13,666	6,600	3,419	0	0	70	0	0	0	0	3,111	0	0
Beauregard	554	344	0	0	0	0	0	0	0	0	344	0	0
Calcasieu	12,291	9,453	4,612	1,768	0	0	123	0	0	0	2,950	0	0
Caldwell	1,142	1,142	1,142	0	0	0	0	0	0	0	0	0	0
Cameron	11,415	7,906	1,695	0	0	0	0	0	0	474	5,569	0	168
Catahoula	3,646	808	0	47	0	0	0	0	0	0	761	0	0
Concordia	12,134	8,750	670	320	0	0	0	0	0	1,250	6,270	0	240
East Carroll	2,085	1,107	521	0	0	0	0	0	0	0	586	0	0
Evangeline	43,970	29,578	16,534	2,066	0	0	0	0	0	9,735	1,243	0	0
Franklin	4,203	3,354	0	0	0	0	158	0	0	0	3,072	0	124
Iberia	859	255	0	0	115	0	0	0	0	0	140	0	0
Iberville	113	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	81,013	54,294	30,982	5,890	850	0	2,422	0	150	3,500	10,000	500	0
Lafayette	931	513	345	92	0	0	0	0	0	0	76	0	0
Madison	8,239	1,869	312	0	0	0	0	0	0	0	1,557	0	0
Morehouse	27,504	14,680	8,512	524	0	0	710	0	0	0	4,934	0	0
Natchitoches	3,466	1,541	1,541	0	0	0	0	0	0	0	0	0	0
Ouachita	6,136	1,645	1,225	0	0	0	420	0	0	0	0	0	0
Pointe Coupee	1,678	402	0	0	0	0	0	0	0	0	402	0	0
Rapides	9,832	3,737	3,737	0	0	0	0	0	0	0	0	0	0
Red River	406	106	106	0	0	0	0	0	0	0	0	0	0
Richland	4,768	3,223	585	0	890	0	882	0	0	0	866	0	0
St. Landry	24,051	15,395	9,085	487	3,538	0	0	98	0	195	1,994	0	0
St. Martin	4,041	1,104	300	144	660	0	0	0	0	0	0	0	0
St. Mary	216	0	0	0	0	0	0	0	0	0	0	0	0
Tensas	4,342	2,257	0	0	0	0	0	0	0	0	2,257	0	0
Vermilion	48,857	32,333	28,564	1,795	947	0	0	0	70	694	263	0	0
West Baton Rouge	580	100	0	0	0	0	0	0	0	0	100	0	0
West Carroll	787	787	0	0	0	0	0	0	0	0	787	0	0
Total	432,168	264,698	155,556	19,954	8,110	70	4,715	98	320	20,548	54,297	500	532
Percent (of Clearfield)		100	58.77	7.54	3.06	0.03	1.78	0.04	0.12	7.76	20.51	0.19	0.20
Percent (of all acres)		61.25	35.99	4.62	1.88	0.02	1.09	0.02	0.07	4.75	12.56	0.12	0.12
Total			188,822							75,876			
Percent (of Clearfield)			71.33							28.67			
Percent (of all acres)			43.69							17.56			

2016 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Hybrid

Parish	2016 Total	Hybrid	Clearfield		Non-Clearfield	Hybrid NS[1]
			CLXL729	CLXL745	XP753	(not-specified)
Acadia	83,598	11,670	3,215	4,706	3,749	0
Allen	15,646	5,010	1,485	2,310	1,215	0
Avoyelles	13,666	6,200	0	3,111	130	2,959
Beauregard	554	529	0	344	185	0
Calcasieu	12,291	3,110	0	2,950	160	0
Caldwell	1,142	0	0	0	0	0
Cameron	11,415	6,211	474	5,569	0	168
Catahoula	3,646	1,945	0	761	0	1,184
Concordia	12,134	10,494	1,250	6,270	1,620	1,354
East Carroll	2,085	586	0	586	0	0
Evangeline	43,970	12,228	9,735	1,243	1,250	0
Franklin	4,203	3,196	0	3,072	0	124
Iberia	859	140	0	140	0	0
Iberville	113	0	0	0	0	0
Jefferson Davis	81,013	22,500	3,500	10,000	8,500	500
Lafayette	931	76	0	76	0	0
Madison	8,239	2,802	0	1,557	1,245	0
Morehouse	27,504	5,807	0	4,934	873	0
Natchitoches	3,466	0	0	0	0	0
Ouachita	6,136	0	0	0	0	0
Pointe Coupee	1,678	1,207	0	402	805	0
Rapides	9,832	0	0	0	0	0
Red River	406	0	0	0	0	0
Richland	4,768	866	0	866	0	0
St. Landry	24,051	3,840	195	1,994	1,651	0
St. Martin	4,041	2,558	0	0	2,558	0
St. Mary	216	0	0	0	0	0
Tensas	4,342	4,342	0	2,257	1,845	240
Vermilion	48,857	1,273	694	263	316	0
West Baton Rouge	580	100	0	100	0	0
West Carroll	787	787	0	787	0	0
Total	432,168	107,476	20,548	54,297	26,102	6,529
Percent (of Hybrid)		100	19.12	50.52	24.29	6.07
Percent (of all acres)		24.87	4.75	12.56	6.04	1.51
Total			74,845		26,102	6,529
Percent (of Hybrid)			69.64		24.29	6.07
Percent (of all acres)			17.32		6.04	1.51

1 Hybrid NS includes hybrid seed rice production not specified, RT silver, XP754, Express, XL723, CLXL756, and XP760

2017 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

COUNTY	2016	2017	% M C	LONG GRAIN																MEDIUM	OTHER
	ACREAGE	ACREAGE	Ratooned	XL723	PRESIDIO	CLXL745	CL153	XL753	TEXMATI	CL111	CL151	CHENIERE	RTLG	BASMATI	MERMENTAU	RT7311	XL760	DIXIEBELLE	RT7312	JUPITER	
East Zone																					
Brazoria	16389	15402																			
Chambers	19726	23376	49		5704	8158			5704					538						3273	
Galveston	1778	389																			
Hardin	556	460																			
Jefferson	19642	20217	80	3417		1132	6186	2042		5924			1516								
Liberty	7678	7055	80	2495		2495	761				1022			282							
Orange																					
East Total	65769	66899	66	7810	7533	15568	9176	2697	7533	7824	1351		2002	1083						4322	
Northwest Zone																					
Austin	2133	2089	70	656				1433													
Colorado	36764	32482	62	18060	8673	1624	292	1527	260		97	715			97	357	455	65			260
Fort Bend	5456	4487	86	902	1526		431	776										341			512
Harris		251			251																
Lavaca	2710	2673	100	2179	494																
Robertson																					
Waller	4895	4311	100	1267	435	819	129	1354				86				160			60		
Wharton	41632	35892	81	13590	5880	2223	3836	2976	36		5056	1435	323		537						
Lamar																					
NorthWest Tot	93590	82185	75	36651	17258	4666	4691	8065	296		5156	2235	323		636	517	455	406	60		771
Southwest Zone																					
Calhoun	1074																				
Jackson	11696	8481	33	3104	4028							1348									
Matagorda	15944	10032	60	3828	4029		261		1914												
Victoria	2170	1451			1451																
Cameron																					
SouthWest Tot	30884	19964	48	6933	9508		261		1915			1347									
Northeast Zone																					
Bowie	644	810																			
Hopkins																					
Red River																					
Northeast Total	644	810																			
State Total	190887	189858	68	51640	34463	20331	14196	10814	9791	7861	6538	3599	2336	1088	639	519	457	408	60	4343	775

Mississippi Rice Variety Acreage Survey.

Variety	2015	2016	2017
CL111	11,961	3,943	800
CL151	16,110	12,381	3,600
CL152	10,848	1,966	
CL153			14,900
CL163	386	20,569	6,700
CL172			1,380
CLXl745	28,245	29,850	27,000
CLXL729	11,452	16,450	8,000
CLXL4534	3,421	19,453	9,000
XL753	21,743	33,000	6,000
XL723	2,586	7,450	6,400
Cheineire	3,022	3,100	1,500
Rex	21,653	32,000	15,000
Mermentau	8,054	6,000	2,000
Lakast	1,421	3,800	2,100
Other	4,810	6,000	9,800
Diamond			3,500
Total CL	82,423	104,612	71,380
Total Hybrid	63,289	106,203	56,400
Grand Total	145,712	195,962	114,180

Missouri Rice Acreage

2016 and 2017 Missouri Rice Acreage and Varieties

Planted acreage in Missouri in 2016 was 236,000 acres.
Long grain made up 98% of the area planted while 2% were medium grains.
There were no available data for specific varieties.
In 2017, Missouri planted 231,000 acres. The variety data came from major rice consultants in Missouri. The breakdown of varieties planted are shown below.

Hybrids
CLXL 745 = 11%
XP 753 = 16%
CL RT7311 = 10%

Medium grain
Caffey and Jupiter = 5%
Others = 2%

Long grain Clearfield
CL153 = 9%
CL 111 and CL 172 = 8%
CL 151 and CL 163 = 5%

Long grain conventional
Diamond = 17%
Roy J = 8%
Lakast = 5%
Wells = 4%

Florida Rice Varieties and Acreage

2016 Rice Census Data

Variety	Acreage
Cheniere	3,919
Express	185
Jupiter	278
LaKast	2,372
Mermentau	5,428
Rex	1,830
Roy J	2,014
Taggart	5,822
Total	**21,848**

2017 Rice Census Data

Variety	Acreage
Diamond	2,481
Express	55
Jazzman	281
LaKast	4,323
Mermentau	677
Mixed	36
Rex	6,613
Roy J	8,288
Roy J (Organic)	319
Taggart	959
Taggart (Organic)	140
Total	**28,370**

RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

THOMAS H. TAI, Chair; ED REDOÑA, Chair - Elect (2020); C. ANDAYA, N. BAISAKH, J. BARNABY, C. DE-GUZMAN, J. EDWARDS, G. EIZENGA, C. HARPER, J. KEPIRO, J. OARD, J. OKAMURO, A.M. MCCLUNG, K.S. MCKENZIE, X. SHA, S.O. SAMONTE, B. SCHEFFLER, R. TABIEN, L. TARPLEY, M. THOMSON, and L.T. WILSON, Participants.

High Priority Issues:

1. **Increasing support for next-generation breeding technologies, developing new and leveraging existing genetic resources, and establishing/ improving information infrastructure.** The panel recognized the increasing importance of new technologies such as gene editing, SNP haplotype selection, and automated phenotyping and the challenges to successfully implementing them. Among these challenges are improving communication and collaboration among research and breeding institutions and establishing the information infrastructure necessary to collect, manage, analyze, and disseminate large-scale genotypic and phenotypic data. Lessons from the continuing need to improve the efficiency and cost-effectiveness of high-throughput DNA marker technology underscore the importance of making substantive investments early on in the process of implementing next-generation breeding technologies.
2. **Emphasis on research aimed at dissecting gene and trait interactions in response to environmental and climate extremes.** The panel recognized the increasing impact of environmental and climate variability on rice productivity and quality. Abiotic and biotic stresses (e.g., water scarcity, increasing temperatures during critical developmental stages, and increasing pest and disease pressures) and the impact these are having on production practices are presenting new challenges for the breeding and genetics community. Potential solutions include increasing research on alternatives to traditional irrigation practices (such as alternate wetting and drying), investigating the rice microbiome, and exploring new targets for genetic analysis and varietal improvement to develop climate-resilient rice. Increased communication between research disciplines and institutions through funding of multi-disciplinary, multi-institutional, and multi-state projects are likely to be critical to making significant advances in the next 5-10 years.
3. **Need for increasing efforts to train and develop the next generation of agricultural scientists.** The panel noted the need to increase the number of rice breeders and geneticists. The community is facing a critical shortage of classical rice breeding expertise and educators needed to train the next generation of applied rice geneticists. Establishment of training block grants or fellowships for domestic graduate students may invigorate academic and breeding programs across the industry to address this serious concern.
4. **Emphasis on research to address factors affecting rice markets.** The panel recognized the need to increase rice crop value through improving all aspects of grain quality (i.e. eating/cooking, nutritional, milling yield, appearance). Support is needed for projects aimed at understanding the genetic and environmental factors affecting these traits using traditional and next-generation breeding/genetic technologies. Strengthening collaborations with cereal chemists, physiologists, agronomists, biochemists, and molecular biologists is needed to maintain competitiveness in the global market and to identify new areas for expansion such as high-value rice products.

Cooperation of rice breeders and geneticists with molecular geneticists, 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.

Current research and development should be continued and new research development initiated in the following areas:

Genetics
Additional information is needed on the mode of inheritance of economically important characters including plant productivity, ratooning, pest resistance, and stress tolerance. Understanding the genetic, epigenetic, physiological, morphological, and environmental factors that influence these traits is important for cultivar improvement. Basic research is needed to determine the factors influencing pollination and fertilization over a wide range of plant environments. Genetic control of the efficiency of solar energy conversion (photosynthetic efficiency, respiration losses, translocation rates, source-sink relationships, etc.) must be explored to determine if such factors can benefit the

development of superior yielding cultivars. 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)-Global.

Molecular Genetics and Biotechnology
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 microsatellites and SNPs are being used to map loci controlling economically important traits. A national effort to maintain and update databases, and genomic information from public resources is needed to provide breeders with the latest tools for genetic improvement. The technology should be applied to mapping the traits listed above that have not been studied. Particular attention needs to be focused on the continued development of SNP markers relevant to U.S. breeding efforts. Gene editing is considered an emerging tool that will complement traditional methods for gene discovery and validation and ultimately, germplasm and cultivar development. Genes for herbicide, resistance to pests and pathogens, and nutritional quality are being identified, transferred to elite lines for field evaluation by marker-assisted breeding, and explored as targets for gene editing for rapid trait improvement. Rice breeders should cooperate with molecular geneticists for proper evaluation and selection of lines that would benefit the rice industry. 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 Environmental and Climate Variability
Superior-yielding, widely adapted cultivars need to be developed that have increased tolerance to low soil nutrients, 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 fertilizer use efficiency. However, due to 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 their response to registered/experimental pesticides that 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 proven advantages in yield, disease resistances and adaptation in the U.S.; and has received wide interest from growers, processers, and researchers. Development of new hybrids that have high yield potential, improved resistance to diseases and insect pests, and the grain milling and cooking properties necessary to meet the needs of domestic and export markets is critical. 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 cutting edge genomic technologies. The world-wide USDA rice germplasm collection contains about 20,000 accessions introduced from 116 countries, provides a wide range of genetic diversity for distant crosses that are essential for yield heterosis. 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. The achievements from research should (1) improve selection efficiency for improved male sterile and restoring lines, (2) identify elite outcrossing characteristics for effective production of male sterile lines and hybrid seed, (3) increase understanding of GCA, as well as, SCA for maximum heterosis, (4) increase purified seed production of male sterile and restorer lines, and (5) determine genes associated with heterosis.

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 fungal races responsible for 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 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 continue. Germplasm resources for resistance to these diseases in various cultural systems and developing markers linked to disease resistance QTL should continue to be emphasized. 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)), rice delphacid (*Tagosodes orizicolus*) 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 through marker-assisted breeding should continue to be pursued. As germplasm lines are recovered from interspecific crosses, cooperative evaluation for disease resistance, insect resistance, and other traits important in commercial production is essential for their application to the U.S. rice industry. Data from these evaluations should be entered in GRIN-Global, GRAMENE or other appropriate databases.

Fertilizer Response

Factors that determine fertilizer (N-P-K) response and lodging resistance, and affect yield components are closely associated in determining total production and grain quality. These factors must be studied collectively in order to understand the effects of quality, quantity, and timing of fertilizer applications on plant growth and yield components. Efforts should be made to develop cultivars with enhanced fertilizer use efficiency.

Milling, Processing, Cooking, and Nutritional Characteristics

Basic studies are needed to learn more about the role of each constituent of the rice kernel in processing, cooking behavior, nutritional value, and health benefits. As these properties are more clearly delineated, new techniques, including bioassays, should be developed to evaluate breeding lines for these factors. These studies should be coordinated with attempts to genetically improve grain quality factors, including translucency, head rice yields, protein content, mineral composition, cooking properties, and resistant starch. Effort should be made to obtain industry feedback on breeding effectiveness for grain quality improvement. Standardization of methods for determination of physicochemical traits should include researchers from around the globe to ensure grain quality meets industry standards and expectations of international markets. There is increased interest in developing rice cultivars to target specialty markets, such as soft cooking rice, aromatics, waxy types, Jasmine and Basmati types, and Japanese premium quality rice. Research efforts need to be directed toward determining quality traits associated with various specialty rice varieties and the analytical methods needed for evaluation and understanding of the genotype x environment x management x processing interactions that impact character expression and 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 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 continue 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-Global, the USDA Rice World Collection public database.

Germplasm Evaluation, Enhancement, Conservation, and Distribution

Wide germplasm bases are needed and must be maintained for sustainable food production by increasing genetic diversity and decreasing production vulnerability. Increased efforts are needed to evaluate and maintain all entries in the active, working collection and to enter all descriptive data into GRIN-Global, the USDA Rice World Collection public database. All breeders and geneticists must make continued 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. The core strategy is an effective way to evaluate large germplasm collections phenotypically and genotypically. Various diversity panels should be developed to facilitate identification of novel alleles for traits of economic interest. Comprehensive evaluations of diversity panel for genome-wide association studies should be pursued by cooperative federal, state, and industry efforts. Molecular database information associated with these traits should be made available to public and private rice researchers. Efforts need to be made to develop high-throughput phenotyping methods, and statistical and bioinformatics methods of analysis to utilize the data. Characteristics desired in the germplasm have been described above. Development of germplasm with high yield, like found in indicas but with the grain quality standards required in the U.S. cultivars should be pursued.

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. This, 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 opportunities for rice breeders to interact with breeders of other crops for information exchange.

ECONOMICS AND MARKETING

L. NALLEY, Chair; L. FALCONER, Chair-Elect (2020); A. McKENZIEe, L. BERNAOLA, N. CHILDS, B. FERRARO, J. KEPIRO, R. SALDIAS, E. FERNANDER, M. SANGVINETTI, B. COATS, A. DURAND, and B. WATKINS, Participants.

Supply/Production Research

Explore the economic viability of alternative irrigation strategies (AWD and Row Rice). Specifically look at the water use efficiency per kg of rice produced. As alternative irrigation strategies are marketed as potentially GHG reducing its pertinent to look at the economic tradeoffs.

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

Develop and expand extension efforts to help disseminate information regarding AWD and Row Rice with regards to returns and the economic risks associated with non-traditional irrigation methods.

Develop and expand extension efforts to help disseminate information regarding organic rice production. Possibly produce production budgets for organic rice.

Analyze the economic impact (benefit-cost ratio) of new technology in rice production (Provisia, etc.).

Policy, Trade, Demand, and Marketing Research

Analyze Chinese rice policies. Current Chinese stocks are the equivalent of India's annual consumption. As such, if these stocks are released there could be market movements. Look at possible outcomes in changes in Chinese rice policy.

Analyze the evolution of the competitiveness of US rice in the Western Hemisphere. As rice quality becomes more of an issue in US exports look to see how Western Hemisphere markets will react in terms of import substitution.

Analyze the impacts of expanding consumption and production of large rice importing countries in West Africa.

Explore why rice futures markets are so thinly traded and what causes large basis in the market.

Identify expansion/contraction of US exports markets with regards to rice quality issues.

Explore how evolving environmental regulations/polices could change the economic landscape of rice production.

Evaluate potential impacts of international trade agreements on global rice trade and the competitiveness of the U.S. rice industry.

PLANT PROTECTION

L. ESPINO, Chair; T. ALLEN, Chair-Elect (2020); Y. JIA, D. GROTH, B. WILSON, J. VILLEGAS, M. MULCAHY, M. VANWEELDEN, L. TARPLEY, Y. WASHIME, T. GEBREMARIAM, N. BATEMAN, B. TRASH, G. LORENZ, and N. TAILLON

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. 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.

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.

Priority areas in which research should be continued or initiated are:

1. Cooperation with breeding programs should be continued for improved disease resistance in rice varieties and hybrids. Screening programs should use field, greenhouse, laboratory and genetic markers to identify and incorporate resistance genes. Diseases to be given significant priorities include blast, sheet blight, bacterial panicle blight, narrow brown leaf spot, kernel smut, stem rot, aggregate sheath spot, and false smut. Novel sources of resistance should be identified and developed for incorporation into rice germoplasm and varieties.

2. Research must be initiated and continued on biological strategies to manage rice disease and reduce dependency on chemical control.

Other priorities are:

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. 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.

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

4. Chemical, cultural and biological management options for bacterial panicle blight need more research. Intensive screening for higher levels of resistance is required. More research is needed to better understand host range, inoculum source and other aspects of the biology of bacterial panicle blight that contribute the epidemics of the disease.

5. 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.

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

7. 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.

8. Additional disease research should be conducted on hybrid rice, niche varieties, and organic systems to provide workable management recommendations for current and future producers. Research should be intiated on the understanding of the diseases and their biology and epidemiology of in organic rice production systems. Research efforts should be made to develop the profitable management options, including, but not limited to, varietal resistance, fertility, seed treatment, cover crop and biological control.

9. Encourage and assist in monitoring the potential development of fungicide resistance in the pathogen populations of sheath blight, narrown brown leaf spot and kernel smut.

10. More research is needed to improve the efficacy of genetic, chemical and cultural options for management of narrow brown leaf spot in the ratoon crop in Texas and Louisanna.

11. Continue studies on using genetic, chemical and cultural management options for improved management of kernel smut and false smut.

12. 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.

13. Research on alternate irrigation (alternate wetting and drying, furrow irrigation, and overhead (pivot) irrigation) and its effect on rice diseases should be encouraged.

14. Research should be initiated to investigate the microbiome to explore novel strategies to manage diseases in rice.

Insects and Other Animal Pests

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), and *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, *Mythimna unipuncta* (Haworth); western yellowstriped armyworm, *Spodoptera praefica* (Grote); 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; yellow sugarcane aphid, *Sipha flava* (Forbes); an exotic stink bug, *Oebalus ypsilongriseus* (DeGeer), found in Florida; sugarcane beetles, *Eutheola rugiceps* (LeConte); billbugs, *Sphenopherous* spp.; and thrips (various species). In 2015, the rice delphacid, *Tagosodes orizicolus* (Muir), was found attacking ratoon rice in Texas; however, the delphacid or its injury has not been detected again since then.

Pests other than insects can damage rice directly or indirectly. These include the panicle rice mite, *Steneotarsonemus spinki* Smiley; the tadpole shrimp, *Triops longicaudatus* (LeConte); crayfish, *Procambarus clarkii* (Girard); and the channeled apple snail, *Pomacea canaliculata* (Lamark). Birds trample and feed on seeds and sprouting and ripening rice. Rodents, through their burrowing activity, damage levees and can directly feed on rice plants.

Priority areas in which research should be continued or initiated are:

1. Conduct research and outreach that leads to the development and adoption of integrated pest management (IPM). Research on IPM includes studies on the biology and ecology of rice pests; the effects of agronomic practices on rice pests and their natural enemies; identification of pest resistant cultivars; assessing the role of natural enemies and pathogens, individually and collectively, in reducing rice pest populations; research to improve sampling and monitoring of rice pests; develop economic injury levels and damage thresholds; research on biological and chemical control compounds; and pesticide resistance management.

2. Monitor rice for possible introduction of exotic pests.

3. Study the environmental impacts of current and novel rice pest management tools.

POSTHARVEST QUALITY, UTILIZATION AND NUTRITION

Z. PAN, CHEN, Chair and Chair-Elect (2020), M.-H. CHEN, S. BOUE, R. FORD, M. LIMMER, J. HEUSCHELE, M. SMITH, J. BEAULIEU, Z. PENG, L. TARPLEY, participants.

Our group recommends three general research areas as top priorities followed with some specific recommendations related to harvest, processing, storage, quality and safety of rice.

Recommended Research Priorities:

1. Develop technologies, sensors, electronic systems and database for improving production efficiency, food safety, product quality and processing quality of rice, such as real-time monitoring and detection devices/systems for rice grain quality during harvest, insect occurrence during storage and grain quality during milling.
2. Study the rice quality (such as chalkiness) and safety (such as arsenic) from genetic, physiological, environmental and production management aspects to improve the rice quality.
3. Develop technologies for producing value added products, and reducing losses and increasing values in harvest, storage and processing.

Specific Recommendations:

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.

Identify available personnel to compile all data of released varieties and create a web-based database to store these data so that it is accessible to the public.

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 resistance management program for phosphine gas, a fumigant.

Determine mechanisms for head rice loss when rice is transferred.

Study the effects of post-harvest storage on grain quality and nutritional value.

Milling Characteristics

Compare the accuracies of milling results from standard laboratory milling and commercial milling.

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.

Utilization of Rice Components
Characterize the 1800 lines of USDA rice core collection for grain quality, disease resistance, and biotic and abiotic stresses.

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 of nutritional importance, 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 and on the exclusion of toxic compounds.

RICE CULTURE

R. MUTTERS, Chair; B. GOLDEN, Chair-Elect (2020); B. LINQUIST, L. TARPLEY, D. HARRELL, C. WILSON, T. WILSON, J. HILL, and G. LAHUE; 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:

In order to secure a safe and abundant food supply, we must intensify the production on the existing agricultural land base while exercising responsible environmental stewardship. Broad categories of recommended research are: (1) Develop management practices to achieve the genetic yield and grain quality potentials of our existing and future rice cultivars; (2) Increase production efficiencies to ensure on-farm economic viability while minimizing the adverse impacts on our air, water, and soil qualities; and (3) Modernize current best management practices by upscaling and integrating emerging technologies into on-farm and post-harvest production practices.

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.

Develop tools and apps that allow growers to remotely access field conditions such as soil moisture and nitrogen status of crop.

Evaluate the adoption of cover crops and the cultural practices used for cover crops in rice production systems.

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 silicon deficient soils, silicon 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 relationships between greenhouse gases, global climate change, and rice production. Quantify the potential to mitigate field-to-atmosphere gaseous losses from rice fields.

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 relationships of global climactic change and rice production.

RICE WEED CONTROL AND GROWTH REGULATION

K. AL-KHATIB, Chair, J. BOND, Chair-Elect (2020), L. TARPLEY, E. WEBSTER, S. OHADI, V. LANGSTON, A. CESEKI, A. GODSAR, D. DICKEY, C. SANDOSKI, L. GALVIN, D. GEALY and K. DRIVER; 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.

Research Priorities

Identification and monitoring of Echinochloa species spread California and mid-south States

Weed management under new water management strategies

Chemical and non-chemical management of herbicide resistant weeds

Weed biology and competition studies

Work with NIFA to create funding opportunity for weed biology and management support in rice.

Extension priorities

Online training for extension and interactive tools

Abstracts of Papers from the Rice Irrigation: Water Use and Greenhouse Gas Management Symposium
Symposium Moderator: Ben Runkle

Methane Reductions, Carbon Markets and Rice Water Management

Chambers, A.S.

In the summer of 2017, the Microsoft Corporation purchased carbon credits generated by rice growers in Arkansas and California. These offset credits were the product of a strategic partnership funded by the U.S. Department of Agriculture's Natural Resources Conservation Service's (NRCS) Conservation Innovation Grants (CIGs) program. The carbon credit transaction represents years of efforts from NRCS and numerous partner organizations. Environmental markets, such as carbon markets and water quality markets, demonstrate advancements in valuation of ecosystem services that are often viewed as market externalities, public goods that are either undervalued or assigned a zero value in our national economy.

For more than a decade NRCS has been a federal leader promoting the use of environmental markets as a mechanism to advance the agency's mission of getting more voluntary conservation on the ground. Our nation's working agricultural and forestry lands provide society with a number of ecosystem services – clean air, clean water, wildlife habitat, etc. Society has begun to appreciate and value these ecosystem services; society has also witnessed the degradation of certain ecosystem services where these societal benefits are not properly valued within the economy. The time to value ecosystem services is now, society recognizes the value of clean air, clean water, threatened and endangered species habitat, and healthy soils; there are opportunities to integrate the value of ecosystem services and societal benefits into economic transactions – monetizing services that were previously considered market externalities.

In the context of U.S. rice production, precise water management on rice fields can produce consistent yields while minimizing water pumping, diesel emissions, reduced water consumption, and reduced atmospheric emissions of methane, a potent greenhouse gas. Rice grown under these precise management conditions is grown in a more sustainable manner and can be differentiated in the market place. The cumulative benefits of growing rice under precise water management, known as alternate wetting and drying (AWD), can be viewed as a win-win-win - a win for society, a win for the environment and a win for the individual farmer.

Conservation agriculture can help American farmers and ranchers transition toward a regenerative future where yields are complemented by reduced input costs and societal benefits like emission reductions. Helping our nation's farmers and ranchers implement conservation practices that generate ecosystem services, then valuing the ecosystem services through value-added products or payments for ecosystem services (i.e. carbon credits) can help farmers and ranchers diversify their revenue streams while meeting the environmental expectations of the next generation of food consumers. The carbon credit transaction highlighted in this discussion is a small, albeit important, component of a much larger sustainability initiative for the next generation of rice growers.

Decision Support Tool for Evaluating Methane Emissions Reduction Opportunities from Rice Production

Thomson, A.M, Linquist, B., Marcos, M., Adviento-Borbe, A., Anders, M., Buttner, P., Freemyer, T., Harrell, D., Linscombe, S., Ottis, B., Parkhurst, R., Ramsey, S., Reba, M., Runkle, B., Snyder, C., and Tarpley, L.

Reducing greenhouse gas emissions from agriculture is a national and global priority to help mitigate the effects of climate change. At the same time, farmers must be able to maintain production and ensure their lands are resilient to environmental variability. These challenges create a need for decision support tools to help farmers evaluate the environmental trade-offs of changing production practices. One tool, designed in a multi-stakeholder context to support farmer decisions as well as provide a reporting platform for sustainability information to consumers through the supply chain, is the Fieldprint® Platform (FPP). Developed over a decade by a diverse range of stakeholders the FPP includes eight metrics of sustainability for commodity crop production in the United States.

Rice was originally added to the FPP in 2013, and at that time, the greenhouse gas emissions metric incorporated a simple estimate of methane emissions based on production and inventory data. In 2017, a group of stakeholders from government, universities, NGOs and industry were convened to consider a revision to this approach. After reviewing the available options, the group recommended following the guidelines established by USDA in 2014 for estimating greenhouse gas emissions from agriculture that follow well established IPCC methodology. The primary challenge with this approach is that prior applications have focused on Asian rice production systems; therefore the available default emissions factors were deemed not appropriate to directly adopt into a tool for U.S. rice producers.

The groups then commissioned a meta-analysis of available data from the literature on rice methane emissions from U.S. locations. This analysis produced a set of regional emissions factors (emissions per season based on standard practice assumptions) and scaling factors (adjusting the standard emissions factor based on alternative farmer practices). The emissions factors are influenced by region (California or the South) and by soil clay content. The management practices used as scaling factors are activities that influence the amount of time a field is flooded (alternate wetting and drying, seeding methods), the treatment of residue (removal, prior crop) and other amendments (sulfur, organic matter). A separate emissions modifier was created to account for higher emissions in ratoon cropping systems.

The results of this analysis were implemented in a spreadsheet calculator and tested for 21 commercial rice fields in the United States. Data on field location, yield and management practices were obtained from the USA Rice Sustainability Task Force from member growers. The management information indicates a range of practices in use, including the water, residue and organic amendment options represented by the scaling factors. Resulting emissions estimates ranged from a low of 24 kg ha^{-1} yr^{-1} for a system with AWD multiple drains, no residue and cultivar CLXL745 to a high of 303 kg ha^{-1} yr^{-1} for a farm with continuous flooding, planting a tall variety and using manure as an amendment. None of the provided examples used ratoon cropping; this practice will add an estimated 1,082 kg ha^{-1} yr^{-1} to the methane emissions.

This method will be incorporated into the FPP tool in 2018 and will be available to farmers freely via a web interface and via use of multiple data partner platforms. The demonstrations indicate that farmers will be able to use the tool to evaluate emissions reductions possible through management practices, factor this information into their long-term planning, and share any change in emissions scores over time with supply chain stakeholders.

Greenhouse Gas Emissions and Management Practices that Impact Them in U.S. Rice Systems

Linquist, B., Marcos, M., Anders, M., Harrell, D., Linscombe, S., Reba, M., Runkle, B., and Tarpley, L.

There have been previous reports on greenhouse gas (GHG) emissions from rice fields and factors that affect those emissions. However, these have been largely based on data from Asian production systems which are different from those in the United States (U.S.), particularly in practices that affect GHG emissions such as water and carbon management. Here, using meta-analytic and regression approaches, we analyze existing GHG data from U.S. rice systems with the objective of quantifying average emissions as well as major practices relevant to U.S. systems that affect these emissions. Due to major differences in production practices, the US rice producing areas were divided into two regions (California and the Southern U.S.). Average growing season CH_4 emissions for CA and the Southern U.S. were 218 kg CH_4 ha^{-1} and 194 kg CH_4 ha^{-1}, respectively. Growing season N_2O emissions did not vary between regions and averaged 0.14 kg N_2O ha^{-1}. Ratoon cropping, common along the Gulf Coast of the Southern U.S., had average emissions of 1013 kg CH_4 ha^{-1}, and N_2O emissions have not been quantified in that system. During the winter fallow period, CH_4 emissions averaged 82 kg CH_4 ha^{-1} and 0.84 kg CH_4 ha^{-1} in CA and the Southern U.S., respectively. In the same regions, N_2O emissions averaged 0.32 kg N_2O ha^{-1} and 1.78 kg N_2O ha^{-1} $season^{-1}$, respectively. Due to limited data on N_2O emissions, only management practices affecting growing season CH_4 emissions were considered. In both regions, having a low amount of residues from the previous season (i.e. due to burning, the field having been fallow or having soybean - a low residue crop) reduced CH_4 emissions by 54%. The practice of alternate wetting and drying (AWD) resulted in CH_4 emission reductions of 39% for a single dry-down to 83% for multiple dry-downs. The application of sulfur resulted in a reduction of 4% of CH_4 emitted for every 30 kg S ha^{-1} applied. In the Southern US where varieties have been evaluated, the hybrid, CLX745, reduced emissions by 26% relative to standard semi-dwarf varieties, while tall varieties increased emissions by 31%. In CA, dry-seeding rice reduced emissions by 60% compared to water-seeding rice. These emissions and practices can be used to estimate GHG emissions from US rice systems. It is often assumed (e.g. IPCC methodology) that the effects of management practices (or scaling factors) on CH_4 emissions are additive. We tested using one versus two practices on observed versus predicted CH_4 emissions and, with the limited available data, the errors were similar. This represents an important step forward in quantifying emissions from these systems and other similarly mechanized systems in Europe, South America, and Asia. However, the factors affecting emissions are complex and improved accuracy will be likely with modeling and additional experimentally-driven observations, particularly at the scale of the production field.

Responses of Rice Physiology and GHG to Management Practices

Tarpley, L., Dou, F., and Mohammed, A.R.

Change in management practice to improve profitability of U.S. rice (*Oryza sativa* L.) crop production typically involves increasing the yield per unit input resource but can also involve adding value. Improvement in sustainability through altered management practice is receiving attention as a means to simultaneously improve yield/unit input and add value, in which the value addition comes via consumer willingness to pay extra for rice or rice products marketed with a 'sustainability stamp.' Change in management practice to simultaneously increase yield, decrease production inputs, and increase ecosystem services requires strong understanding of effects of the changed practices at both the plant level and the field level. To this end, two studies were conducted – one concerning the effects of two alternative water-management practices upon the rice plant physiology; the other upon the effects of nitrogen fertility rate upon greenhouse gas (GHG) emissions.

The physiological responses of two Southern U.S. rice cultivars contrasting in growth form were evaluated under three water-management regimes and two representative soil types. The three water regimes were aerobic (alternate wetting and drying), saturated, or flooded soil conditions. Plant height, numbers of tillers and productive tillers, total grains per panicle, spikelet fertility, 500-grain weight; shoot, root, and grain dry weights; total biomass, chlorophyll concentration (SPAD), photosynthetic parameters, and water input were determined. Results indicate that plants grown under different water regimes had similar numbers of tillers per plant shoot, grain dry weights, total biomass, and chlorophyll concentration. Plants grown under flooded soil condition were taller, had a higher number of productive tillers, higher spikelet fertility, root dry weight, leaf photosynthetic rate, transpiration and water input than those under the aerobic soil condition. Plants grown under the aerobic soil condition showed higher 500-grain weight, whereas plants grown under saturated soil had a lower root dry weight. Depending upon the availability of water, rice can be grown under aerobic or saturated or flooded condition. The best economic choice will be influenced not just by quantity of water used, but also by aspects such as grain size effects on quality, and other factors not studied here such as control of weeds, pests and diseases, along with value addition from marketing of sustainability practice.

The effect of nitrogen fertility rate on greenhouse gas emissions was evaluated in the second study. Mitigating GHG emissions is another large concern in sustainable rice production; flooded rice paddies are one of the major biogenic sources of atmospheric methane. A greenhouse trial was conducted in 2015, in which gas samples were collected using static chambers. In brief, flux measurements of CO_2, N_2O, and CH_4 were performed simultaneously by using static opaque chambers and gas chromatography (GC) techniques. In each experimental plot, a chamber was temporarily mounted onto the pot for gas flux measurements. To measure CO_2, CH_4 and N_2O fluxes, five gas samples from each chamber headspace were collected at 30-min intervals using 60-ml plastic syringes. The gas samples were analyzed with a Shimadzu GC-2014 gas chromatograph containing three detectors: a thermal conductivity detector for CO_2 analysis; an electrical conductivity detector for N_2O analysis; and a flame ionization detector for CH_4 analysis. Gas concentrations were determined by comparison with triplicate runs of standard gases of known concentration. Cumulative fluxes were calculated by trapezoidal integration of measured daily gas fluxes between sampling events with the assumption that mean daily fluxes change linearly between each sampling event/date. When daily, seasonal, and cumulative gas fluxes were combined with soil and crop analyses, the majority of C and N pool fluxes can be quantified. Results indicated that N rate had a significant effect on methane emissions. Compared with the control without crop, rice cultivation increased GHG emissions.

Based on these studies, the potential to modify management practice to simultaneously increase yield, decrease production inputs, and increase value-addition through diverse field-level sustainability improvements exists, but will should be based on strong knowledge of the rice cropping system to ensure success.

Lessons Learned when Adapting Innovative Irrigation Practices to Commercial Rice Farms

Massey, J.H., Reba, M.L., Adviento-Borbe, M.A.A., and Anders, M.M.

Producing rice in the 21st century is a complicated endeavor. It is impacted by numerous forces beyond the immediate control of producers, including weather, trade policies, advances in technology, and changing consumer-preferences. By necessity, production systems have focused on managing short-term risks under a producer's control. However, the rice industry also faces medium- to long-term challenges associated with the declining availabilities of qualified labor and water for irrigation, potential regulation of nutrients, etc. As a result, the rates at which producers adopt new practices and/or technologies will likely need to increase going forward. Numerous factors may slow the adoption of practices that are otherwise broadly viewed as important to the long-term sustainability of the rice industry. Economics, labor and logistical constraints, and differences in risk-aversion among producers may all come to play when adapting innovative practices to commercial farms. This presentation shared lessons learned in farmer adoption of AWD rice irrigation.

Field-Scale Water Management in Mid-South Rice Production

Reba, M.L., Massey, J.H., and Adviento-Borbe, M.A.A.

Understanding irrigation management at the field scale is important to due to the limitations and variability from the impact of a practice. A detailed study looking at four irrigation water management treatments for rice on 16 production-sized (16.2 ha) fields was undertaken in 2017 in collaboration with rice producers Mike and Ryan Sullivan. The study fields are part of a larger farm operation near Burdette, AR. The irrigation water management treatments were replicated four times in four quadrants and include row-irrigation, cascade flood, multiple-inlet, and multiple-inlet plus alternate wetting and drying (AWD). AWD allows the applied irrigation water to subside until the field gets to a "wet mud" state at which time the field is re-flooded. All fields were on precision-leveled ground (0.1% slope) and planted with hybrid rice variety XL753. Initial results on water applied, greenhouse gas emissions and yield are promising using these innovative irrigation practices.

Use of Safe Alternate Wetting and Drying Irrigation Reduced Yield-Scaled Global Warming Potentials in Arkansas Commercial Rice Fields

Adviento-Borbe, M.A.A., Massey, J., Reba, M.L., and Runkle, B.R.K.

Alternate wetting and drying (AWD) practice has been shown to reduce water use, CH_4 emissions and grain arsenic levels associated with continuous flooding. Despite multiple agronomic and environmental benefits of AWD, applicability of AWD in a production farm needs to validate because of potential risk in yield performance. A field study in commercial rice farms in Northeast Arkansas was initiated to quantify grain yield and global warming potentials (GWP) of CH_4 and N_2O emissions from fields managed under AWD practice and conventional flood system. Methane and N_2O emissions were measured using vented flux chamber and gas chromatography methods. Grain yields (~10 Mg ha^{-1}) were similar in AWD and conventional flooded systems and yields were unaffected by intermittent flooding. Seasonal CH_4 and N_2O emissions ranged from 6.3 to 152 kg CH_4-C $ha^{-1}season^{-1}$ and 13.1 to 355 g N_2O-N $ha^{-1}season^{-1}$, respectively. Seasonal CH_4 emissions were significantly higher in continuously flooded fields. N_2O emissions were small in all farms and dry down events did not increase N_2O emissions. Methane emissions contributed 88 to 100% to the total global warming potentials for both water management systems. AWD practice reduced GWP and yield-scaled GWP by 61% relative to continuously flooded fields. Our findings highlight the potential of AWD practice with proper water management as an effective mitigating strategy to reduce GWP without compromising high yield returns in a commercial rice production.

Methane Reductions from AWD Irrigated Rice Production

Runkle, B.R.K., Reba, M.L., and Suvočarev, K.

Rice cultivation is responsible for 11% of the global 308 Tg CH_4 anthropogenic emissions, contributing this potent greenhouse gas to the atmosphere. In this study, the impact of water conservation practices on rice CH_4 emissions was evaluated in production-size fields in Arkansas, the leading state in U.S. rice cultivation. Previous studies indicate that while conserving water, the Alternate Wetting and Drying (AWD) irrigation practice can also reduce CH_4 emissions through the deliberate, periodic introduction of aerobic conditions that disrupt methanogenesis. Seasonal CH_4 emissions from a pair of adjacent rice fields were estimated and compared during the 2015 to 2017 growing seasons using the eddy covariance micrometeorological method on each field. Gaps in the eddy covariance time series are filled with an artificial neural network model associating various meteorological and crop-growth parameters to CH_4 emissions. The studied fields, in Lonoke County, Arkansas, have poorly-drained Perry silty clay soils and have been zero-graded.

To be able to compare the effect of intermittent flooding, the fields were alternately treated with continuous flood (CF) and AWD irrigation. In 2015, the seasonal cumulative carbon losses by CH_4 emission were 4.5 times greater for the CF treatment than the AWD treatment. Data from 2016 and 2017 help clarify differences in innate methane production capacity from each field. When accounting for differences in field conditions and soils, our results show the AWD practice is attributable to approximately 40-80% reductions in the seasonal emissions. The substantial decrease in CH_4 emissions by AWD supports previous chamber-based research and offers strong evidence for the efficacy of AWD in reducing CH_4 emissions in Arkansas rice production. Moreover, at the production field scale, there have been no significant differences in the harvest yield of rice with respect to different water management. The AWD practice has enabled the sale of credits for carbon offsets trading and this new market could encourage agricultural practices that reduce CH_4 emissions on a national scale.

Effect of Water Management on Grain Concentrations of Nutrients and Trace Metal(loid)s

Limmer, M.A., Anders, M., Rothenberg, S., and Seyfferth, A.L.

Water management is widely known to affect both greenhouse gas emissions and trace metal cycling in rice paddies. Here, we will describe two experiments under field conditions where water management was used to manipulate rice trace element composition and greenhouse gas emissions. In the first experiment, two cultivars of rice were grown at the University of Arkansas Rice Research and Extension Center under five different water management techniques. Water management conditions included two levels of alternate wetting and drying (AWD), two levels of furrow irrigation, and a continuously flooded control. Under AWD and furrow irrigation, grain concentrations of arsenic decreased but cadmium increased. Water management also significantly affected grain calcium, potassium, magnesium, manganese, phosphorous, sulfur, and zinc. These results will be presented in the context of previously published greenhouse gas emission data from the site.

In the second study, rice paddy microcosms were subjected to varying levels of flooding, from nonflooded to continuously flooded. Concentrations of trace metals in the porewater, porewater redox, and methane fluxes were measured weekly throughout the growing season. At harvest, plants were divided into several plant parts including polished grain, bran, unripe grain, unfilled grain, rachis, nodes, flag leaves, straw, roots, and root iron plaque extracts. The various plant parts were analyzed for elemental composition. Correlations between the plant, porewater, and methane flux data will be presented.

Farming on the Wild Side: Using Native Algae to Reduce Water and Nitrogen Use

Heuschele, D.J., Reba, M., and Runkle, B.

Winter cover crops provide various ecosystem services such as prevention of soil erosion, reduction of fertilizer use, and retention of soil moisture. Developing cover crops for rice in the Mississippi River Valley has two major challenges; the first is the timing of field management and the other challenge is crop damage from waterfowl. Native filamentous green algae (FGA) populations have the potential to address these challenges, especially in fields managed for zero grade.

Large populations of FGA form tangled mats of algal filaments intermingled with cyanobacteria. FGA grows quickly in stagnant water when water temperatures are mild (13-23°C) and rice is not in production. When water is removed from the system during rice production, the upper layers of the mat desiccate creating a crust that shades and reduces water loss to the rest of the colony and soil substrate. FGA also produces allopathic compounds in both live and dead cells that inhibit sprouting of some aquatic weedy species. These FGA traits may be exploited to withstand drought in an agricultural setting allowing rice producers to extend timing between irrigation and reduce the amount of herbicide. After rice harvest, the addition of water from rain and/or wildlife management flooding promotes FGA growth, unlike other winter cover crops FGA can withstand herbivory from waterfowl and generally does not need to be “reseeded”.

Cultivation of FGA has been successful on a small scale and to a lesser extent on a large scale for biofuels; however, large scale FGA cultivation is genera specific and information on inoculating agricultural fields with FGA is limited. The goals of our project are to 1) determine field conditions necessary to support off-season FGA growth in quantities for field application and management in rice agriculture and 2) determine the impact of FGA and irrigation water management on agronomic and field parameters of rice agriculture.

We are monitoring two 40-acre flooded rice fields in England, AR, historically known to contain large amounts of FGA during the winter and early spring months. During the past five years, FGA covered 90-95% of the field due to its rapid growth in the fall and spring periods. When rice was seeded into the algal mat before complete water removal, it became sandwiched between the algal layers. The rice germinated through the algal mat and the underside of the mat remained green throughout the growing season. The producer observed a reduction in weed growth and higher soil moisture compared to adjacent non-FGA fields. These two FGA fields are being compared with two non-FGA fields for rice agronomics, soil macro-nutrients, and water usage.

During the winter of 2016/2017, the population of FGA only had to 5-35% coverage per plot (m^2). This amount of FGA was not enough to form a field wide mat during the 2017 rice-growing season to assess differences between FGA and non-FGA agronomics. The pH of the field water ranged between 6.9 and 9.0, which did not appear to effect rice production, however, the optimal pH range for algal growth is 5.5 to 6.5. A pH level over 7.5 forces FGA into dormancy. To promote overwinter growth of FGA for the 2018 season, we “seeded” fields with lab cultured FGA in the autumn of 2017. We hypothesize FGA will meet many of the goals of cover crops if the correct field growth conditions can be met.

Abstracts of Papers from the Application of Genomic Technologies to USA Rice Breeding Programs Symposium
Symposium Moderator: Anna McClung

A Reference Genome for U.S. Rice

Scheffler, B.E., Edwards, J., Stein, J., Ware, D., Vaughn, J., Schmutz, J., Peterson, D., Youngblood, C., Duke, M., Grimwood, J., Simpson, S., and McClung, A.M.

The development of reference genomes for rice has served as means for understanding the allelic diversity and genetic structure of a cereal grain that feeds half of the world. It has long been understood that *Oryza sativa* diverged into two major sub-populations, Indica and Japonica, over 400 K years ago. Reference genomes of these two sub-populations were published in 2005, including the de novo sequencing of Nipponbare, a temperate japonica (TEJ) rice cultivar, and the shot-gun sequencing of the indica (IND) cultivar 93-11. Germplasm in the USA is primarily derived from the tropical japonica (TRJ) sub-population which is much more limited in its worldwide cultivation than IND or TEJ. It is possible that the current reference genomes for IND, TEJ and, more recently, AUS, may lack genomic information relevant to TRJ germplasm and breeding efforts. The objective of this project was to develop a reference genome for TRJ germplasm that would be well suited for identification of genes important to USA breeding programs. A number of diversity panels containing global rice varieties have been resequenced and the genomic data has been made public. A merged data set of 4786 global rice accession and some 56 K SNP markers were used to identify a number of accessions that were representative of the TRJ genome. Two of these, Honduras and Carolina Gold, are landraces that served as founder lines in the USA historical rice pedigree. Carolina Gold (CGR) is credited with the establishment of the US rice industry because it was the predominant variety grown for over 200 years on the Southeast coast before USA rice production moved to where it is grown today. For these two reasons, CGR was selected for de novo sequencing and to serve as a reference genome for TRJ germplasm.

To develop a reference genome for Carolina Gold, 96X genome coverage was generated using the RSII from Pacific BioSciences. The average read length used in the assembly was 11,417 bp in 3,284,634 reads giving a total 37,499,187,779 bp used in the final assembly. The present CGR assembly size is 386,298,647 bp in 208 contigs, giving an average contig length of 1,857,205 bp per contig, and an N50 (size of contig above which contains half of the total assembly) of 12,879,605 bp. Another statistic is NG50 (which is based on 400 Mb genome size not total assembly length) is 11,626,317 (meaning that 200 Mb of the genome is contained in contig sizes above NG50). Illumina reads are being used for error correction and 10X Genomics data is being used for checking for positional errors.

To understand the genomic diversity of germplasm pertinent to USA rice breeding efforts, sequence data from over 150 accessions have been resequenced using the Illumina platform to a depth of >20X. These accessions are predominately TRJ material that have historic importance to USA rice. This sequence data will be compared to CGR and Nipponbare to identify genetic differences especially SNPs, InDels and chromosome rearrangements.

CGR should be a superior reference when aligning sequencing reads from TRJ subspecies, particularly those generated by USA breeding programs. Indeed, preliminary results indicate ~2% more Illumina reads from TRJ lines align to CGR versus NPBR. Admixtures of TRJ and TEJ have a 1% improvement. Interestingly, even when aligning reads from TEJ lines, CGR serves as a comparable (<0.2% difference) reference relative to NPBR, suggesting that some of the alignment improvements are due not only to genetic relatedness but to more complete and/or accurate sequence assembly. Work is ongoing to annotate these differentially mapping reads. Once completed, all of data will be released to the public.

Leveraging Genome Sequence Data from Diverse Rice Germplasm for Trait Marker Discovery in Elite U.S. Germplasm

Famoso, A., Angira, B., Addison, C., Dartez, J., Groth, D., Correll, J., Jia, Y., Wang, X., and Pumplin, N.

Significant progress has been made in identifying genes underlying key rice breeding traits, however the majority of this research goes unutilized in applied breeding programs. A key factor limiting translation of this data to applied breeding efforts is that the reported genes are seldom tested within the target environments and across the germplasm of interest to a given applied breeder. Similarly, an abundance of genomic and whole genome sequence data has been generated across rice germplasm, but the direct impact on applied breeding programs has been minimal. Some of the challenges preventing the application these genomic resources to elite breeding programs is that the breeder's germplasm is continuously changing and is often not represented in large sequencing projects, such as the IRRI 3K genomes.

We employ a standard research pipeline to enable us to utilize the valuable genomic data generated as part of the IRRI 3K genomes project. Previously reported genes with desired effects are targeted for haplotype characterization using the 3K genome data set, upon characterizing the haplotype groups present, SNPs are identified that can effectively differentiate all common haplotypes groups in the global rice germplasm. These SNPs are subsequently ordered as KASP assays and run on a standard panel of current U.S. breeding germplasm that represents the diversity of materials typically used for breeding crosses. This panel is routinely phenotyped for traits of interest, allowing the haplotypes to be associated with phenotypes collected in the target environment. This approach has enabled us to leverage the sequence level resolution generated on diverse germplasm collection and apply it to our current breeding germplasm, which is not present in the diverse germplasm that has been sequenced.

This presentation highlighted the discovery and validation steps used within the LSU AgCenter rice breeding program to ensure a trait SNP marker meets our expectations prior to be deployed in our breeding program. A case study was highlighted using blast as an example.

Genome Editing Strategies for Rice Improvement

Thomson, M.J., Kim, B., and Septiningsih, E.M.

Genome editing using CRISPR/Cas9 has the potential to accelerate a wide range of plant breeding applications. We are exploring strategies to optimize and deploy genome editing to rapidly validate genes underlying important QTLs, test allelic effects at key genes, and modify critical traits for rice improvement.

The precision and ease of use of CRISPR nucleases, such as Cas9 and Cpf1, for plant genome editing has the potential to accelerate a wide range of applications for crop improvement. For upstream research on gene discovery and validation, rapid gene knock-outs can enable testing of single genes and multi-gene families for functional effects of candidate genes underlying key quantitative trait loci (QTLs) and genome wide association study (GWAS) loci. Large chromosomal deletions can assist with positional cloning of genes by helping to narrow down the target region. Nuclease-deactivated Cas9 fusion proteins with transcriptional activators and repressors can also be used to up and down-regulate gene expression. Even more promising, gene insertions and allele replacements can provide the opportunity for rapidly testing the effects of differing alleles at key loci in the same genetic background.

The rice community is well positioned to take advantage of these new opportunities, as the wealth of cloned genes, diverse genetic donors, and sequence data present numerous testable hypotheses with clear implications for rice improvement. For example, data from the 3,000 Rice Genomes Project and High Density Rice Array (HDRA) studies can be used to define sequence variation at candidate genes underlying GWAS hits, which can then be rapidly validated using CRISPR editing techniques. Likewise, beneficial genes and QTLs originally identified from exotic germplasm, including landraces and wild relatives, can be rapidly transferred into elite breeding materials without causing negative linkage drag. Towards this end, a survey was performed to identify promising genes that can be used in a genome editing pipeline for rice improvement. We are currently exploring two approaches to develop efficient tools for rice breeding: (1) using CRISPR/Cas9 genome editing of elite rice cultivars to modify specific traits; and (2) editing exotic landraces having valuable traits to remove negative characters that prevent them from being used as efficient genetic donors in breeding programs.

Recently, Texas A&M AgriLife Research has supported the development of a new Crop Genome Editing Lab on the College Station campus to support research and service activities for CRISPR-based genome editing in crop plants. The research team is testing various approaches to CRISPR delivery, including using ribonucleoprotein (RNP) CRISPR/Cpf1 + gRNA complexes with protoplasts and particle bombardment, to provide a non-transgenic approach to genome editing in rice. The service team will perform genome editing across multiple crops to provide breeding and research groups with a rapid genome editing pipeline to test candidate genes in their programs. With CRISPR-based genome editing activities rapidly expanding across many areas of research and development, the next phase will need to carefully navigate the patent and regulatory landscape, as well as considering consumer acceptance, before commercialization of edited products can proceed.

Abstracts of Papers from the Student Oral Competition Panel
Rice Culture

Evaluation of Furrow Irrigation Practices for Mid-South Rice Production

Atwill, R.L., and Krutz, L.J.

Rice irrigation currently accounts for the greatest amount of irrigation water applied per acre over corn, soybeans, and cotton in the mid-south. The alluvial aquifer serves as the major source of irrigation water for rice production in Mississippi; however, it is declining at a rate of 37,000 ha-m yr^{-1} and has done so for approximately 35 years. An experiment was conducted at the Delta Research and Extension Center in Stoneville, MS, to evaluate the yield and physiological response of rice to alternate wetting and drying (AWD) and furrow irrigation practices as compared to a continuous flood. Three rice cultivars were evaluated in six different rice irrigation treatments that include: a continuous flood, optimized AWD, and furrow irrigation with water level thresholds at 10 cm below the soil surface, 20 cm below the soil surface, 30 cm below the soil surface, and 40 cm below the soil surface. Water level in each paddy was monitored and irrigation events were triggered at each respective threshold back to a 10-cm flood for continuous and AWD, and 40 ha-mm was applied for furrow irrigation. Additionally, five fertilization treatments totaling 168 kg N ha^{-1} were applied at different split intervals (100, 75/25, 50/50, 50/25/25, 25/25/25/25) according to growth stage. Conventional and Clearfield herbicides were applied at different growth stages and evaluated for weed control. Data from this experiment suggest that furrow irrigation for mid-south rice production may be economically feasible, and results of furrow irrigation water management strategies on total water use, rice yield, weed control and economic return will be discussed at length. Water management practices that reduce groundwater withdrawals are a viable option for rice producers in the mid-south.

Decreasing Arsenic in Rice Grains with Alternate Wetting and Drying Irrigation

Carrijo, D.R., Akbar, N., Li, C., Parikh, S.J., Green, P.P., and Linquist, B.A.

High arsenic (As) levels in rice grains are a health concern for more than half of the world's population who depend on rice for food, since inorganic As has been classified as a class 1 carcinogen by the International Agency for Research on Cancer. As accumulation in rice grains is greatly influenced by irrigation management and Alternate Wetting and Drying (AWD) has been reported to decrease grain As concentration compared to Continuously Flooded (CF) irrigation. However, there is still lack of knowledge on the optimal timing and duration of drying periods to achieve minimal grain As concentration without decreasing rice yields.

Two field experiments were conducted in the summers of 2015 and 2016 in California. In 2015, A CF control was compared with three AWD treatments having one drying period (reflooded when soil volumetric water content was 35%) imposed at one of these stages: panicle initiation, booting, or heading. In 2016, within each stage three AWD treatments differing in the duration of drying periods were also evaluated, resulting in a total of nine AWD treatments in addition to the CF control. The three different durations were: AWD-Safe, where the soil dried until the perched water table reached 15 cm below the soil surface, AWD35, where the soil dried until soil volumetric water content was 35% and AWD35+4, where soil dried for four additional days after reaching 35% volumetric water content. Soil moisture was monitored throughout the drying periods. After harvest, yields were evaluated and grain total As concentration in polished grains was quantified by inductively coupled plasma mass spectrometry techniques.

In 2015, grain As concentration decreased by 45 – 65% when the soil was dried during panicle initiation or booting stages, compared to CF; however, no decrease was observed when the drying period was imposed during heading. In 2016, AWD-Safe did not reduce grain As concentration independent of the timing when the soil was dried. This was likely because the soil at the root zone remained close to saturation (water potential close to 0 kPa, which corresponded to a drying period of two days on average) in this treatment and thus was not aerated enough to decrease the bioavailability of As in the soil. In contrast, AWD35 and AWD35+4 provided reductions of 41 – 60% in grain As concentration. Soil water potential immediately prior to reflooding in AWD35 and AWD35+4 was on average -72 and -161 kPa, respectively, which corresponded to drying periods of on average 10 and 14 days. The lowest grain As concentration across all 10 treatments in 2016 was achieved with AWD35+4 at booting stage. Similar to what was observed in 2015, in 2016 the AWD35 treatment provided lower grain As concentrations when imposed at panicle initiation or booting than at heading, although this difference was not significant. The same trend was observed for AWD35+4. Importantly, grain yields were not significantly different across all treatments in both years. These findings indicate that the duration and timing of AWD are important factors to be considered when practicing AWD to mitigate As concentration in rice grains.

Does Soybean Maturity Group Influence Rice Nitrogen Fertilizer Requirements?

Ortel, C.C., Roberts, T.L., Norman, R.J., Slaton, N.A., and Hoegenauer, K.A.

The soybean (*Glycine max*) - rice (*Oryza sativa*) crop rotation system is widely used for the benefits provided to both crops. One specific benefit is the nitrogen (N) credits supplied to the rice crop through biological N fixation with soil bacteria and mineralization of the soybean residue returned to the soil system after harvest. This reduction of fertilizer-N need results in a large savings of input costs associated with the crop, helping the producer to maximize profitability, as N fertilizer is often the largest input cost to a rice producer. Increasing the amount of soil-N available to the following rice crop may be accomplished through soybean maturity group (MG) selection and planting date. Different MGs of soybean have different yield potentials and harvest indices, thus returning differing amounts of N to the soil system. Planting date regulates the amount of time spent in vegetative growth stages; therefore, influencing the soil N credits generated. This study intends to determine which factor for a specific soybean MG most heavily influences the soil-N credits generated: soybean grain yield or planting date. The potential to reduce rice N fertilizer need through management of a soybean crop could provide savings with no additional input cost to a rice producer.

Two relative planting dates were considered for soybean management, 'early' including soybean planted in May and 'late' planted in June or July. Two locations within the state were included, with multiple fields at each for replications, totaling five site-years of data. The overall analysis of variance design was randomized complete block with four blocks per replication. Four MGs were planted with a fallow strip in each replication as an untreated check plot. The data was analyzed using a split plot design with MG as the whole plot factor and rice N rate as the split plot factor. Means separation was done using the least significant difference test for those effects having significant F-tests. Comparisons were done at the $\alpha = 0.05$ significance level.

The soybean rice crop rotation was grown on both silt loam and clay soils and drill seeded with 38 cm row spacing of soybean and 19cm row spacing of rice. Treatments applied include four different MGs of soybean grown or a fallow strip the first year of the study. The rice crop then received one of six different single pre-flood treatments using urea, 0, 45, 90, 135, 180, 225 kg N ha^{-1}. The soybean crop was sampled at full seed for total N uptake and again at maturity for grain N and yield. Between crops the soil was left fallow and the soybean residue was spread easily within each plot. At rice emergence, N-STaR soil samples were taken at a 0-45 cm depth for silt loams and 0-30 cm depth for clays to quantify the soil- N credits. The rice crop was sampled at 50% heading for total N uptake using 0.9 m samples from a bordered row and grain yield was measured at harvest.

The results from the 2016 soybean crop and 2017 rice crop show no significant difference between soybean MG grown and rice yield ($P = 0.8059$). There was no significant difference ($P = 0.8067$) in plant available-N between previous MGs the following spring nor was there a significant difference between previous MG and rice total N uptake ($P = 0.9803$).

However, there were differences within the soybean crop of 2016 and 2017. Across planting dates, the 4.7, 5.4, and 5.6 MGs yielded the statistically similar, above the 3.5 MG. The early planted soybean yielded higher than the late planted soybean across all planting dates ($P < .0001$). The 5.6 MG consequently removed the most N from the cropping system through harvest, at 213 kg ha^{-1}. However, the four MGs were not statistically different in their biomass N returned to the soil system ($P = 0.6031$).

The objective of this study is to determine the impact made on soil-N credits from different soybean management techniques on a following rice crop N fertilizer recommendation. These management decisions include planting date, variety, and MG. The relationship between soybean characteristics and the amount of plant available-N for the following crop will allow producers to select the best possible aspects to maximize profitability while minimizing inputs. Understanding how soybean maturity group influences N credits for rice is needed to help producers make the best decisions in regards to their whole farm rotation. This research aims to determine if different yield potentials of MGs lead to different levels of soil-N credits available for the successive rice crop.

Evaluating Post Season Nitrogen Concentrations in Rice Stems

Hoegenauer, K.A., Roberts, T.L., Ortel, C.C., Norman, R.J., Hardke, J.T., and Slaton, N.A.

Proper nitrogen (N) fertilization and management can be very difficult to achieve in direct-seeded, delayed-flood rice (*Oryza sativa L.*). Typical N fertilization rates for rice in the state of Arkansas range from 112 to 245 kg N ha^{-1}. Nitrogen fertilization is can be excessive or insufficient resulting in suboptimal yield. Producers with suboptimal yields are often left wondering why. Insufficient N fertilization rates are often blamed for lackluster yield without any evidence to support the claim. Preseason soil tests and midseason canopy reflectance tests determine N needs for the rice crop; however, no test has been developed to evaluate whether proper quantities of N were present in the plant to produce optimal yield at the end of the season. Therefore, the objective of our research is to develop a post-season N test for rice.

Two locations were planted to two cultivars each. Plots were arranged in a randomized complete block structure with four replications. Six N rate treatments (0, 50, 100, 150, 200, 225 kg N ha^{-1}) were applied preflood. Above-ground biomass samples were collected at harvest. Segments of rice stem were analyzed in 5 cm sections starting at the soil surface and extending to 45 cm above the soil. Segments were analyzed with and without leaf sheaths for each 5-cm section. Nitrogen was analyzed in the form of NO_3-N, NH_4-N, and amino acids. The Cate-Nelson method for bivariate data was used to establish a critical concentration which separates the data into observations that would likely exhibit a response from added N fertilization and those which would not respond to added N fertilization. Linear response and plateau models were fit to the data based on the critical concentration established by the Cate-Nelson method.

Data analysis showed consistent responses with a NH_4-Nand NO_3-N; however, amino acid concentrations were erratic across treatments. Better correlation with yield was seen for NO_3-N compared to NH_4-N. Concentrations of NO_3-N did not differ significantly between samples with leaf sheaths and samples without leaf sheaths. Furthermore, samples with leaf sheaths intact showed a slightly better correlation than samples with leaf sheaths removed. Even though NO_3-Nconcentration increases with decreasing plant height, most sections of rice exhibited similar correlations and model significance to one another. Ultimately a section of 0-20 cm was selected for its ease of sampling and reproducibility. Further testing on various locations and multiple varieties is currently underway to facilitate the development of an accurate state-wide post-season N test in rice.

Nitrogen Management in Rice under Suboptimal Soil Conditions

Rhea, P.S., Hardke, J.T., Norman, R.J., Roberts, T.L., Frizzell, D.L., Castaneda-Gonzalez, E., Plummer, W.J., and Lee, G.J.

In Mid-South rice (*Oryza sativa,* L.) production, nitrogen (N) fertilizer in is most often recommended as a single preflood application (SPF) or a two-way split (2WS) application in a dry-seeded, delayed flood system. The majority of N fertilizer is typically applied at the 4- to 6-leaf stage onto dry soil, and the second application, if necessary, into the floodwater as a midseason application. Environmental factors do not always allow growers to apply early N fertilizer onto optimal dry soil conditions using these recommendations. This study was conducted to determine N fertilization best management practices in rice when faced with dry, wet, and flooded soil conditions.

Two locations, one a silt loam soil and the other a clay soil, were used to evaluate N fertilizer treatments to the cultivar Diamond. Treatments included a control receiving no N, SPF and 2WS treatments applied to dry and wet soils, and several treatments using single and multiple N applications into flooded conditions. Base N fertility rates at each location were determined using the Nitrogen Soil Test for Rice (N-STaR) recommendations of 112 kg N/ha for SPF on the silt loam and 202 kg N/ha on the clay. All plots receiving a fertilizer application into a standing flood were enclosed by galvanized metal flashing to help reduce off-target movement of fertilizer in the floodwater. Biomass, total N uptake, plant height, grain yield, and milling yield were determined at both sites.

Due to a treatment by location interaction, data was analyzed independently by site. On silt loam soil, N treatments applied to dry soil according to standard recommendations, applied to wet soil with elevated N rates, and those applied in multiple applications into the flood ("spoon-fed") were the highest yielding treatments, while standard N rates applied to wet soil and single applications of high N rates into flooded conditions had statistically lower yields. On clay soil, N treatments applied to dry soil according to standard recommendations, applied in single applications of high N rates into flooded conditions, applied to wet soil with elevated N rates, and only one of the spoon-fed treatments were the highest yielding, while some spoon-fed and single applications of high N rates into flooded conditions had significantly lower yields. The different soil types and cation exchange capacity (CEC) at the two locations may help to explain differences in results among treatments. Based on results in 2017, N applications made to dry soil were the most efficient in producing the highest grain yields while additional N was needed to produce similar yields when faced with wet or flooded soil conditions.

Sensor Based In-Season Fertilization for California Rice

Rehman, T., Reis, A., Akbar, N., and Linquist, B.

California rice (*Oryza sativa* L.) growers commonly apply topdress nitrogen (N) fertilizer at panicle initiation (PI) stage. However, these applications are often without consideration of crop N status, and can result in losses both economically and environmentally. Although, some tools are available to guide in-season fertilization decisions, generally these techniques are time consuming, cumbersome, and limited by their small-scale sampling methods. Thus, a comprehensive method to assess in-season crop N status and develop sustainable fertilizer recommendations is needed for CA rice systems. Preliminary studies have shown that remotely sensed Normalized Difference Vegetation Index (NDVI) can predict in-season N status for several crops. Therefore, to investigate its potential in CA rice, on station and on farm N response trials were established over a 3-year period (8 site-years) across the Sacramento Valley rice growing region. A randomized complete blocked experiment was established with main plots receiving urea at rates ranging from 0 – 275 kg N ha^{-1}. At PI, NDVI was measured for each plot and plants were harvested to quantify aboveground biomass (kg m^{-2}), N concentration (g N kg^{-1}), and total N uptake (g N m^{-2}). At maturity, plants were harvested to measure grain yield (kg ha^{-1}). Our objective was to determine the critical level at PI to achieve maximum grain yield for each parameter, and assess how well they correlate with NDVI. Results indicate, of the three parameters, N uptake is the most consistent predictor of final grain yield and also correlates most strongly with NDVI. We found that 11.3 g N m^{-2} are required to achieve maximum grain yield across site-years, which correlates to a NDVI of 0.70. With this information, growers can now quickly assess the N status of their crop by measuring NDVI.

Evaluation of Low-Use-Rate Zinc Fertilization Strategies for Rice

Coffin, M.D., Slaton, N.A., Robert, T.L., Norman, R.J., and Hardke, J.T.

Zinc (Zn) deficiency is the most common yield-limiting micronutrient of rice (*Oryza sativa* .L) grown on loamy-textured soils in Arkansas. Several new fertilization methods using low Zn rates have been developed and marketed to growers, but research regarding their efficacy is lacking.

Our research evaluated the effect of two Zn seed treatment rates and six Zn fertilization methods on rice seedling Zn concentration, early season canopy coverage, and grain yield. Two field experiments were conducted on soils mapped as a Calloway or a Calhoun silt loam. 'Roy J' or 'Diamond' rice was treated with 0 or 3.3 g Zn kg^{-1} as ZnO and combined with no Zn (UTC), granular $ZnSO_4$ applied at 11 kg Zn ha^{-1} (GRAN), 1.68 kg Zn ha^{-1} as MicroEssentials (MESZ) fertilizer, 1.12 kg Zn ha^{-1} as Zn-EDTA applied at the 2-leaf stage (EDTA), and 0.56 and 1.12 kg Zn ha^{-1} of Wolftrax Zn-DDP (DDP) applied preplant onto triple superphosphate and muriate of potash (DDP1 and DDP2). Whole plant samples were taken at the midtillering growth stage for determination of biomass and Zn concentration. Plant canopy coverage was measured three (Calloway) or four (Calhoun) times (cumulative growing degree units, GDU) in ten of the 12 treatments during seedling growth. Analysis of variance on seedling Zn concentration and grain yield was performed using Zn seed treatment rate and Zn fertilization methods as fixed effects and replicate and soil as random effects. Analysis of variance of canopy measurements was performed by soil with measurement time, seed treatment rate, and fertilization method included as fixed effects.

Canopy coverage on the Calhoun soil was not affected by Zn seed treatment rate or fertilization method but did increase with each measurement time (5, 21, 62, and 89% at 398, 580, 728 and 960 GDUs, respectively). On the Calloway soil, rice canopy coverage also increased with time averaging 15, 37 and 88% at 496, 668 and 850 GDUs, respectively. A significant Zn seed treatment rate by fertilization method interaction showed a trend for greater canopy coverage of rice fertilized with MESZ (50-55%). Regardless of Zn seed rate, the lowest canopy coverage was for rice receiving no Zn (40-42%), and intermediate canopy coverage for rice receiving EDTA and DDP (46-47%). Canopy coverage of rice fertilized with GRAN was among the greatest with no seed Zn (51%), but among the lowest with seed Zn treatment (42%).

The Zn seed treatment rate by fertilization method interaction had no significant effect on seedling Zn concentration, but was affected by each of the main effects. Averaged across Zn fertilization methods, application of 3.3 g Zn kg^{-1} to seed increased seedling Zn concentration by 3.2 mg Zn kg^{-1} compared to rice seed treated with 0 mg Zn kg^{-1} (32.3 mg Zn kg^{-1}). Seedling Zn concentration, averaged across seed Zn rates, was greatest for rice receiving GRAN (45.1 mg Zn kg^{-1}). Rice fertilized with MESZ (33.3 mg Zn kg^{-1}) and EDTA (34.2 mg Zn kg^{-1}) produced seedlings with Zn concentrations greater than the UTC (29.7 mg Zn kg^{-1}), but similar to rice fertilized with DDP1 (31.0 mg Zn kg^{-1}) and DDP2 (32.1 mg Zn kg^{-1}). Grain yield was not affected by Zn seed treatment rate, Zn fertilization method or their interaction. Results suggest that low-use-rate Zn fertilization methods provide minimal Zn for seedling rice and should be avoided on fields where there is a high probability of Zn deficiency.

Abstracts of Papers from the Student Oral Competition Panel
Plant Protection

The Spatial Distribution of *Lissorhoptrus oryzophilus* (Coleoptera: Curculionidae) in Untreated Commercial Rice Fields in Louisiana

Mulcahy, M.M., Wilson, B.E. and Reagan, T.E.

Rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel, is one of the most destructive insect pests of rice, *Oryza sativa* L., in the United States. All stages of RWW survive on rice plants; however, only the larvae are regarded as economically damaging. RWW larvae live in the soil and feed on the roots of rice plants. Pruning of rice roots by RWW larvae leads to reductions in tillering, vegetative growth, panicle density and grain weight. Severe infestations of RWW can cause up to 25% yield loss. One means of improving rice production in Louisiana is through the adequate control of economically damaging rice pests such as RWW. Currently, insecticidal seed treatments are used throughout the rice industry as a pre-emptive means of controlling RWW. Three insecticidal seed treatments are presently being recommended for use against RWW. These are chlorantraniliprole (Dermacor X-100), thiamethoxam (Cruiser 5FS), and clothianidin (NipsIt INSIDE 5FS). Chloroantraniliprole has also been shown to work effectively against Lepidopteran pests, and is recommended as a useful tool for managing stemborer populations in rice. While seed treatments have been shown to reduce the damage inflicted by RWW and other pests, they are typically applied as a preventative measure, and therefore do not consider pest densities, thresholds, non-target effects, and cost-benefit ratios. As such, insecticidal seed treatments are traditionally incompatible with integrated pest management (IPM) programs. Our objective was to gain a thorough understanding of the spatial distribution of RWW in untreated rice fields in Louisiana. Since RWW is known to overwinter in non-crop habitats adjacent to rice fields, we hypothesized that infestations of this pest would be concentrated near the edges of rice fields. The information gathered here will be used to improve the deployment of insecticidal seed treatments in accordance with better IPM principles. Eight untreated commercial rice fields in Louisiana were mapped using GPS software, and then surveyed for RWW larvae. This was done by taking soil core samples along transects running from the edges to the centers of the commercial rice fields. The soil core samples were rinsed and bathed in salt water. The number of RWW larvae in each sample was then counted and recorded. The results showed that RWW larvae aggregate along the edges of rice fields. This indicates that insecticidal seed treatments can be applied selectively within rice fields to control this pest. By specifically targeting areas, which are at a higher risk of infestation, we can enhance the practical application of insecticidal seed treatments. Ultimately, this can help us to reduce farmer costs, decrease the build-up of pest resistance by reducing selective pressure, and negate harmful environmental effects.

Evaluation of Rice Water Weevil Populations in Water Conservation Rice Production Systems

Kelly, R., Gore, J., and Catchot, A.

Water conservation has become an important aspect of Mid-South agriculture over the last decade due to declining aquifer levels. Of the agronomic crops grown in the Mid-South, rice is the greatest user of water because it is grown under a flooded culture. Consequently, the biology of numerous Arthropod pests of rice are dependent on flooded conditions. The rice water weevil, *Lissorhoptrus oryzophilus* (Kuschel), is an important and economically damaging insect pest of rice globally. It will only oviposit during flooded culture, so water conservation practices may influence its biology and pest status. One conservation method currently being studied is furrow irrigated rice.

During 2017, an experiment was conducted to evaluate the temporal and spatial distribution of rice water weevil in commercial row watered fields. A total of five fields were sampled across the region. Each field was divided into three zones based on soil saturation levels. In most cases, rice water weevil densities were greatest in the areas of the fields where the flood never dissipated (Zone 3). Rice water weevil larvae densities were very low in areas of fields that never became flooded (Zone 1). Areas that held a brief flood but remained muddy (Zone 2) had intermediate levels of rice water weevil larvae. These preliminary data suggest that water conservation practices in rice will impact the pest status of rice water weevil. In the case of row watered rice, most of the weevils were concentrated in the flooded portion of fields which may create some unique management opportunities for growers.

Tolerance to Rice Water Weevil Injury in Rice

Villegas, J.M. and Stout, M.J.

The rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel, is the most important insect pest of rice in the United States. This insect poses a global threat to rice production having recently invaded rice-producing regions of Asia and Europe. Tolerance is the ability of the crop plant to maintain yield in spite of injury by herbivores. A more susceptible rice genotype generally suffers a greater yield loss than tolerant genotype when exposed to similar levels of injury. This study aims to uncover potential mechanisms of rice tolerance to RWW. Field experiments were established in Crowley, Louisiana, in a randomized block design with four replications in 2017. Each block was composed of 16 plots subjected to factorial combinations of the following treatments: eight cultivars of rice with different levels of tolerance to RWW and two weevil treatments (presence and absence). Exclusion of weevils was accomplished using chlorantraniliprole seed treatment. Core samples were taken in each plot to estimate RWW larval densities. Phenotypic traits such as stomatal conductance and leaf area index were measured at different developmental stages of rice. Finally, yield losses were determined for each variety.

The Impact of Defoliation on Select Growth Stages in Rice

McCullars, L.D., Lorenz, G.M., Hardke, J.T., Bateman, N.R., Taillon, N.M., Clayton, T.L., Plummer, W.A., McPherson, J.K., Black, J.L., and Cato, A.J.

Fall armyworm (FAW), *Spodoptera frugiperda,* has recently become a common pest in rice in the Midsouth. Infestations are sporadic and occur as early as emergence and can last throughout the season until after panicle emergence. Improper insecticidal applications by growers can lead to both economic and ecological impacts; therefore, it is important to understand when these insecticide applications are warranted. The objective of this study is to evaluate yield losses due to infestations of FAW larvae and by simulating FAW defoliation damage.

FAW damage was evaluated at the 2-3 leaf stage, 2nd-3rd tiller, and heading growth stages. Plots were either infested at rates of 0, 6, or 12 armyworms per ft^2, or manually defoliated at 0, 25, 50, and 100% of plants. Plots of 3'x 3' were utilized for this study, and a randomized complete block design with four replications was utilized for both the FAW infestation and manual defoliation. Overall not much damage was observed through both infestations of FAW and manual defoliation. However, a slight decrease in yield was associated with infestations of 6 and 12 larvae per square foot at the 2-3 leaf stage, and at the 2nd-3rd tiller stage when 100% of the plot was manually defoliated. Although a decrease in yield was observed for some growth stages, it is clear that additional data is needed before a confident recommendation for control of FAW can be created.

Evaluation of Insecticide Termination for Rice Stink Bug, *Oebalus pugnax*, in Arkansas Rice

Cato, A.J, Lorenz, G.M., Hardke, J.T., Bateman N.R., Taillon, N.M., Clayton, T.L., Plummer, W.A., McPherson, J.K., Black, J.L., and McCullars, L.D.

The stages of rice grain maturity that are most susceptible to rice stink bug, *Oebalus pugnax,* (RSB) damage have been properly identified; however, the level at which they are no longer capable of causing appreciable damage during the hard dough stages is unclear. A study in 2016 determined that appreciable levels of peck are possible through 60% hard dough, but the infestation level of RSB that warrants an insecticide application is still unknown. The objective of this study was to determine the infestation level of RSB that is capable of causing appreciable levels of peck during hard dough.

Rice stink bug damage was examined using 4 hard dough percentages (20, 40, 60, and 80%), 2 infestation levels (25 and 50 RSB per cage), and 2 cultivars (Hybrid and Conventional) using cages containing plots of rice measuring 0.91x0.91 meters (3' x 3'). The randomized complete block design included four replications of each combination, and eight uninfested cages for each cultivar. Peck percentages and milling quality of harvested plots were then utilized as response variables. Both the conventional and hybrid cultivars exhibited no trend across the infestation level by hard dough percentage combinations, and average peck values did not exceed 0.32% and 0.22% respectively. These observed values are much lower than grade 3 rice at 3% peck. Although these data suggest that RSB infestation levels at 2x and 4x threshold may not be capable of causing appreciable peck in hard dough, additional data is needed to confirm this trend and build a confident insecticide termination recommendation.

Unraveling the Role of Epicuticular Wax in Rice Defense against Rice Water Weevil and Fall Armyworm

Bernaola, L., Tai, T., and Stout, M.

Interactions between plants and insect herbivores are important determinants of plant productivity in agricultural ecosystems. In response to insect attack, plants have evolved a range of defenses to overcome these challenges and thus reduce the threat of injury and loss of productivity. Plant structural traits such as wax cuticles can act as a physical barrier for insect herbivore attachment, feeding, and oviposition; the plant cuticle is one trait of particular focus in crop protection. Epicuticular waxes (EW) form a slippery film or crystals of the aerial surfaces of many land plants that prevent uncontrolled loss of water and protection to different biotic and abiotic stresses. In rice (*Oryza sativa* L.), mutations that reduce EW have been known just recently. However, whether wax mutations on rice affect rice water weevil (RWW, *Lissorhoptrus oryzophilus*) and fall armyworm (FAW, *Spodoptera frugiperda*) performance have not been investigated yet. Consistently, these two important pests cause significant economic problems in different rice producing areas. Mutant approaches can be used as a tool to understand the role of EW in plant-insect interactions with more precision. The aim of our study was to compare the resistance of EW mutants and wild-type (WT) rice plants against RWW and FAW. We hypothesize that EW mutants will have weaker resistance to pests than WT plants. In greenhouse experiments, we used three lines with mutations (7-17A, 6-1A, and 11-39A) in the production of EW of rice and their wild-type (Sabine). Plants were grown for one month before conducting two choice (RWW) and two no-choice (FAW) experiments. Our results showed that numbers of larval weevils and weight gains of armyworms were higher in wax mutants than in WT. These results indicate that epicuticular waxes are involved in rice resistance to weevils and armyworms. Understanding plant physical barrier to biotic stresses may be helpful for the development of resistant varieties for reducing pest insect damage.

Identification and Mapping of a Novel Gene Controlling Cercospora Resistance in Rice

Addison, T.K., Angira, B., Dartez, J., Thornton, J., Groth, D.E., and Famoso, A.

Cercospora janseana is a fungus that causes Narrow Brown Leaf Spot in rice. It is characterized by linear, reddish-brown spots that appear on the leaves around heading. Under favorable conditions *Cercospora* can be a major problem to Louisiana rice production systems causing leaf necrosis, which can result premature ripening of seeds as well as reduction of overall yield and milling quality. The last major outbreak of *Cercospora* occurred in 2006 and affected more than 50 percent of the total acreage planted. Genetic resistance to *Cercospora janseana* exist but it is difficult to select for in field conditions due disease pressure varying yearly along with no simple method for inoculations. In 2016 and 2017, a bi-parental population consisting of 292 RILs from a cross between two elite cultivars was grown under field conditions at the Rice Research Station in Crowley, LA. Initial QTL analysis was performed using 115 SNP markers. A large effect QTL (LOD = 73.2, R^2 = 67.1) for *Cercospora* resistance was identified in both years. In 2017, 14 additional markers were added to the QTL region and the gene was narrowed to a target region of 300 kb. Bulk seed of five RIL families were screened to identify plants with residual heterozygosity at the QTL region and these plants were selfed to generate 6,000 segregating plants for a recombinant screen.

Abstracts of Papers from the Student Oral Competition Panel
Weed Control and Growth Regulation

Which Rice Growth Stages are Most Susceptible to a Sub-lethal Rate of Paraquat?

Lawrence, B.H., Bond, J.A., Golden, B.R., Edwards, H.M., Peeples, J.D., and McCoy, J.M.

Paraquat is widely utilized for preplant herbicide applications in corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean [*Glycine max* (L.) Merr] to control glyphosate-resistant weeds. Paraquat is applied preplant to these crops often in mixtures with other herbicides representing different modes of action for improved postemergence and residual weed control. Due to Mississippi's diverse cropping systems and extended planting windows for corn, cotton, and soybean, incidents of off-target paraquat movement to rice have increased in recent years. Rice is most sensitive to off-target movement of systemic herbicides during early reproductive growth stages; however, little is known of the effects of paraquat off-target movement to rice at different growth stages. Off-target herbicide movement to rice from applications containing paraquat often creates a complex situation because multiple modes of action are represented. Therefore, research was conducted to determine at which growth stages rice is most susceptible to exposure to a sub-lethal rate of paraquat and if mixing a sub-lethal rate metribuzin or fomesafen with paraquat compounds the negative effects.

Two studies were conducted from 2015 to 2017 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to characterize rice performance following exposure to a sub-lethal rate of paraquat applied at different growth stages and to evaluate rice response to a sub-lethal rate of paraquat applied alone or in mixtures with sub-lethal rates of metribuzin or fomesafen. Experimental design for both studies was a randomized block with four replications. In the timing study, paraquat was applied at 0.075 lb ai A^{-1} to spiking to one-leaf rice (VEPOST), two- to three-leaf rice (EPOST), three- to four-leaf rice (MPOST), 7 days postflood (7 d PTFLD), and to rice at panicle differentiation (PD). In the herbicide mixture study, treatments were arranged as a two-factor factorial with Factor A consisting of paraquat applied at 0 and 0.075 lb A^{-1} and Factor B being herbicide mixture and including no herbicide mixture, metribuzin at 0.037 lb ai A^{-1}, and fomesafen at 0.035 lb ai A^{-1}. In both studies, visual estimates of rice injury were recorded 3, 7, 14, 21, and 28 d after treatment (DAT), and rice height was recorded 14 DAT. The number of days to 50% heading was recorded as an indication of rice maturity. Rough rice yields were collected at maturity. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

Injury to rice following exposure to paraquat was >41% 14 and 28 DAT regardless of application timing. Injury 14 DAT was greatest following paraquat applied VEPOST; however, by 28 DAT, injury was greatest following MPOST, 7 d PTFLD, and PD treatments. Rice heights 14 DAT were reduced 42% with paraquat applied MPOST. Delays in rice maturity were >6 d regardless of paraquat application timing with delays in maturity up to 2 wk following paraquat applied at PD. Rough rice yields were reduced to 8% of the nontreated following rice exposure to paraquat at PD; however, rice exposed at VEPOST produced yields 94% of the nontreated control.

In the herbicide mixture study, rice injury 14 and 28 DAT was <10% following applications of metribuzin or fomesafen alone. Rice injury was 54 to 58% following rice exposure to paraquat alone or mixed with fomesafen; however, the addition of metribuzin to paraquat increased rice injury to >68% 14 and 28 DAT. Pooled across herbicide mixtures, paraquat delayed rice maturity 9 d. Rough rice yield was reduced at least 28% following exposure to paraquat compared with where no paraquat was applied.

These data indicate the greatest levels of injury, delays in maturity, and reductions in yield occurred following rice exposure to paraquat during early reproductive growth stages. Early-season injury to rice following exposure to paraquat had less effect on rice yield compared with injury occurring at later developmental stages. However, delays in rice maturity were ≥ 6 d with all treatments, so harvest efficiency could be affected regardless of growth stage at which exposure occurred. Although rice yield was only affected by exposure to paraquat late in the season, the addition of metribuzin to paraquat increased early-season injury. Rice exposure to paraquat negatively affected rice growth and development regardless of timing of exposure or mixture; therefore, caution should be exercised when applying paraquat in proximity to emerged rice.

Rice Response to Glyphosate or Paraquat Exposure during Reproductive Growth Stages

McCoy, J., Golden, B., Bond, J., Bararapour, T., Gore, J., and Dodds, D.

In 2017 1.69 million hectares (4.2 million acres) of principal crops were planted in the state of Mississippi. Of this acreage, 48,552 hectares (120,000 acres) were devoted to rice production in 2017. The close proximity to other crops such as cotton (*Gossypium hirsutum* L.), corn (*Zea mays*), and soybean [*Glycine max* (L.) Merr.], creates a great potential for off-target herbicide movement onto rice fields. The growing adoption of harvest-aid use across upwards of 0.809 million soybean hectares (2 million acres) throughout Mississippi only furthers the risk of late season exposure to off-target herbicide movement. Therefore research was conducted evaluating rice response across multiple cultivars to late-season exposure to glyphosate or paraquat.

Research was established in 2016 & 2017 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate rice grain yield and yield component response to late season off-target herbicide movement. Secondary objectives of this research were to identify differences in visual injury response across multiple rice cultivars, identify differences in visual injury response across multiple herbicide chemistries, and to identify differences in rice response across multiple application timings. To achieve objectives 1-3 treatments were arranged in a randomized complete block with a five (rice cultivars) × three (herbicide chemistry) factorial. The rice cultivars evaluated were CLXL745, XL753, CL163, Rex and Jupiter. Herbicide chemistries evaluated were none (0 lb ai/A), glyphosate (0.1125 lb ae/A) and paraquat (0.025 lb ai/A). Herbicide applications were initiated at the 50% heading growth stage of each respective cultivar. To achieve the fourth objective treatments were arranged as split-plot design consisting of herbicide, glyphosate or paraquat, as the whole plot and application timing as the sub-plot. Applications of glyphosate (0.1125 lb ae/A) or paraquat (0.025 lb ai/A) were made to the rice cultivar CL163 initiated at the 50% heading growth stage with subsequent applications in one week intervals up to harvest. Rates were based on 0.10 of the labeled harvest-aid rate in Mississippi. Herbicides were applied at a constant carrier volume of 140 L/ha with a CO_2 pressurized backpack sprayer. Visual estimates of rice injury were recorded 3, 7, 14, 21, and 28 day after treatment. At maturity a small plot combine was utilized to harvest each plot and collect rough rice yields. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

Visual estimates of leaf injury from glyphosate applications were not observed for any rice cultivar or application timing. Visual injury to all rice cultivars following exposure to paraquat ranged between 5 to 25%; however, less injury was observed in hybrid rice cultivars. Inbred cultivars Rex and Jupiter incurred injury up to 25%; whereas, hybrid cultivars CLXL745 and XL753 incurred ≤ 15% injury.

Rice grain yield was influenced by late-season exposure to glyphosate and paraquat. Yield reduction from the untreated control ranged from 3 to 32% across cultivar and herbicide chemistries. Hybrid cultivar yield reduction for glyphosate and paraquat was observed to not differ from the untreated control. Grain yield reduction for inbred cultivars ranged from 14 to 32% and 18 to 28% for glyphosate and paraquat, respectively. Across application timings rice yield reduction for glyphosate and paraquat was observed to range from 2 to 14% and 3 to 16%, respectively. Paraquat application was observed to significantly reduce yield up to the date of draining. Yield reductions from herbicide applications were observed to decrease as rice neared maturity.

Preliminary research suggests that rice may be influenced by late-season off target herbicide movement. Observations suggest differences in response to exposure to glyphosate and paraquat exists across cultivar and application timing. Further research will be required to validate and quantify the differential response of cultivars and application timings to late-season off target herbicide movement onto rice.

Planting Depth of California Rice Cultivars Influences Crop Stand and Weed Control

Ceseski, A., Godar, A.S., Lee, M., and Al-Khatib, K.

California rice is predominantly aerially-seeded into continuous flood, and is grown as a monoculture with no winter cover crops. Herbicides are the chief method of weed control. Due to decades of continuous use of this program, herbicide resistance is widespread in the region, and management of resistance while maintaining economically viable yields is becoming increasingly difficult for many growers. We intend to develop a program of dry-seeding rice which drills the rice below surface weeds. This preplanted stale-seedbed technique delays crop emergence and should allow most grasses and sedges to be controlled by glyphosate -which is not yet labeled for California rice- and other economical herbicides labeled for California rice.

Field trials were conducted over two years at the Rice Research Station in Biggs, CA. Cultivar M-206 was planted at three depths (D1-D3) between 1.27 cm and 5.08 cm, and treated with seven herbicide programs plus untreated control (UTC). Each treatment included glyphosate applied just as the rice seedlings were breaching the soil surface, and all but one treatment included other herbicides. Each depth was flush-irrigated until the last treatment was applied, then flooded for the remainder of the season. Weed coverage and density were recorded, as well as crop physiology and yield metrics.

Greenhouse trials were conducted at the Rice Research Station and at University of California, Davis. Four common cultivars (M-105, M-205, M-206, M-209) were planted into draining plastic tubs for each study. Study 1 measured coleoptile vigor over time for each cultivar, at three depths from 2.54 cm to 7.62 cm. Study 2 measured emergence and physiological characteristics for each cultivar planted at seven depths ranging from 0 cm to 7.62 cm.

Field trials indicated that using glyphosate alone resulted in good weed control compared to UTC across all depths. *Echinochloa spp.* density decreased by 30% - 40% at D1 over both seasons. At deeper planting depths weed control was more variable year over year. *Echinochloa spp.* decreased by 21% in year 1, but decreased by 60-70% at the deeper plantings in year 2. Sedges were largely absent in year 2, but with glyphosate alone were decreased by 30% - 40% in year 1.

Rice yields for glyphosate-only treatment were low across all planting depths, and inconsistent across years. In year 1, yield was 3400-4770 kg ha^{-1}. In year 2 yield was below 2000 kg ha^{-1} for all depths. Yields for weed-free plots were highest at the shallowest planting depths in both years, ranging from 8800 kg ha^{-1} to 11100 kg ha^{-1}. At deeper depths the highest yields ranged from 3660 kg ha^{-1} to 8900 kg ha^{-1}. Yields were generally higher in year 1 for all treatments. Greenhouse studies indicate that M-205 and M-209 have similar coleoptile vigor, emergence rates, and total emergence across all depths. Both cultivars performed better than M-105 and M-206 in all studies. Future field studies will use one of these cultivars.

Our results suggest that drillseeding rice below the weed seedbank can achieve weed control and yields competitive with more common practices, however herbicide application timing and water management are critical to realizing that potential. Planting at deeper depths allows for later applications of glyphosate and generally better weed control, but at a cost of reduced yields.

Weed Control in Organic Rice Using Plastic Mulch and Water Seeding Methods in Addition to Cover Crops

Mahato, G.R., Huang, B., McClung, A., Zhou, X.G., Dou, F., Watkins, B.,
Bagavathiannan, M., Way, M., and Ntamatungiro, S.

Weeds are a major yield limiting factor in organic rice farming and are more problematic than in conventional production systems. Water seeding is a common method of reducing weed pressure in rice fields as many weeds connot tolerate flooded field conditions. The use of cover crops is another method of reducing the weed seed population in a field by competing with the weeds and preventing seeds from forming. The use of plastic mulch as a weed barrier is effectively used in some organic crops, like vegetables and fruits, that have high economic value. This research was conducted to evaluate the effectiveness of plastic mulch and water seeding methods as means to control weeds in organic rice.

For the plastic mulch weed control study, in fall 2016 a mixture of annual ryegrass and crimson clover was planted and, in the spring, terminated and incorporated. The field was covered with Black Plastic Mulch 4ft. x 100ft. 1.0 Mil Embossed 3 weeks after cover crop termination. Six rice varieties including conventional and weed suppressive cultivars were tested using CRD experimental design with four replications. Twelve experimental hybrids were also tested using three replications and the same experimental design. The plots were hand seeded into the soil by making holes into the plastic mulch. Each plot consisted of single row with 14 plants spaced on a 15 cm x 30 cm grid. Plots were irrigated to achieve plants stand and continuous flooding was maintained after rice plants attained height of 12-15 cm.

Another separate water seeded experiment was conducted in an area of the field previously planted to a fall cover crop mixture of oats and crimson clover. After termination of the cover crop in the spring, ten rice varieties were water seeded using RCBD design with two different seeding rates of 224 kg/ha and 448 kg/ha and four replications. After four weeks, a section of the plot was thinned to be the equivalent of six hill plots as a means of having similar comparison to the plastic mulch study. Data collected included days to heading, grain yield, and incidence of straighthead using a scale of 0 (none) -to 9 (100%) for both experiments.

Weeds were effectively controlled in both the plastic mulch and water seeded trials. Weed pressure in the plastic mulch study was lower than the water seeded study during the whole growing season. However, weeds present in the water seed trial were primarily within the open areas of the field, not within the plots per se. Prevalent weeds included red stem and duck salad. Severe straighthead and panicle blanking were observed in the water seeded trial. Straighthead was found higher in the high seeding rate versus the lower. Rice varieties Rondo, Jasmine 85 and Cocodrie showed high straighthead scores whereas PI312777 and Presidio were moderate. Moreover, straighthead in thinned plot area was significantly lower than the high density area of the plots in both seeding rates. Conversely, rice varieties planted under plastic mulch had only moderate straighthead except for the highly susceptible Cocodrie. Some hybrid lines showed low straighthead scores with high yield.

The results suggest that plastic mulch and water seeding can be effective means of weed control in organic rice systems. However, water seeded plots were more susceptible to straighthead than when plastic mulch is used as a weed barrier.

Survey of Bearded Sprangletop Response to Clomazone in California Rice

Driver, K.E., Al Khatib, A., and Godar, A.

Bearded sprangletop (*Leptochloa fusca* (L.) Kunth ssp. *fasicularis* (Lam.) N. Snow) is a problematic weed in California rice production and few herbicides provide efficacious control. As control of bearded sprangletop has declined, suspicion of resistance has increased due to the continuous rice cropping system in the region. Seed from 21 populations were submitted by growers from the California rice growing region and screened for clomazone resistance. Greenhouse experiments were conducted at the Rice Research Station in Biggs, CA to determine bearded sprangletop population sensitivity to clomazone. Experiments were arranged in a randomized complete block design with a factorial treatment structure; factor 1 being treatment and factor 2 being bearded sprangletop population. Treatments consisted of 1) non-treated, 2) 673 g ai ha^{-1} clomazone, and 3) 2019 g ai ha^{-1} clomazone. Plant height and control of bearded sprangletop were recorded weekly for 3 weeks. At 3 WAT, bearded sprangletop biomass was harvested and dried. Four populations were confirmed resistant at both rates tested. However, the survival of the treated plants resulted in reduction of biomass ranging from 30 to 98% at 3 WAT. A decrease in height ranging from 29 to 72% was observed for all populations that survived 2019 g ai ha^{-1} clomazone treatment. Clomazone resistant bearded sprangletop plants were initially injured but began to recover 14 DAT. Additional studies are being conducted to test the level and mechanism of resistance.

Evaluation of Provisia Mixed with RiceOne, Command, or Prowl

Osterholt, M.J., McKnight, B.M., Webster, E.P., Telo, G., Rustom Jr., S.Y., and Webster, L.C.

With the confirmation of imidazolinone-resistant (IR) weedy rice (*Orzya sativa L.*) and documented cases of barnyardgrass [*Echinochloa crus-galli (L.) P. Beauv*] resistance to various sites of action, BASF launched quizalofop resistant rice in 2017 and sold under the tradename Provisia. Quizalofop provides postemergence (POST) control of weedy rice and broad spectrum control of annual and perennial grass weeds common in rice production. However, quizalofop offers very little residual activity, and with over 65% of the rice acres under a dry-seeded planting system, rice growers often rely on preemergence (PRE) and/or POST herbicides to help manage weeds.
RiceOne is a pre-packaged mixture of clomazone and pendimethalin at 128 and 307 g ai L^{-1}, respectively. Louisiana rice growers could potentially benefit from an early-POST (EPOST) application of quizalofop mixed with RiceOne. However, research in Louisiana has documented cases of antagonism of quizalofop when mixed with other labeled rice herbicides. The objective of this research was to evaluate a potential mixture between EPOST applications of quizalofop mixed with RiceOne, clomazone, or pendimethalin.

A field study was conducted in 2017 at the LSU Agricultural Center H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA. Treatments were arranged as a two-factor factorial in a randomized complete block design with four replications. Factor A consisted of EPOST applications, two- to three-leaf, of quizalofop at 0 or 120 g ai ha^{-1}. Factor B consisted of EPOST applications of clomazone at 336 g ha^{-1}, pendimethalin at 806 g ha^{-1}, a mixture of clomazone at 336 g ha^{-1} plus pendimethalin at 806 g ha^{-1}, or RiceOne at 1142 g ai ha^{-1}, and no mixture herbicide. Clomazone and pendimethalin rates applied alone are equal to the rates found in the pre-packaged mixture of RiceOne.

Herbicide applications were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 190 kPa. Plot sizes were 1.52 by 5.2 m and included eight, 19.5 cm drilled-seeded rows planted with Provisia rice variety 'PVL01-B'. Eight rows of IR 'CL 111' rice and eight rows hybrid IR 'CLXL 745' rice was planted perpendicular to Provisia rice. Awnless red rice was broadcasted at 50 Kg ha^{-1} in the plot area prior to drill seeding at 50 Kg ha^{-1}. A second application of quizalofop at 120 g ha^{-1} was applied 28 days after the initial treatment (DAIT) over the entire research area. Visual injury ratings from 0 to 100 were recorded at 10 and 21 DAIT, where 0 = no injury and 100 = plant death.

At 10 DAIT, red rice treated with clomazone, pendimethalin, clomazone plus pendimethalin, or RiceOne was controlled 0%; however, quizalofop mixed with any of the residual herbicides controlled red rice 97 to 98%. The red rice control when treated with the mixtures was equivalent to quizalofop applied alone with 98% control. At 10 DAIT, barnyardgrass when treated with clomazone, pendimethalin, clomazone plus pendimethalin, or RiceOne was controlled 68 to 88%; however, quizalofop mixed with any of the residual herbicides controlled barnyardgrass 98%. At 10 DAIT, amazon sprangletop [*Leptochloa panicoides (J. Presl) Hitchc.*], when treated with clomazone, pendimethalin, clomazone plus pendimethalin, or RiceOne was controlled 86 to 91%; however, quizalofop mixed with any of the residual herbicides controlled amazon sprangletop 98 to 99%. Similar results were observed at 21 DAIT.

Clomazone, pendimethalin, clomazone plus pendimethalin, or RiceOne mixed with quizalofop resulted in a neutral interaction with no antagonism observed. This research indicates that a residual herbicide such as RiceOne, clomazone, or pendimethalin can be used in mixture with quizalofop without a negative interaction occurring. The addition of RiceOne will add two more sites of action when applied in mixture with quizalofop, and this can be another tool for the management or delay of herbicide resistance, especially for barnyardgrass and Amazon sprangletop.

Antagonism of Quizalofop by ALS-inhibiting Herbicides in ACCase-resistant Rice Production

Rustom, S.Y., Webster, E.P., McKnight, B.M., Telo, G.M., Webster, L.C., and Osterholt, M.J.

The introduction of imidazolinone-resistant (IR) rice (*Oryza sativa* L.) in 2002 allowed producers to control red rice (*O. sativa* L.) with a herbicide for the first time. However, IR rice has naturally outcrossed with its weedy and wild relatives resulting in IR red rice. Additionally, IR hybrid rice seed has a history of dormancy and can become weedy when allowed to establish in following growing seasons as a volunteer. These IR volunteers, red rice, and outcrosses will be referred to as weedy rice. Weedy rice can compete for nutrients and light at a higher rate than cultivated rice, and can result in many different phenotypic characteristics such as plant height, dark to light green vegetative color, various grain color, presence of awns, medium to long grain size, and pubescent to glabrous leaves.

Another weed management concern in rice production is barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.]. Barnyardgrass resistant to propanil, quinclorac, imazethapyr, or imazamox has become a common problem throughout rice producing regions in the southern United States, and the potential exists for the spread of these resistant biotypes.

In response to IR weedy rice and barnyardgrass resistant to several different modes of action, BASF developed a new herbicide resistant rice called Provisia™. Quizalofop is the herbicide targeted for use and it will also be called Provisia™. Quizalofop is a Group 1 herbicide that inhibits ACCase enzyme, and provides POST control of annual and perennial grasses with little to no activity on broadleaf or sedge weeds. Historically, quizalofop has been used to reduce red rice and grass infestations in soybean production applied at rates of 35 to 85 g ai ha^{-1}.

Herbicide mixtures have proven to benefit producers with regards to broadening the weed control spectrum and maximizing economic returns. However, ACCase herbicide activity is often antagonized when applied mixed with other herbicides. Herbicide mixtures can indicate one of three responses: synergistic, antagonistic, or neutral. The focus of this research was to determine antagonistic, synergistic, or neutral responses of barnyardgrass and weedy rice treated with quizalofop mixed with various ALS-inhibiting herbicides used in rice production.

A field study was conducted in 2015 and 2016 and the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate quizalofop activity when applied alone or mixed with ALS-inhibiting herbicides. Plot size was 5.1 by 1.5 m with eight, 19.5 cm drill-seeded rows planted as follows: 4 rows of ACCase-resistant 'PVL024B' rice, 2 rows of IR 'CL-111' rice, and 2 rows of IR-hybrid 'CLXL-745' rice. In addition, awnless red rice was broadcast in the research area at 50 kg ha^{-1}. The CL-111, CLXL-745, and red rice were planted to represent a weedy rice population. The research area was also naturally infested with barnyardgrass. Each herbicide application was applied when the rice was at the three- to four-leaf growth stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}.

The study was a randomized complete block with a factorial arrangement of treatments with four replications. Factor A consisted of quizalofop applied at 120 g ha^{-1} or no quizalofop. Factor B consisted of penoxsulam at 40 g ai ha^{-1}, penoxsulam plus triclopyr at 352 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, bispyribac at 34 g ai ha^{-1}, orthosulafamuron plus halosulfuron at 94 g ai ha^{-1}, orthosulfamuron plus quinclorac at 491 g ai ha^{-1}, imazosulfuron at 211 g ai ha^{-1}, bensulfuron at 43 g ai ha^{-1}, or no mixture herbicide. A second quizalofop application was applied to all treatments at a rate of 120 g ha^{-1} at 28 days after the initial quizalofop treatment (DAT). A crop oil concentrate was added to each herbicide application at a rate of 1% v v^{-1}. Antagonistic, synergistic, or neutral responses were determined using Blouin's modified Colby's analysis by comparing an expected control calculated based on the activity of each herbicide applied alone to an observed control.

All ALS herbicides mixed with quizalofop indicated antagonistic responses for red rice, CL-111, CLXL 745, or barnyardgrass control at either 14 or 28 DAT. At 28 DAT, quizalofop mixed with penoxsulam or bispyribac controlled barnyardgrass 33 to 38%, compared with an expected control of 91 to 92%. In addition, these same mixtures controlled red rice, CL-111, and CLXL-745 61 to 67% at 28 DAT compared with an expected control of 96 to 97%. A second application of quizalofop at 120 g ha^{-1} was applied at 28 DAT. At 42 DAT, neutral responses were observed for all mixtures except with quizalofop mixed with penoxsulam containing products, which indicated an antagonistic response despite the second independent application of quizalofop. These data indicate penoxsulam should be avoided in ACCase-resistant rice production. Furthermore, these data can aid in the development of weed management strategies for ACCase-resistant rice production.

Halosulfuron Applied at Reduced Rates with Quizalofop in Provisia Rice

Webster, L.C., McKnight, B.M., Webster, E.P., Osterholt, M.J., Rustom S.Y., and Telo, G.M.

Imidazolinone resistant (IR) weedy rice (*Oryza sativa* L.) and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] resistance prompted BASF to develop an acetyl coenzyme A carboxylase (ACCase) resistant (ACCase-R) rice (*O. sativa* L.) to be sold under the tradename of Provisia®. The targeted herbicide for use is quizalofop, a member of the aryloxyphenoxypropionate herbicide family. The targeted single application rate of quizalofop is 92 to 155 g ai ha^{-1}, not to exceed 240 g ha^{-1} per year. ACCase-R rice will allow quizalofop to be applied postemergence (POST) in ACCase-R rice for control of annual and perennial grasses including weedy rice and barnyardgrass.

Herbicides are often applied in a mixture to broaden the weed control spectrum, save time, and save application costs. Herbicide interactions may result in one of three responses: synergistic, antagonistic, or additive/neutral. ACCase herbicide antagonism for grass weed control is commonly observed when applied in a mixture with a broadleaf or sedge herbicide. Halosulfuron mixed with quizalofop has been shown to be slightly antagonistic for weedy rice and barnyardgrass control. Increasing the ratio of graminicide to broadleaf or sedge herbicide in a mixture can potentially reduce the antagonism of the graminicide. The objective of this study was to evaluate reduced rates of halosulfuron on quizalofop activity. A Gowan supplied halosulfuron (halosulfuron-P) (Permit label, Gowan Company, Yuma, AZ) and an Aceto supplied halosulfuron (halosulfuron-H) (Halomax label, Aceto Agricultural Chemicals Corporation, Lake Success, NY) were evaluated at reduced rates in a mixture with quizalofop.

A study was conducted in 2017 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana. Plot size was 1.5 by 5.1 m with eight, 19.5 cm drill-seeded rows of ACCase-R 'PVL01-B' long grain rice. In addition to PVL01-B, eight, 19.5 cm drill-seeded rows of IR 'CLXL-745', and 'CL-111' were planted perpendicular to the PVL01-B at 84 kg ha^{-1}. Awnless red rice was broadcasted at 50 kg ha^{-1} across the research area, and the area was naturally infested with barnyardgrass.

Each halosulfuron formulation was a separate study. The study was a randomized complete block with a two-factor factorial arrangement of treatments with four replications. Factor A consisted of POST applications of quizalofop at 0 and 120 g ha^{-1}. Factor B consisted of POST applications of either halosulfuron formulation at 0, 17, 35, and 53 g ai ha^{-1} or a pre-packaged mixture of halosulfuron and thifensulfuron at 34 and 53 g ai ha^{-1}. At 21 days after the initial treatment (DAIT), a second application of quizalofop was applied at 120 g ha^{-1}. All herbicide applications were applied with a crop oil concentrate at 1% v v^{-1}. Visual evaluations for this study included barnyardgrass, red rice, CL-111, and CLXL-745 control at 7 and 21 DAIT. Rice yields were obtained and adjusted to 12% moisture.

For halosulfuron-H, CLXL-745 treated with quizalofop applied alone was controlled 97% at 7 DAIT and 99% at 21 DAIT. At 7 DAIT, CLXL-745 treated with quizalofop plus halosulfuron-H at 17, 35, and 53 g ha^{-1} was controlled 91, 93, and 91%, respectively; however, at 21 DAIT, the same mixtures resulted in 99% control for all three rates of halosulfuron-H. At 7 DAIT, CLXL-745 treated with halosulfuron-H plus thifensulfuron at 34 and 53 g ha^{-1} in a mixture with quizalofop was controlled 91 and 93%, respectively, and at 21 DAIT, the same mixtures resulted in 99% control for both rates of halosulfuron-H plus thifensulfuron evaluated. No reduction in control was observed for red rice, CL-111, or barnyardgrass when halosulfuron-H or halosulfuron-H plus thifensulfuron were mixed with quizalofop. ACCase-R rice treated with halosulfuron-H at 53 g ha^{-1} mixed with quizalofop yielded 4410 kg ha^{-1}, which did not differ from any of the halosulfuron-H or halosulfuron-H plus thifensulfuron containing applications.

In the second study, evaluating halosulfuron-P, no reduction in control was observed for red rice, CLXL-745, CL-111, or barnyardgrass when halosulfuron-P or halosulfuron-P plus thifensulfuron were mixed with quizalofop. ACCase-R rice treated with halosulfuron-P at 53 g ha^{-1} mixed with quizalofop yielded 5140 kg ha^{-1}, which did not differ from any of the halosulfuron-P or halosulfuron-P plus thifensulfuron containing treatments.

In conclusion, the slight reduction in quizalofop activity on barnyardgrass when mixed with halosulfuron-H at 7 DAIT did not differ with reduced rates of halosulfuron-H. This research indicates no antagonism occurred from any rate or brand of halosulfuron evaluated; however, research in Louisiana has shown slight antagonism with halosulfuron-P mixed with quizalofop.

Abstracts of Papers on Breeding, Genetics, and Cytogenetics
Panel Chair: Thomas Tai

Gearing Up for the Next 100 Years of Rice Breeding in California

Andaya, V.C., Andaya, C.B., and McKenzie, K.S.

Looking back from the moment a California rice station was born more than a hundred years ago to what is now known as the Rice Experiment Station (RES), one can only feel the enormous pride of those who became part of this organization. From its humble beginnings and rich traditions of conventional rice breeding up to this age of exciting tools in molecular rice breeding and precise genetic modification, the Rice Experiment Station is building on its successful rice breeding traditions that have been handed down by its dedicated rice breeders.

RES celebrated its centennial in 2012 with the hope and focused determination of continuing its mission of breeding better rice varieties in the next 100 years for the California rice farmers. A century of history in rice breeding provides important knowledge and insights based on the experiences of rice breeders in the past using traditional breeding methods, its limitations and challenges, successes and failures. These insights and knowledge imparted to the next generation of RES rice breeders will prepare them to tackle new breeding challenges such as new pests and diseases, further increasing grain yields while improving quality, changing consumer preferences and demand for new rice products, etc. The scientific and technical challenges may even be complicated by government regulations and new rules, acceptability of new varieties derived by non-traditional means or by gene editing, and couple that with market forces, consumer preferences, patents and variety protection restriction to germplasm exchange, and so on.

Building on the effective rice breeding traditions rather than making a very aggressive transformation to cutting-edge gene technologies, is how RES thinks of gearing up for the next 100 years of rice breeding. We will discuss how we merged and adopted new technologies into conventional breeding to run more cost-effective and successful breeding program.

To see the future, one has to look at the past. Looking forward is as critical as looking back. We can only hope this is going to be a wild and exciting ride into the 22nd century of rice breeding.

Rice Variety Development in Louisiana: Objectives, Technologies, and Resource Allocation

Famoso, A., Addison, C., Angira, B., Bearb, K., Cerioli, T., Conner, C., Guidry, G., Groth, D., Harrell, D., Kongchum, M., Linscombe, S., Oard, J., Utomo, H., Williams, B., and Wenefrida, I.

The rice breeding program at the LSU AgCenter H. Rouse Caffey Rice Research began over 100 years ago and has released over 50 new varieties that have been grown throughout Louisiana and the southern U.S. Significant support of the program is generously provided by Louisiana rice producers through a check-off fund. The objective of the program is to continuously develop new varieties that increase the profitability of the rice producers and rice industry. The primary trait targets include yield, grain quality, disease resistance, and agronomic traits such as lodging resistance and early maturity.

Although the primary objective of the breeding program has not changed over the years, the size and scale of the program has continually increased over the years. New technologies and collaborations have been key in increasing the size of the program and the accuracy of the data collected. This talk will provide an overview of the LSU AgCenter rice variety breeding program and discuss some of the key advances in technologies over the years that have facilitated growth and success of the program. Modern technologies, such as molecular markers, precision phenotyping, and computer breeding software offer the potential to further increase the size and accuracy of applied breeding programs. The opportunities and challenges of integrating modern technologies into the program will be discussed in the context of applied breeding goals and resource allocation.

Breeding Related Research Activities in Texas Inbred Rice Varietal Development Project

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

Population development, selection and performance trials of breeding lines are the major activities in the breeding program. However, research activities such as selection of donors and identification of new or important traits, inheritance/genetic studies, and generation of new variants are also conducted. Highlights of studies conducted related to drought, grain quality and mutation breeding are presented below.

Water is getting scarce worldwide, and limited water was a problem in Texas over the past three years. The occurrence of drought is expected to be prevalent with climate change. A three-year study was conducted to determine the effect of drought on previously identified stress tolerant lines. Two identical blocks of 13 entries were planted each year, one with a maintained flooded and the other with a flood removed at the reproductive stage but flushed when leaf drying was observed. Milling and yield data were collected, and three estimates of drought were determined: drought intensity index = 1-(Yd/Yf), drought susceptibility index = (1 – Yd/Yf)/ (1 – Xd/Xf) and geometric index = $(Yd*Yf)^{1/2}$, where Yd and Yf are the entry yield in drought and flooded fields, respectively, and Xd and Xf are mean yield in drought and flooded fields, respectively. Some entries were consistently good, particularly the breeding lines TXDT-0001 and TXDT-0013; however, TXDT-0002 (4610 selection) had the best yield potential under drought conditions followed by TXDT-0012 (Empasc 105 selection). The 2016 winter had very low temperatures and freezing temperatures killed highly susceptible ratooning entries in other trials but not in the drought study. Thus, the plots in the drought study were scored for cold tolerance twice (Dec. 21, 2016 and March 22, 2017). The ratoon plants were exposed for 109 days with minimum temperature range of -2 to15ºC, 52 days with mean daily temperature of -1 to 13ºC and 17 days with maximum temperature range of 7 to 14ºC. More than 10 consecutive days with temperature below 15ºC (critical low temperature) was recorded twice in December and once in November and January. There were significant variations among entries in ratoon plant stand and the two scoring dates for cold tolerance. Rondo and TXDT-0012 showed consistent high susceptibility to cold temperature, as did the two indicas, TXDT-0002 and TXDT-0003. Moderate cold tolerance was noted among breeding lines from an LQ243a/Saber cross. TXDT-0001 and TXDT-0013, identified earlier as drought tolerant, were the most cold tolerant and are potential donors for ratoon cold tolerance.

Milling quality is very critical in export markets. Not only is the percentage of whole-milled rice or head rice important but also chalkiness, color and translucency. The ratoon crop (RC) or second harvest after the main crop (MC) is still a popular practice in Texas. Mixing of the MC and RC of a variety is generally done. Previous studies comparing MC and RC milled rice showed that the percentage total (% Total) and whole-milled (% Whole) rice were genotype dependent. However, % Total of RC was always lower than MC for each genotype and the opposite was true for % Whole. MC had more chalk than RC. The 2016 MC and RC harvests of 25 genotypes from Eagle Lake and Beaumont were evaluated for whiteness and transparency using a Zaccaria whiteness meter to determine variation in MC and RC milled rice (time of harvest, TH), locations (L) and among genotypes (G). Glutinous and commercial imported rice were included with Antonio and Presidio for comparison. Milled rice whiteness varied significantly among genotypes, between MC and RC but not location. Significant interactions were noted: L x G and L x TH. Highly significant variations for translucency were found among genotypes, locations and TH, G x TH, and G x L x TH but not G x L. In general, the degree of whiteness and translucency varies among varieties with RC darker and less translucent than MC. Milled grains of the U.S. varieties from the 2016 Uniform Rice Regional Nursery were also evaluated for whiteness and translucency but only in the MC. The checks from MC and RC studies were included for comparison. There was high significant variation in whiteness and translucency in U.S rice varieties. Eight (Presidio, Antonio, Mermentau, Titan, MM-14 and M-206) had whiteness comparable to Thai rice and Uncle's Ben rice and 10 were as translucent. Many of the U.S. varieties were comparable to Presidio in whiteness and translucency.

A project on mutation was started in 2014. The rice variety Antonio was treated with ethyl methanesulfonate to identify mutants for genetic studies. Herbicide screening identified more than 200 vigorous looking plants two weeks after herbicide spraying and 72 early germinating seedlings in early February field planting. Before bulk harvesting the initial selections, some morphological mutants were observed such as high spikelet sterility, dwarf high tillering, lighter leaf color and different grain type. Only one of the herbicide survivors showed promise but several showed cold and drought tolerances in later screenings. Morphological mutants were true to type but the very high tillering dwarf mutant varied in maturity and height. However, it was still much shorter than the wild-type.

Missouri Rice Breeding: Current Status, Challenges and Opportunities

De Guzman, C.T.

Missouri is currently the fourth largest US rice producing state where production is largely concentrated in the Bootheel region. Rice research in Missouri started in the 1980's with the establishment of the rice research farm located in Campbell Missouri. The recruitment of the first rice breeder, Dr. Donn Beighley, in 2000 started the rice breeding program. In 2015, the first medium grain rice variety MM14 was released with a potential yield of up to 10.5 ton/hectare with excellent grain and milling quality. The program is succeeded in 2016 by Dr. Christian De Guzman following the retirement of the previous breeder. In 2017, previous germplasms were evaluated for yield and quality, with about 1800 head rows planted, and conducted a small-scale preliminary yield trial consisting of 40 lines. Furthermore, twenty-two F_2 populations from Dr. Steve Linscombe's program in LSU for both conventional and Clearfield long and medium grains were planted and individual plants were selected using a pedigree approach to identify superior lines. Approximately 3000 F_3 lines are currently being grown in Puerto Rico nursery and an additional 3700 individual F_2 plants from the same populations are planted in the greenhouse using single seed descent for rapid generation advance. Our crosses during the 2017 season resulted in about 70 F_1 of long and medium grains from elite inbred and varieties that are high yielding, with good milling yield and quality and are adapted to Missouri growing conditions. Additional crosses are underway in the greenhouse for spring 2018.

The early season planting in 2017 revealed opportunities for possible expansion of the Missouri rice breeding program. The seeds planted in the field under low temperature resulted in delayed germination of up to three weeks. Mid- and late-season cold temperature also affected the flowering and grain filling of cold-sensitive genotypes, which significantly reduced yield. Continuous screening for rice with cold tolerance is thus deemed an essential part of the Missouri breeding program. In addition, the Missouri conditions present an opportunity to exploit the low field temperature for seed production of environmentally-sensitive male sterile lines. Results from the male sterile lines planted under low field temperature in Missouri showed > 50% fertile spikelets compared to 0% under greenhouse conditions with controlled temperature of 75-80 ºC. This indicates that further testing to identify critical temperature and date of planting are necessary to maximize seed set.

Another challenge is the reduction of arsenic (As) uptake in medium grain rice varieties. Previous research on furrow and flooded conditions showed that As was below the detection limit in furrow irrigated rice. However, varietal testing in Missouri revealed varying arsenic uptake with some lines consistently showing high and moderately low As in both furrow and flooded field conditions. This presents another opportunity to breed for medium grain rice with low arsenic uptake for the processed rice market.

A Simple and Robust Crossing Method for a Rice Breeding Program

Sha, X., Beaty, B.A., Bulloch, J.A., and Scott, T.L.

Rice hybridization or crossing in the US was traditionally carried out using a vacuum emasculator to remove anthers from spikelet of selected female plants, and pollinating by bagging of both an emasculated female panicle and a designated blooming male panicle, or by dusting with selected blooming panicles collected from field or greenhouse over emasculated female panicles. This method is tedious, time consuming, labor intensive, and inefficient. Nowadays, the public breeding programs deal with additional breeding goals such as herbicide resistance and hybrid development, therefore more crosses are needed to achieve these breeding goals. Here, we propose a new method involving the hot water emasculation combined with collection of blooming panicles from designated male parents from field, and pollination in the greenhouse. By using this new method, we successfully produced an average of 596 single crosses involving 57 female and 135 male parents each in the last 3 years, with an average of 27 seeds per cross. Most importantly, each year we only spend 11 days on crossing including staff training. This has enabled us to move on and focus on more pressing tasks.

Application of Molecular Breeding in Louisiana Rice Variety Development

Angira, B., Addison, T., Dartez, J., Thornton, J., and Famoso, A.

Utilization of molecular markers has the potential to improve the efficiency of breeding programs, but implementation and integration into applied programs have been limited. Some of the limitations include cost, throughput, time, labor and logistical challenges. Recently, the rice variety development program at the H. Rouse Caffey Rice Research Station has begun incorporating marker assisted selection (MAS) as a routine component of the breeding process. The MAS is integrated in the traditional plant breeding pipeline and selected plants are selfed and grown as panicle rows in the subsequent season for phenotypic evaluation. Each year the program samples and evaluates ~30,000 F_2 or F_3 plants for MAS of desirable plants. Trait SNP makers are used extensively in early generations (F_2 and F_3) to improve the efficiency of selection. MAS is focused on traits/loci of large effect, including blast resistance, Clearfield and/or Provisia herbicide resistance, amylose content, gel temperature, grain size, pubescence, and plant height.

Seeds are germinated into 96 well flats that correspond to 96 well DNA plates. Individual plants are sampled 7-10 days after planting for DNA extraction and marker analysis. Upon analysis and selections, desired plants are transplanted approximately one week after sampling. Incorporation of MAS into the variety development process requires significant logistical considerations in terms of cost, throughput, and time.

Association Analysis and Marker Development for Grain Quality Traits Using USDA Diverse Rice Germplasm Collections

Edwards, J.D., Huggins, T.D., Chen, M., Jackson, A.K., and McClung, A.M.

New molecular markers are being designed and validated for grain quality improvement based on computationally assisted analysis of genome wide association study (GWAS) findings across multiple panels and multiple grain quality traits. The traits include grain dimensions, apparent amylose content (AAC), alkali spreading value (ASV), protein content, and chalk percent. The markers utilize the Kompetitive Allele Specific PCR (KASP) SNP technology. Discovery of SNPs associated with grain quality was accomplished using the USDA rice core subset (RCS) and mini-core (MC) GWAS panels. High density genotyping in these panels comes from public re-sequencing data on the MC and simple sequence repeat (SSR) markers on the RCS. In addition, public single nucleotide polymorphism (SNP) data from the High Density Rice Array (HDRA) genotyping of rice diversity panels 1 and 2 were merged with resequencing data from the MC which included 189 RCS accessions to yield a combined dataset of 383 individuals and 122,102 SNPs. Perl scripts were developed to define significant chromosomal regions from p-values and allele effects of the GWAS, find overlapping segments across traits and panels, and assist in candidate gene identification by summarizing curated known genes in those regions. By comparing GWAS across traits, it was possible to determine if a segment influenced a single grain quality trait or multiple traits, and whether there was a likely candidate gene for that region. From those results, significant SNPs were targeted for KASP marker development. These markers are now being validated in breeding lines and diverse collections.

Developing Molecular Markers for Use in Marker-Assisted Selection from Rice Genome-Wide Association Studies

Eizenga, G.C., Edwards, J.D., Jackson, A.K., Jia, M.H., Boykin, D.L.

Rice association mapping panels are collections of rice (*Oryza sativa* L.) accessions developed for genome-wide association (GWA) studies. One of these panels, the Rice Diversity Panel 1 (RDP1) was phenotyped by various research groups for several traits of interest, and more recently, genotyped with 700,000 SNP (single nucleotide polymorphism) markers using the high density rice array (HDRA). GWA analyses were conducted to identify GWA-QTL based on SNP markers associated with the particular trait of interest. To test the validity of these marker-trait associations and expedite the rice breeding process, markers are being developed from these associated SNPs and tested in biparental mapping populations and/or other association mapping panels.

The RDP1 is composed of 423 diverse accessions originating from 79 countries and representing the two rice subspecies, *Indica* and *Japonica*, and five major subpopulation groups, *indica*, *aus*, *aromatic*, *temperate japonica* and *tropical japonica*. The panel was evaluated for 34 agronomic traits, most of which were yield components. The agronomic data collected from 2006 through 2010 was analyzed using a generalized linear mixed model with the GLIMMIX procedure in SAS, with year and replication nested within year as fixed effects, and accessions considered a random effect to calculate adjusted means for GWA analyses. Both least squares means (LSmeans) and best linear unbiased predictors (BLUPs) were evaluated as adjusted means for subsequent GWA analyses, with BLUPs selected for the quantitative traits and LSmeans for categorical traits.

GWA analyses were performed using a mixed linear model in the Tassel 5.0 Pipeline (www.maizegenetics.net /tassel). The HDRA genotypic data (www.ricediversity.org) was further filtered for a minor allele frequency set at $\geq$ 0.05. SNPs with heterozygosity >10%, $\geq$ 40% missing calls, or not matching the Nipponbare reference, were excluded, resulting in 275,655 SNPs for GWA analyses. Tassel 5 was used to calculate population structure via principal component analysis (PC) and kinship. Manhattan and Q-Q plots were generated using the R package qqman. To group adjacent SNPs into significant regions, custom Perl scripts were developed with a threshold value to declare a SNP significant and find a maximum distance between significant SNPs to determine the start and stop of pseudomolecule positions for the significant region. To identify candidate genes, lists of annotated genes within 50Kb of the SNP with the highest significance in each region were obtained from the MSU7 and RAP1 rice gene annotations using a custom Perl script. Lists of annotated genes in the overlapping region were then manually examined to identify likely candidate genes based on annotated gene functions affecting the trait of interest found in either the Oryzabase or QTARO database based on pseudomolecule coordinates.

To validate the GWA mapping, a biparental recombinant inbred line (RIL) population was developed from the RDP1 *tropical japonica* accessions, Estrela and NSFTV199. This population was genotyped with 132 SSR markers and phenotyped for 15 traits previously evaluated in RDP1 that were related to plant morphology, panicle architecture and seed shape. Across all traits, 42 of the 70 Estrela/NSFTV199 RIL-QTL overlapped with RDP1 GWA-QTL and were found in at least one of the six GWA analyses, which included all RDP1 accessions, the two subspecies (*Indica* including both *indica* and *aus*, and *Japonica* including *temperate* and *tropical japonica*), and three subpopulation groups (*indica*, *tropical japonica*, *temperate japonica*). A total of 40 known genes were identified in these overlapping regions.

As proof of concept, we focused on two panicle architecture traits, number of primary branches per panicle and number of florets per panicle, to develop SNP markers based on the GWA-QTL. These traits are important for increased yield and may have potential for use in marker assisted selection (MAS). Regions on chromosomes 1, 4, 7 and 8 associated with the known genes, *GH1A*, *RFL*, *FZP* and *ASP1*, respectively, were selected for developing SNP markers. Currently, Kompetitive Allele Specific PCR (KASP) markers are being developed based on the most significant SNPs revealed in these QTL regions. These markers will be validated in the Estrela/NSFTV199 population, rice mini-core association mapping panel and other available biparental population(s) phenotyped for these two traits. Haplotypes will be developed to maximize marker use efficiency for breeding programs. After validation, these SNP markers will be available for rice breeders to use in MAS to select for increased number of primary branches and/or florets per panicle.

Regulation of Symbiotic Gene Expression in Rice

Thomas, J., Kim, H.R., Rahmatallah, Y., Glazko, G., and Mukherjee, A.

Biological Nitrogen Fixation (BNF) is increasingly viewed as a viable alternative to fertilizers for supplying nitrogen to plants. Several reports have shown that the BNF in cereals (e.g., rice, corn, wheat, etc.) comes from nitrogen-fixing bacteria. For instance, major cereal crops can form beneficial associations with nitrogen-fixing bacteria like *Azospirillum* and *Herbaspirillum*. Interestingly, these bacteria induce no specialized root structures (e.g., root nodules in legumes) and use different mechanisms to colonize plant roots. Our current understanding of the molecular aspects and signaling that occur between important crops like rice and these nitrogen-fixing bacteria is limited.

In this study, we used an experimental system where the bacteria could colonize the plant roots, and then used this colonization model to identify regulation of gene expression at different stages of symbiosis. We used RNA sequencing to identify 1,622 differentially expressed genes (DEGs) in rice roots 1 day post inoculation (dpi) and 1,995 DEGs at 14 dpi with *Azospirillum brasilense*. Similarly, we identified 1688 DEGs in rice roots 1 dpi and 1,515 DEGs at 14 dpi with *Herbaspirillum seropedicae*.

We identified several host pathways that could be potentially involved in these symbiotic interactions. Our data also suggest the presence of a molecular dialogue between the symbiotic partners that might be crucial for recognition and initiation of these symbioses. Using reverse transcriptase polymerase chain reaction analysis, we validated the RNA sequencing gene expression results of a few genes. Findings from this study will improve our understanding of the regulation of gene expression occurring in rice roots during beneficial interactions with nitrogen-fixing bacteria.

Transcriptomic Analysis and Agronomic Characters of Two Rice Genotypes under Drought Conditions

Liang, Y., Tabien, R., Tarpley, L., Mohammed, A.R., Dou, F., and Septiningsih, E.M.

Water scarcity is becoming more problematic globally and has threatened crop production. Rice is one of the most sensitive crops to water deficit, especially during the reproductive stage. Therefore, it is imperative to develop varieties that thrive and have good yield under drought conditions. The aims of this study are to evaluate agronomic traits and to perform transcriptomics study of two Texas rice cultivars, Rondo and the advanced breeding line 4610, under drought stress during reproductive stage. Rondo is a Texas elite rice cultivar with high yield but sensitive to drought stress; while the advance breeding line 4610 was previously reported as less affected by drought. A field experiment was conducted in Beaumont station in 2016. The experimental design was RCBD with 3 replications in both drought and irrigated conditions. The drought treatment was conducted prior to flowering stage. Transcriptome data were gathered from leaf samples taken from 14 and 21 days after drought treatment. RNA was extracted using RNeasy-Plant Mini kit (Qiagen) and checked for quality on a 2100 Bioanalyzer (Agilent). TruSeq Stranded RNA-Seq libraries were prepped at the Texas A&M AgriLife Genomics and Bioinformatics Service (TxGen) as per SOP (Illumina). Libraries were run on multiple lanes of an Illumina HiSeq 4000 to provide at least 25 million reads (75 nt pair-end) per sample. The raw sequencing reads were trimmed to remove low quality bases and adapters using the program Trimmomatic; then mapped to the reference genome using HISAT2. The number of reads mapped to each gene were counted using StringTie. For detecting the differential expressed genes (DEGs), DESeq2 package in R was used. This data was then subjected to gene ontology annotation and further analysis. The field experiment data showed that 4610 is more tolerant than Rondo, with higher hundred-seed weight, less decrease in spikelet fertility, less decrease in filled grain number and less decrease in yield. RNA-seq data analysis identified 350 DEGs in Rondo and 352 DEGs in 4610 at 14 days; and 2143 DEGs in Rondo and 349 DEGs in 4610 at 21 days. Some genes are differentially expressed in both genotypes. Further analysis is underway to gain more insight about the function of these genes under drought stress.

Protein Lysine Malonylation, Succinylation, and 2-Hydroxyisobutyrylation in Developing Rice Seed

Meng, X., Xing, S., Perez, L.M., Peng, X., Wang, C., and Peng, Z.

Protein lysine malonylation, succinylation, and 2-hydroxyisobutyrylation have been recognized as new post-translational modifications in recent years. It is plausible that these modifications may have a greater functional impact than lysine acetylation due to bulkier structural changes and larger charge differences introduced on the modified lysine residues. However, the identity of proteins harboring these modifications and their corresponding functions in cereal plants remain largely unknown. Using antibody-based affinity enrichment of modified peptides followed by nano-HPLC/MS/MS analyses, we identified from a few hundreds to over nine thousands modification sites for these modifications in developing rice (*Oryza sativa*) seeds, respectively. Distinct sequence motifs at the modification sites were identified for each of the modification. Proteins with different sequence motifs were shown to be favorably associated with unique metabolic pathways or protein function domains. Many of the modified proteins and the corresponding modification sites were conserved from *E. coli*, human, to plants. Remarkably, heavy modifications were detected on major seed storage proteins together with the key enzymes participating in central carbon metabolism and storage starch biosynthetic pathways, which are essential for rice seed nutrition reservoir development. Rice proteins with co-modifications of succinylation, malonylation, 2-hydroxyisobutyrylation, acetylation, ubiquitination, and phosphorylation were studied through a comprehensive comparison analysis. In addition, the impact of lysine modification on lysine bioavailability in rice proteins was also analyzed. Our study delivers a platform for expansive investigation of the molecular networks administrating cereal seed development via post-translational modifications.

Developing Rice Varieties with Enhanced Salt Tolerance

Subudhi, P.K., Ontoy, J., De Leon, T.B., and Puram, V.R.R.

Rice is one of the most important cereals that feed more than half of the world's population. Salinity is a major abiotic stress that affects rice production in many parts of the world. Since rice is highly vulnerable to salinity at the seedling stage, majority of studies focused on identification and utilization of QTLs for salt tolerance to accelerate development of high yielding salt tolerant rice varieties. We report here the progress made in understanding the genetics of seedling stage salinity tolerance and development of salt tolerant rice varieties.

Several mapping populations were developed from crosses involving two known salt tolerant donors, Pokkali and Nona Bokra, and cultivars adapted to the southern rice growing regions of the USA. Evaluation of these populations for salinity tolerance was done at the seedling stage in hydroponic experiments. Genotyping was done by both SSR and genotyping by sequencing based SNP markers.

Apart from mapping of QTLs for salt tolerance attributes in multiple mapping populations, several QTLs were validated using introgression lines (ILs). The salt tolerance QTLs were introgressed in multiple genetic backgrounds from salt tolerant donors and several salt tolerant lines with various combinations of QTLs for salt tolerance were developed. Effort was made to accumulate desirable salt tolerance QTLs from multiple parents in complex crosses followed by backcrossing. The salt tolerant ILs identified in this study will aid in development of salt tolerant varieties by accumulating favorable alleles through marker-assisted selection.

Identification of Seedling Vigor-Associated Quantitative Trait Loci in Temperate Japonica Rice

Cordero-Lara, K.I., Kim, H.J., and Tai, T.H.

More than half of the world's rice growing regions consist of irrigated ecosystems which account for 75% of global rice production. Rice cultivation in much of this area is based on the transplanted puddled rice (TPR) system. Advantages of the TPR system include reduced competition from weeds and good crop establishment as healthy, uniform rice seedlings are produced in nurseries for transplanting and the anaerobic conditions of the puddled soil promote increased access to nutrients. However, TPR-based rice production is becoming unsustainable as water, labor and energy resources grow increasingly scarce.

The alternative to TPR is direct-seeded rice (DSR) cultivation. As the name implies, DSR involves sowing of seeds directly into soil (i.e., dry- or drill-seeding) or pre-germinated seeds into pre-flooded fields (i.e., water-seeding). DSR requires less labor and water resources than TPR. In the U.S., virtually all rice production involves DSR with dry-seeding predominantly employed in the southern U.S. rice belt and water-seeding used almost exclusively in California and in some parts of Louisiana. Good stand establishment is a major challenge for DSR cultivation since germinating seeds and developing seedlings are exposed to an array of abiotic and biotic stresses. Thus, strong seedling vigor is an important breeding objective for varieties used in DSR production systems.

A quantitative trait loci (QTL) analysis of seedling vigor traits was conducted under dry-seeded conditions using 176 recombinant inbred lines developed from a cross of two California *temperate japonica* rice varieties M-203 and M-206. Height at early seedling (HES) and height at late seedling (HLS) stage, growth rate (GR), and fresh weight were evaluated in a growth chamber. Assessment of HES, HLS, and GR was also performed in outdoor basins in 2015 and 2016.

M-203 was significantly better for all traits in the growth chamber, however, no significant differences were observed between the parents in the outdoor basins with the exception of HES in 2015. Genotyping by sequencing was used to construct a map of $>$6,000 single nucleotide polymorphisms. Six QTL were detected in the growth chamber, one each on chromosomes 2, 9, 10, and 12 and two at the same position on 1. qFW1 and qHES1 explain 34.6% and 8.7% of the phenotypic variation observed for their respective traits and correspond to previously reported QTL for shoot length. All positive effects were contributed by the M-203 allele except for the qHLS12. Two QTL, qHES8 (12.3%; M-206 allele) and qHES9 (9.4%; M-203 allele), were detected in the outdoor basin 2016, but none in 2015. RIL-187 was consistently among the highest vigor lines in all environments and additional evaluations confirmed this finding.

The molecular and genetic resources developed here will facilitate further investigation of seedling vigor and breeding of enhanced *temperate japonica* rice varieties.

Sequence References of the Amino Acid Transporter OsAAP6 Found Among High-Protein Rice Lines and Field Performance of Marker-Assisted Breeding Lines

Utomo, H., and Wenefrida, I.

High-protein rice can directly support the food industry that emphasizes more on nutritional values. As a source of natural plant protein, the high-protein rice can be used in the formulation of food products for optimum fitness and health. In the global scope, there are more than 750 million people currently suffering from chronic malnutrition. About 520 million of them depend on rice for a majority of their carbohydrates. High-protein rice can be used to help solve this worldwide problem across social, cultural, and economic strata. Our breeding program that emphasizes on grain nutrition and quality improvement has resulted in advanced lines possessing high protein content and improved grain quality.

One of the high-protein lines was released as the cultivar Frontière in 2017 registered as CV-150, PI 647794, and PVP No. 201500310. This is the first high-protein cultivar successfully developed for commercial applications. It has an average grain protein content of 10.6% (w/w), which is a 53% improvement from its original protein content, with an average yield of 6,662 lb/A, amylose content of 21.8%, milling of 60.5/68.9%, and intermediate gelatinization temperature.

To evaluate the basis for the elevated levels of grain protein content, molecular analyses were conducted among elite high-protein rice lines. The studies included sequencing of a genomic region of 6 kb in chromosome 1 that covers the OsAAP6 gene and its 5'-untranslated region. The gene codes for the seed specific amino acid transporter. Sequence data on the 12 elite high-protein lines revealed one of the signatures for the elevated levels of grain protein content among high-protein rice lines. Field performance of high-protein lines and marker-assisted breeding lines further demonstrated the complexity of its regulatory functions.

Performance of High-Protein Lines Compared to the Released Cultivar Frontière

Wenefrida, I., Utomo, H.S., and Groth, D.E.

The first long-grain, high-protein, non-GMO rice cultivar, Frontière, was released in 2017 and was registered as CV-150, PI 647794, PVP No. 201500310 with an average grain protein content of 10.6% (w/w), a 53% improvement from its original protein content. Its average yield was 6,662 lb/A, with an amylose content of 21.8%, milling of 60.5/68.9%, and intermediate gelatinization temperature characteristic. The objective of this study is to develop new high-protein rice lines with improved yield. Five new advanced high-protein lines with protein contents of 10.5% or higher were evaluated in multi-location tests in a randomized complete block design, with three replications, and in three locations that represent the rice growing areas in the state. Additionally, 15 advanced lines were also evaluated in Preliminary Yield trials at the H. Rouse Caffey Rice Research Station near Crowley, LA.

Besides grain protein content and yield, other important characteristics including heading date, plant height, disease resistance, and grain quality components were also evaluated. Several new high-protein lines tested showed improved yield compared to Frontière, 11-17% increase. Important grain qualities, such as the gelatinization temperature, pasting, and cooking quality, all varied among high-protein lines. There was a significant interaction between high-protein lines and some of the grain quality components. When cooked, the high-protein lines typically tended to be fluffier or softer than regular non-high-protein rice.

No cultural practice adjustment is necessary to grow high-protein rice, and; therefore, it can readily be scaled-up for larger production as needed. With the cultivar Frontière that has an average yield of 6,662 lb/A (4,590 lb/A, milled rice), for example, planting this high-protein rice can produce an additional 160 lb/A of natural protein. This extra protein is equivalent to the same amount of protein from 610 lb of meat or 1,420 gallons of milk. This is one of the most efficient ways to produce plant-based natural protein with no extra cost.

Relationships between Shoot and Root Growth Support Indirect Selection for Increased Root Biomass

Pinson, S.R.M., Barnaby, J.Y., Bui, L.T., and Chun, J.

The size and vigor of below-ground tissues (roots) impact the health and growth of above-ground plant tissues, and vice versa. One would therefore expect covariance between the growth dynamics of shoot and root structures. Furthermore, the root system of a rice plant is largely composed of nodal roots, which are produced along with tillers from the same individual nodes. With tiller and root development being synchronized and physically connected in this manner, one would expect that genetic and environmental factors that stimulate the production of tillers in a rice seedling would also increase root biomass. The converse is also expected. By determining rates of water and nutrient acquisition, the size and architecture of a root system would be expected to impact shoot growth and development. Numerous genes and QTLs associated with the number and timing of rice tiller production have been reported. There have also been several studies defining optimal rice tillering ability as a key yield component. Other studies have identified QTLs affecting root structure and development in rice. However, because the tillering and root QTL studies were conducted independently in unrelated mapping populations, they could not evaluate covariance and trade-offs between tiller number (TN), shoot biomass (SB), and root biomass (RB).

We examined relationships between tillering, root growth, and shoot growth in 6-week-old seedlings of three populations of rice recombinant inbred lines (RILs): Lemont x TeQing RILs (LT-RILs), Kaybonnet-*lpa* x Zhe733 RILs (KZ-RILs), and Francis x Rondo RILs (FR-RILs). Six-week old seedlings were evaluated based on previous LT-RIL and KZ-RIL TN QTL studies which showed that TN QTLs revealed by TN counts at 5- to 6-wks were more predictive of final panicle number and grain yield than were TN QTLs that became detectable only in later stages.

Measurement of RB is difficult and laborious. With the known physical synchrony between tiller and root initiation, we were particularly interested in determining if TN was sufficiently predictive of RB for it to serve as a non-destructive surrogate in future research and breeding. Relationships between TN, SB, and RB were therefore evaluated by first selecting divergent high-TN versus low-TN subgroups among the three RIL populations, then determining the impacts of divergent TN selection on SB and RB. The LT-RILs and KZ-RILs had been previously characterized and mapped for TN QTLs at multiple seedling and mature plant stages; previously collected TN data were used to select high vs low TN subsets from the LT-RIL and KZ-RIL populations. FR-RIL selections were based on TN from 2 replications of 6-week-old FR-RILs. Selected RILs plus parents of each population were then evaluated for TN, SB, and RB using 3 replications of greenhouse-grown single plants. At 6-weeks after seeding, TN was counted then seedlings were gently uprooted, rinsed of soil, divided into shoots and roots, dried, then weighed to obtain SB and RB per plant.

Our results showed that TN, SB, and RB were positively correlated in all three RIL populations. This suggests that laborious evaluation of RB could be avoided by using indirect selection for either TN or SB. TN offers the added benefit of providing non-destructive data prior to flowering, which speeds breeding by allowing for both selection and new crosses to be accomplished in a single generation. Our results further indicated impact of *Sd1*/*sd1* on relationship between tillering and root growth traits. The *sd1* semidwarf gene is known to improve grain yields by diverting carbohydrates and biomass from above-ground vegetative tissues into grain. By selecting four progeny subsets from the KZ-RIL population, specifically, high and low TN selections of both *Sd1/Sd1* and *sd1/sd1* genotypes, we were able to ask if *sd1* also alters the partitioning of resources between shoots and roots (SB/RB). Although the TN-RB correlations were significant and positive in all three RIL populations, the correlations were stronger among the *sd1* KZ-RILs ($r = 0.42$) than among the *Sd1* KZ-RILs ($r = 0.27$), and were stronger yet among the LT-RILs ($r=0.62$) where both parents and all RILs are *sd1*. While selection for increased TN resulted in increased RB among the LT-RILs, FR-RILs, and *sd1* KZ-RILs, in contrast, it resulted in a numerical decrease in RB among the *Sd1* KZ-RILs. SB did not differ significantly due to TN selection in any of the populations. As for differences in resource allocation (SB/RB) due to *sd1* versus *Sd1*, selection for increased TN resulted in decreased SB/RB ratios (more resources to roots than shoots) for all populations except the *Sd1* KZ-RILs in which selection for increased TN resulted in a non-significant but numerical increase in SB/RB. While the use of TN as a surrogate for RB and SB/RB in breeding selections appears more consistent in populations not confounded with *Sd1/sd1* segregation, it must be noted that selection for increased TN among the *Sd1/sd1* segregating FR-RILs did increase both RB and the prevalence of *sd1*among selections. This co-selection of *sd1* and increased TN was not necessarily due to pleiotropism. A TN QTL near the *sd1* locus was previously identified in the *sd1/sd1* LT-RIL population.

Interspecific Variation in Physiological and Foliar Metabolic Responses to Reduced Soil Water Availability

Barnaby, J.Y., McClung, A.M., Rohila, J.S., Henry, C.G., Ziska, L.H., and Sicher, R.C.

Climatic uncertainty, particularly with regard to water resources, may alter irrigation management of rice, an essential cereal grain acknowledged as the primary food source for more than half the world's population. *To reduce water use,* an *alternate wetting and drying (AWD)* system has been developed, but understanding the impact of water stress on physiological and metabolic responses controlling grain production is needed. Of the two known critical yield reduction stages, i.e. the transition phase from vegetative to reproductive stage and the grain fill stage, the former stage, in relation to grain production, is largely elusive.

Seven cultivars displaying different yield responses to water stress were grown under four different continuous irrigation levels applied using a sub-surface drip irrigation system to understand physiological and metabolic responses to different stress levels at the transition stage. Our objectives were twofold: (1) to evaluate cultivar differences in physiological and metabolic responses to four irrigation treatments varying 0, 30, 70, or 95% water deficit; and (2) to assess whether these changes were associated with variation in yield.

Cultivars that had relatively stable yields in response to water stress, i.e. Saber, Kaybonnet, and Francis, had distinctive physiological responses compared to the high responsive cultivars, PI312777 and Teqing, under the moderate stress condition (70% water deficit). In addition, non-responsive cultivars accumulated stress-induced carbohydrate metabolites even at mild and moderate stress conditions (30 and 70% water deficit, respectively) whereas for highly responsive cultivars this was observed only after a moderate stress condition.

Overall, these data suggest that cultivars, with physiological stress indicators (i.e. A, g_s, SPAD, and leaf Tm) detected under the mild stress condition (30% water deficit), accumulated carbohydrate metabolites, known as osmolytes, compared with the other cultivars. Furthermore, those cultivars, (Saber, Francis, and Kaybonnet) displayed relatively stable yield production upon water stress regardless of their yield potential under fully irrigated conditions.

Seed Weight Reduction of Selected Japonica and Texas Rice Genotypes at Low Temperature Germination

Samonte, S.O.P.B., Tabien, R.E., Wilson, L.T., Yan, Z., Christensen, E., and Harper, C.L.

Planting rice early in the season reduces crop exposure to rain, which occurs during the end of the growing season and can cause reductions in grain yield and quality. It also enables the production of a second or ratoon crop. Early planting would greatly benefit from the planting of cold tolerant cultivars. The objective of study was to analyze the variation in cold tolerance in rice, as exhibited by seed weight reduction when exposed to low temperature during germination.

A replicated study was conducted at the Texas A&M AgriLife Research Center at Beaumont in 2017. Seed of selected genotypes, check cultivars, Texas elite lines (TX ELs), and hybrids and their parents were sown in petri dishes. Two temperature treatments were applied, low temperature (LT; day/night temperature was $19/11^{0}$C) and ambient temperature (AT; whole day temperature was $24C^{0}$). These treatments correspond to temperatures in Beaumont that were averaged across 1987 to 2017, with LT being the mean daily maximum and minimum temperatures during the week of Feb 15 to 21 and AT being the mean daily maximum temperatures for the week of April 2 to 8. Dry mass of each seed of all genotypes were measured before application of temperature treatments and at 3 days after check cultivar Presidio started to germinate. Only the 120 genotypes that had germination percentages greater than 75% in the AT treatment were selected and advanced for further analyses. Seed weight reduction percentage (SWRP) of each genotype was estimated as its cold tolerance index and is based on the amount of dry mass metabolized or translocated from the seed to the growing shoot or root during the early germination stage.

Based on analyses of variance of data from this preliminary study, genotype was a significant factor, while temperature and genotype x temperature were not significant factors affecting starting seed weight. Seed weight reduction percentage was significantly affected by temperature and genotype (both had *P-values* < 0.01). SWRP values at low temperature ranged from 14.2% (Rondo) to 37.1% (hybrid). There were 10 genotypes that were not significantly different from the top cold tolerant genotype based on a 5% LSD test, and these included TX EL RU1703181 and Katy (both having SWRP values of 31.4%). Some cultivars and their respective SWRP values were Antonio (29.2%), LaGrue (28.7%), Minghui 63 (27.8%), Presidio (24.8%), Saber (24.4%), and Cypress (23.7%). Heterobeltosis of the top cold tolerant genotype, which was a hybrid, was 46%. This type of cold tolerant study and its results are useful in selecting cold tolerant inbred and hybrid genotypes in breeding programs.

Impact of Rice Genotype and Canopy Structural Components on Diurnal and Seasonal Patterns of Light Interception

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

Light interception by a rice crop is affected by the stage of crop growth and by the structural components of the rice canopy (leaf sheaths, leaf blades, panicle rachis, and grain) which can be represented by canopy- and organ-level light extinction coefficients. Inbreds and hybrids that have leaves that are relatively more erect are thought to produce a greater yield than those that do not due to reduce light saturation and therefore less light captured by upper leaves and increase light penetration and higher photosynthetic rates for lower leaves. For the analyses presented herein, a number of 3-line hybrids and associated inbred maintainer and restorer parent lines were evaluated to estimate heritability of canopy structure as represented by canopy-level and organ-level light extinction coefficients. Hybrids tend to have leaves whose degree of erectness differs from that of the corresponding maintainers and restorers, in some cases in a predictable manner. However, leaf erectness changes greatly through the course of a crop's growth as well as throughout a season so a rice crop canopy cannot be strictly defined as being more erect or less erect, unless within the context of the stage of crop growth. Herein, we present some of the major conclusions from our research on canopy light capture.

Abstracts of Posters on Breeding, Genetics, and Cytogenetics
Panel Chair: Thomas Tai

Increasing the Efficiency and Effectiveness of Curation of the USDA-ARS World Rice Collection

McClung, A.M., Bockelman, H., Jia, M., and Edwards, J.

The world rice collection is part of the USDA-ARS National Small Grains Collection (NSGC) that includes cereal crops wheat, oats, barley, and rye, as well as related wild species. The *Oryza* accessions include 12 species that comprise 9% of the NSGC. Over 19,000 rice accessions originating from 114 countries are in the collection. Seed of these accessions are rejuvenated, the plants and grain are phenotyped, and the data are made public through the Germplasm Resource Information Network (GRIN) website. All rejuvenation and phenotyping activities are performed at the Dale Bumpers National Rice Research Center (DBNRRC) in Stuttgart, AR, and the harvested seed is provided to the NSGC in Aberdeen, ID, where it is cleaned, stored, and distributed to the public. Each year, the DBNRRC rejuvenates nearly 2,000 accessions that have depleted seed reserves or seed quality has deteriorated due to length of storage. These accessions are grown either at the Stuttgart location or using winter nursery facilities. The rice collection has been characterized for some 42 traits over the years, many of these in response to recommendations by the Rice Crop Germplasm Committee. However, the whole collection has not been completely characterized for all traits. Over 60% of the collection has been phenotyped for such traits as grain amylose content, alkali spreading value (ASV), grain dimensions, plant height, days to heading, lodging, allelopathy, and salt tolerance. Other traits like grain aroma, protein content, parboiling loss, straighthead susceptibility, sheath blight tolerance, and ratoon ability have been characterized on a few hundred to a few thousand of the accessions, usually due to the difficulty or expense associated with analyzing the trait. The DBNRRC has endeavored to improve the efficiency and effectiveness of curation activities for the rice collection by implementing a number of new quality assurance procedures that utilize genotyping, bar-coding, and new field management methods. Because of the tremendous diversity of the collection, managing materials in the same field environment that differ by 120 days to heading, grow to over 160 cm in height, and are extremely susceptible to lodging can be very challenging. We now organize planting of the accessions in the field according to previous data regarding days to heading. This facilitates data collection and harvest on the earliest maturing accessions first. In addition, because of the susceptibility to lodging, we have limited the amount of nitrogen fertilizer applied to the field to 56 kg/ha and have increased the space between accession-plots to 0.6 m to prevent the possibility of seed mixtures at harvest. Because of the large number of accessions that are rejuvenated each year, only a single field plot is included of each. However, plots of the U.S. adapted varieties Presidio (early maturing, semidwarf) and Rondo (late maturing, medium height, lodging susceptible) are repeated throughout the field and height and heading data are collected as means of assessing field variability and the relative adaptation of the NSGC germplasm to the southern U.S. growing environment. Field books are made that include previous phenotypic data on the accessions as means of verification that planting or seed mix-ups have not occurred. Accessions that have been in storage for nearing 20 years are grown to assure distribution of seed sources with good viability. In the past, these were planted in the field without any prior knowledge of viability resulting in many plots with failed plant stands, an inefficient use of labor and research facilities. Over the last two years, we have implemented a new germplasm tracking program to increase the efficiency of curation activities. Accessions are received from NSGC at the beginning of the year to allow time for germination tests. Bar-codes are generated to track seed packets and petri plates used for germination. Remnant seed of accessions that are viable are then planted in the summer nursery. Accessions that have extremely poor germination are subjected to extra procedures for rejuvenation including dehulling of the grain and treating with bleach, culturing in magenta boxes using Murashige and Skoog tissue culture media, and transplanting into the greenhouse to generate seed. Following the seed germination evaluation, tissue is collected from the seedlings and used for molecular marker assays. Currently, some 2000 rice accessions have been genotyped with 23 markers (SSRs, SNPs, and indels) including 13 that are associated with known grain quality, agronomic, and disease resistance traits. Because of the relatively low cost of genotyping and the predictability for classifying germplasm for some traits, we are using these genotypic data to replace some previous phenotyping efforts (ex. amylose, ASV, aroma, etc). In addition, marker analysis is used to predict if the accession belongs to the Indica or Japonica *O. sativa* sub-population or to *O. glaberrima*. Both phenotypic and genotypic data will be made available to the public through GRIN with the goal of making the collection more robust and useful to researchers.

Rice Diversity Panels Available through the Genetic Stocks *Oryza* Collection

McClung, A.M., Bernhardt, L., Edwards, J.D., and Eizenga, G.C.

The Genetic Stocks *Oryza* (GSOR) Collection was established in 2004 at the USDA-ARS, Dale Bumpers National Rice Research Center (DBNRRC) located in Stuttgart, AR. The mission of GSOR is to provide unique genetic resources to the rice research community for genetic and genomics related research. GSOR is part of the National Plant Germplasm System (NPGS) and the accessions are maintained and distributed from DBNRRC as long as they are considered of value to researchers and seed supplies are available. The collection includes mutants, mapping populations, and diversity panels. Currently, five diversity panels are available for distribution, with another under development. All of the diversity panels have been created as a means of capturing allelic variability within the scope of the targeted population. Each panel has been created from a single plant, pure seed source of each accession in the set and the panel has been phenotyped and genotyped to varying degrees. Seed is freely available for most accessions, however, some have restrictions and/or require a material transfer agreement.

The USDA Core Collection was provided to GSOR in 2007 and consists of 1,794 global rice varieties representing ~10% of the whole world rice collection that is curated by NPGS. The USDA Core Collection has been genotyped with 72 genetic markers and characterized for over 50 agronomic, biotic stress, and grain quality traits. Images of panicles and whole grain (dehulled) rice are accessible for each accession through the NPGS Germplasm Resource Information Network (GRIN). Within the USDA Core Collection is the Mini-core which is a subset of 217 accessions that represent ~1% of the NPGS rice collection. The Mini-core has been extensively phenotyped and recently, resequencing of the panel has been completed with the data now available to the public.

The USA Rice Pedigree Panel was developed as a result of funding from USDA-NIFA (National Institute of Food and Agriculture) in a collaborative project with Cornell University, and it consists of 153 accessions that represent most of the germplasm used in over 100 years of rice breeding in the southern USA. Each accession has been phenotyped for height and heading, and genetically characterized using genotyping-by-sequencing (GBS). High resolution images of the plant at heading, seed and whole grain rice are available through GSOR.

The Rice Diversity Panel 1 (RDP1) was developed through funding from the National Science Foundation in a collaborative project with Cornell University. The 423 RDP1 accessions that originate from 79 countries are available through GSOR. The GSOR website provides data on 29 plant, panicle, and seed traits, and 43 genetic markers, as well as, high resolution images of panicles, seed, and whole grain rice of the RDP1 accessions. In addition, allelic data using some 700,000 SNPs is available to the public for this panel. The same 700,000 SNP genotyping platform was used to characterize the Rice Diversity Panel 2 (RDP2) which was developed by the International Rice Research Institute (IRRI), Los Banos, The Philippines. The RDP2 includes 1,445 accessions from 92 countries. The panel was imported into the USA and, through a multi-institutional collaboration, brought through quarantine within two years. Images of the original grain received from IRRI are on the GSOR website. Some of the accessions failed successful grow-out in quarantine facilities and had to be reimported. However, seed production was sufficient for distribution of 873 accessions following quarantine, while 460 accessions were rejuvenated at Stuttgart in the field during 2016 and 2017. For these latter accessions, plant images at heading and phenotypic assessment of six plant traits are available.

Soon, the DBNRRC will add a new *Tropical Japonica* Core collection to GSOR. The collection will include some 500 global accessions from the *tropical japonica* sub-population which is the source of most cultivars grown in the USA. Introgression of germplasm from other sub-populations into U.S. cultivars has had limited success because many agronomic and grain quality traits are considered unacceptable for domestic production and markets. In addition, crosses with non-*japonica* germplasm frequently have problems with incompatibility and sterility, making the materials difficult for breeders to utilize. The *Tropical Japonica* Core panel will be phenotyped and genotyped and will serve as a resource for the rice research community interested in identifying allelic variation that will be of value for cultivar improvement efforts in the USA.

Variation in Rice Grain Quality and Yield in Different Weather Conditions

Cai, H.Y., Tabien, R.E., Harper, C.L., Carre, P., Jones, K., and Tarpley, L.

Crop grain quality and yield are greatly influenced by air temperature and solar radiation, but no systematic research has been conducted on how mean daily weather variation in different years at different growth stages influences rice grain quality and yield. In this study, 16 rice cultivars released in recent years in the U.S. and their growing weather conditions for three years were evaluated to determine their relationships. The cultivars were included in the 2014-2016 uniform regional rice nursery grown in Beaumont and were evaluated for grain chalkiness, percentage whole grain, and main crop grain yield. Mean weather conditions, including daily maximum temperature, daily minimum temperature and daily solar radiation, were determined at three growth stages: 20 days after emergence to 50% heading (stage I), 50% heading to maturity (stage II) and 20 days after emergence to maturity (stage III). All together there were four dates of emergence, all the cultivars had the same emergence dates in 2014 and 2015, but in 2016, six of them were seeded 10 days earlier than the other 10 cultivars; these were differentiated as emergence 2016-1 and emergence 2016-2, respectively.

The mean weather conditions varied among different emergence dates within corresponding growth stage. Emergence 2014 had the lowest mean daily minimum temperature in three growth stage while emergence 2016-2 had the highest at stage I and stage III, and the largest difference was around 1.4°C among four emergence dates at stage II. For daily maximum temperature, emergence 2016-2 behaved the highest at stage II and stage III, and the largest difference was around 1.7°C at stage II. The largest difference for daily solar radiation was nearly 3 MJ m^{-2} day^{-1} at stage II.

Grain chalkiness of each variety ranged from 1.75 to 13.43% and 12 cultivars behaved significantly different across three years. Jupiter, Cocodrie, CL151 and Antonio had nearly the same chalkiness percentage among three years; Percentage of whole grain ranged from 44.91 to 68.6% and seven varieties showed significant differences across three years. There was great variation for grain yield, 15 cultivars in 2014 yielded significantly higher than in the other two years and the mean yield of each emergence dates ranged from 7.2×10^6 to 9.9×10^6 kg/ha. The aromatic cultivar, Jazzman, had the most stable yield across three years but it was generally lower than the other tested cultivars.

Results of the linear regression analyses indicated that, for chalkiness, there was a positive relationship with mean daily solar radiation and maximum temperature at stage I and stage II, with corresponding standardization regression coefficient (SRC) 0.64 and 0.77 (Chalkiness = 0.77(max temp) + 0.64(solar radiation). For percentage of whole rice, a negative correlation with SRC -0.46 were observed with mean daily minimum temperature at stage II (% whole grain = 51.35 - 0.46(min temp). For the yield, negative and positive correlations were observed with SRC of -3.13 and 1.93 with mean daily minimum and maximum temperature at stage III (Yield = -3.13(min temp) + 1.93(max temp)). Compared with yield, chalkiness and percentage of whole rice had a relative weaker relationship with weather conditions, and the R^2 of the former is 0.69 but the latter are both 0.2. Yield was found positively correlated with chalkiness, indicating that increasing yield can lead to more chalky grains under similar conditions. With these results, it can be concluded that weather conditions and the future climate conditions will not only influence grain yield but also rice grain quality. The effects, however, are relatively small for the quality traits relative to yield, possibly because quality traits are less sensitive to climatic factors compared with yield.

Determination of Genetic Sources and Threshold Environment of Arkansas and GSOR Male Sterile Lines

North, D.G., Fei, S., Moldenhauer, K.A.K., Counce, P., and Shakiba, E.

Hybrid rice is produced from the crossing of two genetic distinct parents and the resulting F_1 hybrid performs greater than its parents. Male sterility is induced in parental lines of hybrid production to replace the need of artificial emasculation to improve the amount of F_1 seed. The two-line system is one of the methods in hybrid rice production that requires an environmental sensitive male sterile (EGMS). Male sterility alleles are affected by photoperiod (PGMS), temperature (TGMS), or a combination of the two (PTGMS). To release hybrid cultivars the University of Arkansas Rice Research and Extension Center (RIRE) has worked on developing EGMS lines. The objective of this study to find out if those EGMS lines are TGMS, PGMS, or both and determine the threshold male sterile environment. A total of four male sterile lines 236s, 801s, 805s, and 811s were developed by the RIRE. Four mutated lines - GSOR 1, GSOR 2, GSOR 3, and GSOR 4 – that developed sterility traits were produced by the Dale Bumpers National Rice Research Center. Three panicles from 10 plants of 236s, 811s, 805s, and the four GSOR lines were pollen stained during the 2017 summer season at RIRE in Stuttgart, AR. The lines were replicated three times and planted at three different dates: April 25, May 2, and May 8. These dates were selected based on the rice growing season in Arkansas. The results of 811s and 805s revealed that the selected planting dates were acceptable for inducing sterility. The results of 236s revealed that April 25 is the absolute date for a sterile environment. According to the findings, the critical time for inducing sterility is from the R1 growth stage to 15 days after. The GSOR lines were mostly fertile in all conditions with only a few being sterile which suggests that sterility may not be induced by the environment. The evaluation suggests that 236s, 805s, and 811s are TGMS. This study will continue to evaluate these lines in different environments in the following year.

Morphogenetic Analysis of Aromatic Rice (Amber) Varieties from Iraq

Alawadi, H.F., Tabien, R.E., and Ibrahim, A.M.

One of the major contributors to genetic divergence in rice is the aroma of milled rice. Most rice growing countries have their heirloom aromatic varieties. Amber is the popular aromatic rice in Iraq. This study aims to assess the phenotypic and genetic diversity among nine traditional Amber varieties of Iraq, two U.S. aromatic and two non-aromatic as checks. A replicated field experiment was conducted at Texas A&M AgriLife Research Center in Beaumont, Texas, in 2015 and 2016. All trials were laid out in a randomized complete block design with three replications. Results showed significant differences in several morphological traits. Highly significant variation was noted in plant height, flag leaf area, panicle length, numbers of tillers, day to 50% heading and ligule length. 'Amber43'and 'Amber' were the two tallest entries with 2-year average height of 168 and 158 cm, respectively but these were comparable to Amber Coarse and the checks, Jazzman, Antonio, and Presidio. 'Amber43' had significantly larger average flag-leaf area than Amber. 'Amber33' and 'Amber' had the longest average panicle length at 28 and 27 cm, respectively, and these were significantly longer than Amber 43 and Amber Coarse. For number of tillers, 'Amber Coarse' had the highest number of tillers with an average of 329 per sq meter, about two times than the checks, Jazzman, Della, and Presidio. 'Amber 33' was the last to flower (97 days to 50% heading) and it was 20 days later than conventional U.S. rice like Presidio. There were no significant differences among the aromatic and non-aromatic types for botanical traits such as culm angle and strength, internode color, and flag leaf pubescence, angle, and color in trials but not for ligule length. Amber 33 had the longest ligule, significantly longer than Della but not to Amber and Anber. The DNA extractions of the 13 entries using a modified CTAB method were all completed at the AgriGenomics Lab in College Station, Texas. DNA analysis will be done using Single-Nucleotide Polymorphism markers to determine the genetic diversity within the 13 rice germplasms. Data analysis will be done using TASSEL software to calculate the genetic distances among these test entries.

Identification and Characterization of EMS-Derived Antonio Mutants

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

Mutation induction using a .8% solution of ethyl methane sulfonate (EMS) on the rice variety Antonio were conducted in 2014. Several generations of the mutants have been planted, advanced and observed over the past few seasons. Some unique mutations were noted and have been identified and categorized based on their phenotypic variations found within the population. Due to the interest in understanding functional genomics these mutants could be possible stepping blocks in helping to assign a function to specific DNA sequences. Explaining genetic factors which influence plant mechanisms and morphological development through current and future studies could help introduce desirable traits into the breeding programs.

Plants with abnormal phenotypes relative to normal Antonio were selected, evaluated and advanced for trait expression over several seasons. In 2017, M_3 plants were grown in the field arranged in single 10 foot rows for easy evaluation and observation over the growing season. Several mutants were identified including very high tillering dwarf plants segregating for both maturity and height. Some of these mutants reached maturity approximately 118 days after emergence, which is average for Antonio. However, many have yet to head out after over 150 days. Heights also ranged greatly for these dwarf mutants going as low as 26 cm while average Antonio plants generally reach heights of 96.5 cm. Variation in tiller counts were also noted among the very high tillering mutants with some exceeding over 80 per plant. Other mutants observed included plants with seed shape variations, various degrees of sterility and awn development on some plants. Continued research into the evaluation and characterization of these mutants is ongoing and are currently under investigation. Several of these identified mutants will be presented and discussed highlighting their abnormal phenotypic variations relative to normal Antonio.

Generation and Characterization of Rice Mutants for Functional Genomics and Breeding

Tai, T.H., Kim, H., and Magee, S.C.

Over the past 15 years, our program has been involved in the generation and characterization of induced mutant populations of rice for forward and reverse genetics applications. Powerful sequencing-based mutation detection has increased the value of mutants generated by traditional mutagenesis, enabling functional genomics research and development of breeding germplasm using the same genetic resources. One such dual approach is the Targeting of Induced Local Lesions in Genomes (TILLING) method. We have used this reverse genetics approach to identify mutations in genes involved in phytic acid content, starch biosynthesis and arsenic uptake and accumulation. In addition, various mutants of interest have been identified by visual evaluation and other forward genetics screens.

Rice mutant populations in the varieties Nipponbare, Kitaake, and Sabine were generated using various chemical mutagens including ethyl methanesulfonate, sodium azide, and methyl nitrosourea. Targeted gene sequencing and reduced representation sequencing were employed to evaluate mutation density to determine suitability of mutant populations for reverse genetics. Mutations in genes of interest were identified by traditional TILLING, TILLING by sequencing, and targeted exon capture and sequencing. Rice grain mutants were identified by visual inspection of brown rice samples, the alkali spreading value test, and I_2/KI staining. Mutants with low phytic acid content were identified using an indirect colorimetric assay that detects high inorganic phosphate. Screening with germanium was performed to identify mutants with putative alterations in silicon/arsenic uptake and accumulation. Reduced epicuticular wax mutants were identified by visual assessment after misting leaf surfaces with water.

Using chemical mutagenesis of rice seeds, mutant populations suitable for forward and reverse genetics were developed. A publicly available TILLING resource was generated using the variety Nipponbare, which has been used to identify mutations in an array of target genes. Mutation detection by sequencing has also facilitated the characterization of the mutation density and type in rice mutant populations derived from the variety Kitaake, enabling the comparison of different chemical mutagenesis protocols. Forward genetic screens of the Nipponbare, Kitaake and Sabine mutant populations has also resulted in the identification of a number of interesting mutant phenotypes for germplasm enhancement and gene function studies. Rice mutant populations generated using traditional mutagenesis remain an important resource in light of consumer and industry concerns over biotechnological approaches such as genetic transformation and gene/genome editing. Advances in non-GMO technologies such as high throughput sequencing have increased the value and utility of these mutant populations.

Development of Rice Mutants with Altered Starch Traits for the Enhancement of Grain Quality

Kim, H. and Tai, T.H.

High concentration of carbohydrates dominantly starch is stored in rice (*Oryza Sativa* L.) endosperm and biosynthesis and accumulation of starch is directly influencing on rice grain quality such as kernel appearance, eating and cooking qualities, and milling yield. To improve rice grain quality, induced plant mutants related to starch traits are being developed through forward and reverse genetics from the rice mutant populations derived by chemical mutagens in Nipponbare (n=4,096) and Kitaake (n=2,000). Approximately 120 putative mutations using M2 and M3 were identified using Targeting of Induced Local Lesions in Genomes (TILLING) or targeted exon capture designed for 16 starch related genes. Additionally, more than 20 putative mutants (M4 or M5) were selected based on altered grain appearance. Using homozygous mutant grains, grain quality was evaluated based on grain morphologies, shape of starch granule, and physicochemical properties. Currently, several putative mutants were selected based on harboring starch mutations and clear phenotypic variations on the grain and backcrossed. These materials will be used for further breeding program to improve grain quality.

Identification of Rice Mutants with Altered Responses to Germanium

Magee, S.C., Kim, H., and Tai, T.H.

Germanium is an analog of silicon. However, unlike silicon, which is beneficial for plant growth, development, and productivity, germanium is toxic to plants and its uptake and accumulation results in the formation of necrotic lesions. Researchers have successfully exploited this attribute to screen for mutants in rice that are altered for uptake in silicon resulting in the identification of silicon transporters, which are also responsible for the uptake of inorganic arsenic under the anaerobic conditions found in flooded rice fields. The objective of this project is to identify additional mutants with altered response to germanium exposure and characterize their uptake of germanium, silicon, and arsenic. Using a hydroponic culture system, rice seedlings from over 850 mutant lines (M5 generation), derived from sodium azide mutagenesis of the temperate japonica cultivar Kitaake, were screened for altered uptake of germanium as evidenced by differences in the development of toxicity symptoms compared to wild type. Preliminary screening revealed about 30 lines, which showed greater sensitivity to germanium toxicity by producing more rapid or stronger symptoms (i.e. formation of lesions and eventual death). Another 55 lines showed less severe symptoms of which 11 lines were rated as tolerant. These lines are currently being re-tested to confirm the initial observations and further characterization of these mutants will be presented.

Mapping of Salt Tolerance Traits in Different Genetic Backgrounds

Subudhi, P.K., Puram, V.R.R., and Ontoy, J.

Salinity is an important abiotic stress affecting rice production worldwide. Development of salt tolerant varieties is the most feasible approach for improving rice productivity in salt affected soils. In rice, seedling stage salinity tolerance is crucial for better crop establishment. Quantitative trait loci (QTL) mapping using introgression lines (ILs) is useful for identification and simultaneous transfer of desirable alleles into elite genetic background.

In the present study, two IL populations of a salt tolerant donor 'Nona Bokra' were developed in the backgrounds of two high yielding rice varieties 'Jupiter' and 'Cheniere' to elucidate the genetic basis of seedling stage salinity tolerance. Both populations were evaluated for salt tolerance at seedling stage in hydroponic experiments and genotyped using simple sequence repeat markers.

The majority of QTLs identified for various morpho-physiological traits (salt injury score, Na^+ content, K^+ content, Na/K ratio, chlorophyll content, root length, shoot length, shoot dry weight) were with small effects. The phenotypic responses, genomic composition, and QTLs identified from the study indicated that Na/K homeostasis and Na^+ compartmentation may be the key contributor to salinity tolerance. The salt tolerant ILs identified in this study will not only aid in map based cloning of salt tolerant determinants but also accelerate development of salt tolerant varieties by accumulating favorable alleles through marker-assisted selection.

Identification of Early Flowering QTLs in Rice (Oryza sativa) with QTL-seq Method

Meng, X., Jeanniard, A., Liu, G., and Peng, Z.

Next generation sequencing technologies provide new insights into accelerating gene mapping in many species. QTL-seq method, developed in 2013, can rapid identify plant QTLs by whole-genome resequencing of DNAs from two populations showing extreme opposite trait values for a given phenotype in a segregating progeny. Cultivated rice is a facultative short-day plant that flowers early in short day (SD) and late in long day (LD) conditions. Shortening rice life span could reduce field management cost and enable double cropping, which would break yield barriers and greatly increase the economic output. Here, we generated a stable rice (*Oryza sativa*) mutant that insensitive to light changes, which flowers about 15-25 days earlier under LD and 7-15 days late under SD compared to wild type (WT). In this study, we used QTL-seq method to sample DNAs from a F3 population derived from WT and mutant under natural LD to generate 'Early' and 'Late' bulks. The resulting DNA bulks were applied to whole genome resequencing with >30x coverage. Short reads were aligned to the reference sequence and single nucleotide polymorphism (SNP) was analyzed. Candidate QTLs on chromosome 6 and chromosome 8 were identified through SNP-index and sliding window analyses according to QTL-seq method.

QTL Mapping for Yield Traits in 'LaGrue' Rice

Rice, A.D., Moldenhauer, K.A.K., Pereira, A., and Shakiba, E.

'LaGrue' is a long grain, high-yielding rice variety released by the University of Arkansas. The variety has been used as a parent in the production of other high-yielding varieties but there is very little knowledge on the genetics that give LaGrue its high-yielding potential. The main objective of this project is to do a QTL mapping study to look for traits that give LaGrue its high-yielding potential. The first objective is to look for yield traits that are associated with high yield in LaGrue. We conducted a yield trial study where we compared LaGrue to three other cultivars; 'Bengal,' 'Lemont,' and Mars.' We used a randomized complete block design where with three replications for each cultivar at two different planting dates. We sampled 10 plants from each replicate from one planting date and harvested all replicates to determine the average total yield of each cultivar. The yield traits that were analyzed from the 10 plants sampled were number of tillers/plant, number of panicles/plant, number of spikelets/plant, number of seeds/plant, 1000 seed weight, and total yield/plant. We also created three bi-parental populations by crossing LaGrue with Bengal, Lemont, and Mars to potentially use as a QTL mapping population. The results from this evaluation will tell us which yield traits LaGrue excels in and to determine which bi-parental population should we use for QTL mapping.

Candidate Gene Analysis of the Quantitative Trait Locus GW8.1 Associated with Grain Length in Rice

Ahn, S., Kang, Y., and Shim, K.

A quantitative trait locus (QTL) *gw8.1* was detected in the population derived from a cross between the elite *japonica*cultivar, 'Hwaseong'and *Oryza rufipogon* (IRGC 105491). Near isogenic lines (NILs) harboring the *O. rufipogon* segment on chromosome 8 showed increased grain length and weight compared to those of the recurrent parent, Hwaseong. This QTL was mapped to a 175.3-kb region containing 28 genes, of which four were considered as candidates based on the presence of mutations in their coding regions and as per the RNA expression pattern during the inflorescence stage. Leaves and panicles obtained from plants harvested 5 days after heading showed differences in gene expression between Hwaseong and *gw8.1*-NILs. Most genes were upregulated in *O. rufipogon* and *gw8.1*-NIL than in Hwaseong. Scanning electron microscopy analysis of the lemma inner epidermal cells indicated that cell length was higher in *gw8.1*-NIL than in Hwaseong, indicating that *gw8.1*might regulate cell elongation. Among the candidate genes, LOC_Os08g34380 encoding a putative receptor-like kinase and LOC_Os08g34550 encoding putative RING-H2 finger protein were considered as possible candidates based on their functional similarity.

Integration of DNA Marker Technology on a Budget

Andaya, C.B., Yeltatzie, G.B., McKenzie K.S., and Andaya, V.C.

The Rice Experiment Station (RES) in Biggs, California, uses the conventional pedigree breeding method in rice varietal improvement but has now been augmented by the use of DNA marker technology. Although different marker technologies and genotyping platforms are available, plant breeders at the Station consider the reliability of the markers to accurately select for the trait of interest, the simplicity and practicality of their use and their cost effectiveness. RES started building its facilities and manpower in 2007 to take advantage of the available DNA technologies and genomic resources. The poster will describe how DNA markers has been integrated into the breeding program at the station to support traditional breeding. The use of DNA markers to select for blast resistant materials and the use of grain quality markers to select for materials with the right cooking quality will be emphasized. The role of markers to map genes for traits of importance to California farmers such as stem rot resistance and herbicide resistance as well as the eventual release of CA rice varieties will also be presented.

Improving Efficiency of Genetic Analysis by Merging Capillary Electrophoresis and KASP Methods

Boyett, V.A., Thompson, V.I., Jin, X., and Shakiba, E.

Marker-assisted selection (MAS) using trait-linked microsatellite markers is a proven tool to assist rice breeders during the development of improved germplasm. The technology has been in use in the University of Arkansas Rice Research and Extension Center's (UA RREC) rice breeding program for 16 years.

Most of the DNA markers in use currently were developed over a decade ago for resolution by capillary electrophoresis (CE). With more rice breeders using MAS and each breeder increasing materials for molecular analysis, improving throughput to reduce data turnaround time while still maintaining data integrity is imperative. Concomitant with the demand for faster data turnaround times are the rising operating costs and maintenance requirements for CE analysis. Improving throughput and reducing analysis costs can be accomplished by moving to a more cost-effective and faster analysis platform of endpoint fluorescence detection such as Kompetitive Allele Specific PCR (KASP™).

Kompetitive Allele Specific PCR is a fluorescence resonance energy transfer (FRET) platform suitable for analysis of single nucleotide polymorphism (SNP) and insertion-deletion (InDel) markers. The KASP system offers several advantages over CE analysis: 1. Unlike CE analysis, there is not any post-PCR processing of the amplification products prior to analysis. The KASP plate is also the analysis plate. 2. The FLUOstar Omega SNP Reader does not require any reagents or time-consuming maintenance procedures to read a plate. 3. A 96-well KASP plate can be read in less than 2 minutes, whereas the ABI 3500xL takes 160 minutes to run a 96-well plate. 4. While there are some allele-specific SNP markers developed originally for CE analysis, cross priming makes calling alleles and data interpretation difficult. Interpretation of the KASP data is simple with straightforward allele calls, saving valuable time on data analysis. 5. At 48 cents per sample, KASP chemistry costs only 27% of the price of ABI 3500xL analysis at $1.75 per sample.

One major disadvantage of the KASP system, though, is that while SNP markers are considerably more abundant in the rice genome than microsatellites, few have been mapped to traits of agronomic importance. At the UA RREC, we have been successful in converting eight markers linked to grain cooking quality, leaf texture, and Clearfield technology from CE analysis to KASP markers, but most traits are still assessed with highly informative microsatellite markers. More trait-linked SNP and InDel markers are needed, and efforts are continuing to convert more microsatellite markers to KASP markers for improved options for rice DNA marker-assisted selection.

Marker-Assisted Breeding for Blast-Resistant Hybrid Rice

Shi, J., Fan, J., Huang, F., Wang, W.W., and Huang, T.Y.

Rice blast, caused by the ascomycete fungus *Magnaporthe oryzae*, is one of the most serious diseases in rice in China and other rice-producing countries of the world. Thirteen Lijingxin Tuan Heigu (LTH) monogenic lines carrying various resistance genes were selected and evaluated for blast resistance by artificial inoculation in a greenhouse and natural infection in the field at various locations in Sichuan Province, China. Among them, the monogenic lines carrying*Pi2*, *Pi9*, *Pikm*, and *Pi1* genes showed highest levels of resistance to rice blast. The cloned alleles *Pi2* and *Pi9* in the Pi2 locus respectively showed a resistance frequency of 96.63 and 90.57% in the greenhouse evaluations and produced an average leaf blast rating of 0.58 and 0.60% in the field evaluations. The cloned alleles *Pi1*and *Pikm* in the Pik locus respectively showed a resistance frequency of 28.74 and 93.83% in the greenhouse evaluations and produced an average leaf blast rating of 4.66 and 0.55% in the field evaluations. These results demonstrated that these resistance genes still maintain high levels of field resistance to the rice blast disease in Sichuan Province. We further used the hybrid rice restorer line Yahui2115 (YH2115) with *Pi2* as a blast-resistant parent for crossing in the hybrid rice breeding program. Through using SRM24 and AP22, molecular markers specific for *Pi2*, we have developed excellent new hybrid rice cultivars with *Pi2* that has a broad spectrum of resistance against the rice blast disease.

Hybrid Rice Seed Production Test at Beaumont, Texas 2017

Yan, Z., Wilson, L.T., Christensen, E., Martin, L.

Efficient seed production is critical to hybrid rice development. A non-replicated study was conducted in 2017 at the Texas A&M University AgriLife Rice Research Center in Beaumont, Texas, to assess the impact of sowing date on seed production. The yield performance of 24 combinations of restorers and male sterile lines were evaluated for each of three male sterile planting dates, for a total of 72 treatment combinations, with the sowing dates chosen to produce the greatest overlap between male and female flowering. Three restorers x four thermo-sensitive genic male sterile lines and the same three restorers x four cytoplasmic male sterile lines were evaluated. The restorer lines were sown in the greenhouse on March 23 and April 2, and the seedlings transplanted when 20 days old, using a 15.2 cm between and within row spacing. Transplanting alternated using seedlings from each of the two sowing dates. Seeds from each male sterile line were sown in the greenhouse on each of three dates (May 1 to June 5), with the 15-day old seedlings transplanted into six rows, using a 15.2 cm between and within row spacing.

A 11.36 L solution of Gibberellin acid (GA) water solution (0.176 g GA/L) was applied at 5% heading to improve panicle exertion from the boot, with a second application of 22.72 L applied three days later. The pollen was dispersed using plastic poles (3.5 x 289 cm) that were shaken back and forth or swung through the upper part of the restorer rows at noon during the heading periods.

The highest yield (2,718 kg/ha) was achieved with 279s x 173R. Subsequent analyses will focus on determining 279s x 173R grain quality. If grain quality is acceptable, replicated experiments will be conducted to determine lodging resistance and whether seed production can be increased using chemical aids.

Detection of Blast and BPB Resistance Genes in Potential New Rice Varieties for South U.S. Rice Production

Perez, L.M., Redoña, E.D., and Peng, Z.

Host resistance in plants remains the most sustainable and economic approach for disease control in rice. In particular, the weather and microclimate in rice paddies of southern US favor the occurrence of rice blast and bacterial panicle blight (BPB) caused by *Magnaporthe oryzae* and *Burkholderia glumae*, respectively. We used three blast resistance genes, Pita, Pi54, and Piz, and 2 QTLs for bacterial panicle blight resistance, RBG2 and qRBS1, in DNA fingerprinting analyses of 179 advanced breeding lines and 21 check cultivars from the 2017 Uniform Regional Rice Nurseries (URRN) located in Stoneville MS. The results showed that 32% of the tested lines contained at least one resistance gene (blast and/or BPB). Breeding lines that showed at least one blast resistance genes were 28.5% while those showed at least one QTL for BPB resistance were 11.8%. Only four entries showed a combination of blast and BPB resistance genes or QTLs. This initial study showed that a low percentage of resistance to blast and BPB disease is expected in the next generation of varieties that will be released for rice production in Mississippi and southern US. Implications of the results will be discussed.

Genetic Analysis of Rice Blast Disease Resistance Genes using USDA Rice Mini-Core and a Mapping Population

Li, W., Jia, Y., and Yang, J.

Rice blast disease caused by the fungal pathogen *Magnaporthe oryzae* (*M. oryzae*) is one of the most destructive diseases of cultivated rice, resulting in significant yield loss each year all over the world. Developing and utilizing blast resistant rice varieties is the most economical and effective method to reduce the damages by *M. oryzae*. However, resistance to *M. oryzae* mediated by major resistance (*R*) gene can be easily lost after a few years. Resistance mediated by quantitative trait loci (QTL) is more durable and long lasting. Identification and utilization of effective QTL is now the new focus for rice breeders worldwide.

Toward this goal, the objectives of the present study were to 1) determine leaf and panicle disease reactions of the USDA mini-core collection consisting of 217 diverse rice germplasm accessions, and 2) evaluate leaf blast reactions of 249 recombinant inbred lines (RILs) derived from the cross of two U.S. rice varieties, Cypress and LaGrue (MY2), under greenhouse conditions.

For the first objective, leaf blast reactions were determined 1 week after inoculation of rice seedlings at V3 to V4 stages using a mixture of blast races (IB-49, IC-17, and IB-54 at 1-5 X 105 spores/mL) and the same mixture was used to inoculate rice at the booting stage with a syringe, and panicle blast was rated 3 weeks after inoculation. We found that 11 accessions were resistant and 168 accessions were susceptible to leaf and panicle blast diseases, respectively. However, 38 accessions were only resistant to panicle blast and 12 were only resistant to leaf blast. The observed discrepancies of leaf and panicle blast can be due to environmental conditions during inoculation or difference in host gene expression at different growth stages.

Cypress was reportedly susceptible to IB-1, IB-49, and IC-17 and resistant to IB54, whereas LaGrue is susceptible to the blast races IB-54, IG-1, IH-1, IC-17, and IB-49. For the second objective, disease reactions of 249 MY2 RILs are being evaluated with one isolate from each race, IB-1, IB-49, IC-17, IB-54, IH-1, and IG-1, for leaf blast reaction using the same procedure described above, and results will be presented.

Differential Expression Analysis Underlying Heat Tolerance in Rice Using RNA-Seq

Mustahsan, W., Tarpley, L., Mohammed, A.R., Septiningsih, E.M., and Thomson, M.J.

High night temperatures (HNT) can impose detrimental constraints to rice production. The effects of HNT on decreasing yield and grain quality are not well understood at a genetic level. Therefore, a RNA-Seq genome-wide transcript profiling analysis is being utilized to identify genes contributing to HNT tolerance. A greenhouse trial was conducted at the Texas A&M AgriLife Research Center in Beaumont, Texas to evaluate agronomic traits and to perform transcriptomics study of nine rice varieties, including Texas varieties Colorado and Antonio, under high nighttime temperature (HNT) conditions during the reproductive stage. Infrared heaters were used to precisely obtain HNT conditions (30°C) versus ambient night temperatures (25°C) during the booting stage. Within this experiment, half of the plants also received treatment with 1-MCP, an ethylene inhibitor that can help better understand oxidative stress mechanisms. The physiological data collected from the HNT greenhouse experiment was then used to identify two contrasting heat tolerance rice varieties for further study. In order to gain a deeper understanding of the genetic interactions and differential genes which control the expression of heat tolerance, next-generation sequencing (Illumina TruSeq RNA Stranded prep) tools were used to perform genome-wide transcript profiling analysis to identify differentially-expressed genes under high night temperature stress. Transcriptome data were gathered from leaf samples taken at booting stage (35 days) after HNT and 1-MCP treatment. RNA was extracted using Qiagen: RNeasy-Plant Mini kit and checked for quality on a 2100 Fragment Bioanalyzer (Agilent). TruSeq Stranded RNA-Seq libraries were prepped at Texas A&M AgriLifeGenomics and Bioinformatics Service (TxGen) as per standard procedures (Illumina). Four lanes of an Illumina HiSeq HO-50 were used to provide 50 bp single-end reads per sample. The raw sequencing reads were trimmed to remove low quality bases and adapters using edgeR on R-Studio; then mapped to the reference genome (IRGSP 1.0 -MSU) using STAR. The number of reads mapped to each gene are counted using StringTie. For detecting the differential expressed genes (DEGs), edgeR (R-Studio) and DESeq2 package in the CyVerse platform were used to identify the most highly differential expressed genes among contrasting genotypes under different treatments. Preliminary results from gene ontology reports showed various biological and molecular components, including heat shock factors that play a contributing role in heat tolerance. The results from this study can be used to better understand the genetic control of high night temperature tolerance as the foundation for developing more versatile HNT donors for future breeding programs.

Proteome-Wide Post-Translational Modifications Identification in Developing Rice (*Oryza sativa*) Seeds

Meng, X., Mujahid, H., Xing, S., Perez, L.M., Peng, X., Zhao, Q., Redoña, E.D., Wang, C., and Peng, Z.

Post-translational modifications (PTMs) are covalent modifications that occurr during or after protein biosynthesis. Lysine residue (K) frequently undergoes PTMs involving short-chain acyl-CoA metabolites. A wide array of novel protein PTMs has been discovered throughout recent years include crotonylation, succinylation, malonylation, and 2-hydroxyisobutyrylation on lysine residues. PTMs have been reported to play critical roles in regulation of gene expression, cell signaling, protein activity, photosynthesis, abiotic/biotic stress-tolerance, flowering time, seed development and fertility, etc., in plants. Utilizing antibody-based affinity enrichment and nano-HPLC/MS/MS analyses, we efficaciously identified hundreds to thousands lysine sties and proteins targeted by acetylation, succinylation, malonylation, crotonylation or 2-hydroxyisobutyrylaton in developing rice seeds. Functional annotation analyses indicated that a wide variety of vital biological process were preferably subjected to PTMs, including central carbon metabolism, starch biosynthesis, lipid metabolism, protein biosynthesis and metabolism, and defense responses. Our finding showed that the modification sites were conserved across plant, human, and mouse in both histone and non-histone proteins. A number of rice proteins were substrates for multiple kinds of PTMs. This study provides novel insights into the potential functions and regulations of PTMs as well as multi-modifications mediated cross talk during cereal grain development.

Abstracts of Papers on Plant Protection
Panel Chair: Luis Espino

Field Evaluation of Advanced Rice Lines to Sheath Blight in Arkansas

Belmar, S.B., Kelsey, C.D., Moldenhauer, K.A.K., and Wamishe, Y.

Sheath blight of rice caused by *Rhizoctonia solani* AG1-1A continues to be an ongoing disease challenge for rice breeders developing new varieties with adequate levels of resistance/tolerance. The breeding-pathology support at the Rice Research and Extension Center (RREC) near Stuttgart, AR, routinely establishes a disease nursery in the field to evaluate rice breeding lines to the major diseases. The objective of this study was to search for the relative tolerance or susceptibility of rice plants to sheath blight. Newly developed rice lines in ARPT (Arkansas Rice Performance Test) and URRN (Uniform Regional Rice Nursery) were planted late April with the Hege 1000 to produce hill plots. Test entries were replicated four times. Agronomic practices for rice production in AR were used throughout the growing season. Since resistance for sheath blight disease in rice is largely quantitative, slower growing *R. solani* AG1-1A isolates were chosen so that the plants' response would not be overwhelmed by the pathogen. Inoculum was prepared using a sterilized corn/ryegrass seed media inoculated with a week old culture consisting of two relatively slower growing isolates. Approximately, three grams of air-dried inoculum was applied to dry foliage when plants reached panicle differentiation. Rice plants were left in a flooded field undisturbed so lesion formation could develop at the waterline on a known susceptible line. Approximately a month later, a 0 (no disease) to 9 (severe disease) visual rating scale was used to capture how far up the plant height symptomatic lesions were formed. Although none of the entries provided complete tolerance, differences were detected among the test lines in reaction to the pathogen. In 2017, 12 lines from ARPT and 60 from URRN rated 6.3 or less and were categorized as relatively tolerant to the pathogen. Fifteen and 39 lines showed sheath blight susceptibility with ratings of 7.3 or higher from the ARPT and URRN tests, respectively. Among the subset of 40 ARPT entries that were tested both in 2016 and 2017 rice growing seasons, only 32% showed agreement in rating scores. Variability of environmental conditions from season to season are often contributed to disparities in disease ratings. Due to the quantitative nature of tolerance in rice to sheath blight, a multi-season disease evaluation is encouraged to obtain reliable data for use in breeding programs.

Development of Sheath Blight-Resistant Breeding Lines for Southern U.S. Environments

Galam, D., Sanabria, Y., Groth, D.E., Al-Bader, N., Meier, A., Geniza, M., Jaiswal, P., and Oard, J.H.

Rice sheath blight disease caused by *Rhizoctonia solani* is a major biotic constraint to high grain yield and quality for most commercial U.S. varieties. Although different breeding lines with high levels of "partial resistance" have been developed such as MCR010277 (MCR), none has been used directly as a commercial variety. The objective of this research was to leverage MCR and other accessions to identify DNA markers and candidate genes for development of new sheath blight-resistant breeding lines with high grain yield and quality traits.

In previous research, MCR was used as a resistant parent and crossed to susceptible variety Cocodrie (CCDR) to develop 322 RILs of the RiceCAP SB2 mapping population. Filtering of whole genome sequences of MCR and CCDR identified numerous candidate SNP markers and genes putatively associated with sheath blight resistance. A subset of candidate markers were identified by genotyping extreme resistant and susceptible SB2 RILs. Selected SNP markers on four chromosomes were validated in several breeding lines across two separate field environments. In a separate study, seven elite breeding lines with high grain yield and quality carried SNP markers for sheath blight resistance on seven chromosomes while susceptible lines contained none of the selected markers. A regulatory gene on chromosome 9 was shown in RNA-Seq studies to play a role in sheath blight resistance of MCR. This research demonstrates that a combination of traditional breeding and genomic approaches can facilitate rapid development of elite breeding lines with high grain yield and quality traits for southern U.S. environments.

Dynamic Changes of Rice Blast Fungus in the USA through Six Decades

Jia, Y., Wang, X., Bianco, T., Jia, M., Wamishe, Y., and Valent, B.

Rice blast disease caused by the fungus *Magnaporthe oryzae* is a serious rice disease in the USA and worldwide. *M. oryzae* is highly adaptive and changeable due to the instability of its genome and resistance genes which are effective only when *M. oryzae* isolates contain the cognate avirulence (*AVR*) genes.

Analysis of *AVR* genes, genetic identity, population structure, and pathogenicity in *M. oryzae* strains help identify effective blast resistance (R) genes for deployment to prevent blast disease. A total of 1,022 M. oryzae isolates were collected from the southern USA from 1959 to 2015 for this study. The *AVR* genes in *M. oryzae* were determined based on the presence and absence of amplicons by Polymerase chain reaction (PCR) with AVR gene specific primers with the fungal genomic DNA directly from filter papers from storage. Genetic identity and population structure of *M. oryzae* was determined with 10 neutral polymorphic microsatellite markers. Pathogen virulence was first evaluated with the international rice differential rice varieties, Raminad Str. 3, Zenith, NP125, Usen, Dular, Kanto 51, Sha-tiaotsao, and Caloro, along with Katy and M202 as resistant and susceptible controls, respectively.

The presence of *AVR* genes in *M. oryzae* isolates was then verified with expected disease reactions using International Rice Research Institute monogenic rice lines carrying the corresponding blast resistance genes. Through these analyses, we showed that *M. oryzae* isolates have become more diverse and virulent over a period of six decades. However, we found *AVR-Pib, AVR-Pi9, ACE1 (AVR-Pi33)*, and *AVR-Pizt* in over 90%, *AVR-Pita1* in over 80 %, and *AVR-Pik* in 37% of the isolates. DNA sequence analysis revealed that *AVR-Pita* and *AVR-Pik* were rapidly evolved under positive selection whereas few changes in *AVR-Pi9*, *AVR-Pi33*, *AVR-Pib*, and *AVR-Pizt* were found in sequenced US isolates. Overall, frequencies of mutations at *AVR-Pita* and *AVR-Pik* genes were found to correlate with the frequencies of the deployment of the cognate *R* genes in rice varieties in the southern USA.

These findings suggest that blast *R* genes, *Pib, Pi9, Pi33, Pizt*, and *Pi-ta*, are effective *R* genes to reduce damage by rice blast disease in the southern USA. A strategy for future *R* gene deployment in different southern U.S. will be presented.

Are We There Yet for Rice Disease Control?

Jia, Y.

Plant resistance (*R*) genes play an important role in fighting against plant pathogens. For the past two decades, significant efforts have been directed to map and clone *R* genes. Most of the cloned plant *R* genes encode proteins with leucine rich repeat and nucleotide binding sites (NLR), their cellular action and structure/function relationship have been largely unraveled. It has now become clear that plant immunity is involved in at least two tiers of defense responses.

The first tier is involved in detecting pathogen molecules by surface receptors referred to as PAMP triggered immunity and the second tier, referred to as elicitor triggered immunity (ETI), is involved in recognition of elicitors by NLR proteins that either directly or indirectly trigger robust defense responses.

Current knowledge on molecular mechanisms of host-pathogen interactions will be reviewed. Specifically, 1) the reliability of the reference genome, 2) how pathogen has evolved, 3) how pathogen effector genes are selected, 4) what we can learn from DNA sequences of effectors, 5) what is the real power of the effectors, 6) how plant NLR genes and their cognate partners work together in triggering effective disease resistance responses. Pros and cons of the development of new resistance cultivars via a marker assisted selection and genetic engineering will be discussed.

Field Response of Advanced Rice Entries to Bacterial Panicle Blight Using *Burkholderia glumae*

Mulaw, T., Gebremariam, T., and Wamishe, Y.

Bacterial panicle blight (BPB) is one of the most threatening diseases for rice production in Arkansas and other southern rice producing regions. The disease is caused largely by *Burkholderia glumae* formerly known as *Pseudomonas glumae.* BPB has moved from being an emerging to a well-known disease since many of the conventional commercial rice varieties became susceptible. The disease was seen increasing in rice production fields in the southern USA since 1995. The disease was so severe in 2010 and 2011 causing up to 50% yield loss in susceptible varieties. The Rice Extension Program at the Rice Research and Extension Center (RREC), the University of Arkansas System, Division of Agriculture, started evaluating rice varieties and advanced breeding lines for bacterial panicle blight resistance since 2012. In 2017, 200 entries in Uniform Regional Rice Nursery (URRN) were evaluated for BPB using bacterial suspension of the major causal species, *B. glumae.* The 200 entries were planted in hill plots interspaced with Jupiter and Bengal after each 10 entries. The rice variety Jupiter was used as a reference for moderately resistant and Bengal for susceptibility. Each test entries were replicated twice. *B. glumae* was isolated from symptomatic panicles and plated on CCNT (a semi-selective agar medium). Selected isolates of *B. glumae* were assessed for hypersensitive reaction on a wild tobacco leaves and for pathogenicity on rice seedlings. *B. glumae* suspension was prepared from a 2-day-old culture grown on King's B medium. The suspension was adjusted to approx. 10^8colony forming units/ml (CFU) and sprayed twice a week in an interval of 3 to 4 days between boots split to flowering stage of crop development. - Due to differences in growth stages, the artificial inoculation was carried out for up to four weeks. Data were collected 3 weeks after the last inoculation. Disease rating were taken using a 0 to 9 scale where 0 is no disease and 9 severe disease. Of the 200 entries, 20 entries rated 2 and 3 and appeared to show better resistance than Jupiter and were categorized as resistant (R); 11 entries rated 4 similar to Jupiter and were grouped as moderately resistant (MR); 34 entries that rated 5 and 6 were grouped as moderately susceptible (MS). Those that rated 7 similar to Bengal were categorized as susceptible (S) and the remaining 98 entries rated higher than Bengal (8, 9) and were grouped as very susceptible (VS). Although BPB is sporadic and weather dependent, resistance appears to be its ultimate long-term management option. Therefore, pursuing for resistance should be important to rice breeders and pathologists in developing cultivars.

Organic Rice IPM Research Update in the United States

Zhou, X.G., McClung, A., Dou, F., Watkins, B., Bagavathiannan, M., Way, M.,
Huang, B., Ntamatungiro, S., Shade, J., and Abugho, S.

U.S. organic rice production has steadily increased over the past decade, with a majority of the acreage being grown in the southern region. Because of the warm and humid environments and the long growing season in the region, weed, disease and insect pests are among the primary factors limiting organic rice production. This 3-year USDA NIFA OREI-funded multistate research project addresses these issues and aims at developing viable management strategies that minimize the damage caused by these pests. This presentation updates the research of the first two years of this project.

Field trials were conducted under organic management in Texas and Arkansas in 2016 and 2017 to understand the impacts of cover crop and soil amendment, seed treatment, seeding rate, and rice cultivar on disease, weed and insect pests, grain yield, and economic benefits. The winter cover crops annual ryegrass, cereal rye, crimson clover, and crimson clover mixed with oats produced sufficient aboveground biomass, resulting in a reduction in weeds and an improvement in the supply of N and other nutrients. Soil amendment with mustard seed meals reduced the loss of stand caused by a seedling disease complex. Annual ryegrass and crimson clover reduced both narrow brown leaf spot and brown spot diseases. Gibberellic acid seed treatment increased seedling height. Seed treatment with the biocontrol agents Sonata (*Bacillus pumilus*), Integral (*B. subtilis*) and BioEnsure (fungal endophytes) resulted in a significant improvement in stand establishment. BioEnsure seed treatment also improved whole and total milling yields. XL753, XL723, Rondo, Jasmine 85 and Tesanai 2 were among the best cultivars showing good stand, aggressive growth, weed and disease suppression, and high yield potential. No significant differences in the rice water weevil populations were observed among cultivars. Seeding at 150% of recommended rate for conventional systems improved stand establishment and weed suppression. The economic optimum seeding rate for Presidio and XL753 was 80 and 47 kg/ha, respectively.

Winter cover crops can suppress weeds and diseases and provide N and other nutrients that improve organic rice production. Selection of resistant or tolerant rice cultivars such as XL753, Jasmine 85 and Tesanai 2 is the key to effective management of these pests. Increasing seeding rate and seed treatment with gibberellic acid and biocontrol agents can ensure adequate stands for weed suppression and yield potential. Through a variety of communication techniques, the project has reached large national and global audiences, with most located in Arkansas, California, Missouri, and Texas.

Development of Biological Agents that Promote Rice Health and Growth

Maharjan, A., Leonard, J., Calderon, R., and Ham, J.H.

Healthy growth of rice is essential for maximum yield from a given rice variety but challenged by various biotic and abiotic environmental factors. Massive amounts of chemical fertilizers and pesticides are applied to rice fields for maintaining high yields by avoiding nutrient-deficiency and biotic stresses, such as diseases and insects damages. However, this causes not only significant economic costs for purchasing the materials but also serious environmental damages resulting from fertilizer runoffs and pesticide drifts. Thus, it is imperative to develop a sustainable method that enhances the growth and health of rice throughout the entire growing season, and rice-associated bacteria are best candidates of the biological agents that can exert the desired activity on rice plants. Several strains of *Bacillus* sp. isolated from rice rhizosphere exhibited strong antifungal and antibacterial activities against major rice pathogens including *Rhizoctonia solani* (sheath blight pathogen), *Magnaporthe grisea* (blast pathogen), and *Burkholderia glumae* (bacterial panicle blight pathogen). Interestingly, rice seed treatment with at least one of them also resulted in significant growth promotion of rice seedlings. In an attempt to identify rice-associated beneficial bacteria in a more comprehensive scheme, bacterial strains isolated from various parts of rice plants, regardless of their antimicrobial activities, are currently tested for their effects on the growth of rice seedlings. Effects on the tolerance of rice seedlings to the sheath blight pathogen *R. solani* are also examined with the same bacterial strains. In addition, non-symbiotic nitrogen-fixing bacterial are screened using a nitrogen-free medium to identify bacterial agents that can reduce the required amounts of nitrogen fertilizers for maximum yield. It is expected that single or combinational usage of the beneficial bacteria identified in this study will greatly facilitate sustainable rice culture, reducing the needs of chemical fertilizers and pesticides.

Endophytes: As Management Strategy for Major Rice Diseases

Mulaw, T., and Wamishe, Y.

Endophytes are microorganisms (bacteria or fungi) that dwell within robust plant tissues by having a symbiotic association. They are ubiquitously associated with almost all plants studied until date. Some commonly found endophytes are those belonging to the genera *Trichoderma* spp, *Bacillus* spp, *Pseudomonas* spp. and so forth. Endophytic population greatly affected by climatic conditions and location where the host plant grows. This study was largely focused on cultivable endophytes and their interactions with the pathogens of the major rice diseases. The objectives include 1) isolation and identification of endophytes and 2) evaluation of the endophytes in protecting rice plants against fungal and bacteria pathogens. The endophytes were isolated from seeds. Seeds were surface-sterilized using 95% ethanol followed by sodium hypochlorite (4% available chlorine). Seeds were washed and rinsed three times with sterile water. Then, they were allowed to dry on a sterile filter paper for 10 min in a sterile laminar flow chamber. Seeds were plated on potato dextrose agar (PDA) to isolate fungal endophytes and on nutrient agar (NA) medium to isolate endophytic bacteria. Pure cultures were obtained by sub-culturing. Because many pathogenic organisms can colonize plants internally, only known fungal and bacteria species with a biocontrol potential were selected for this study, namely, *Trichoderma* spp, *Bacillus* spp, and *Pseudomonas* spp. All isolates that belongs to those species were test for pathogenicity using tobacco plant hypersensitive reaction and pathogenic isolates eliminated from further study. Standard morphological features and DNA sequence-based analysis were used for the identification of endophytic fungi and bacteria isolates. Antagonistic activities of *Trichoderma* isolates against two fungal rice pathogens, *Magnaporthe oryzae* and *Rhizoctonia solani AG1-1A* were determined *in-vitro* on potato dextrose agar (PDA). Based on their performance to control these pathogens, a single *Trichoderma* isolate were selected. Three *Bacillus* sp. were also selected based on dual confrontation plate experiment for their biocontrol activity against *Burkholderia glumae*, the major causal agent of bacterial panicle blight (BPB) disease to continue further analysis in the greenhouse on plants. To evaluate the endophyte-host plant interactions in protecting host plants against blast and sheath blight disease causing pathogens, tests were tests were carried out by spraying *Trichoderma* sp. as pre-inoculation or post-inoculation treatment for endophyte colonization or establishment. Development of disease symptoms were also monitored continues until final data collection. Disease ratings to both diseases were taken using the standard disease rating scales for the respective diseases. Results showed that endophyte *Trichoderma* sp. isolate from rice has anti-fungal potential to control rice blast and sheath blight diseases. The *Trichoderma* that is isolated from seeds of Arkansas is a true endophyte that able to antagonize *Magnaporthe oryzae* and *Rhizoctonia solani AG1-1A*, the causal pathogens to rice blast and sheath blight disease, respectively. Use of such biocontrol agents, would be useful to the increasing need of organic farming and in reducing the use of chemical fungicides that risk the environment including human health.

Endophytes for Rice Disease Management

Uppala, S., Gaire, S., Liu, B., and Zhou, X.G.

Sheath blight (*Rhizoctonia solani* AG1-IA) and narrow brown leaf spot (*Cercospora janseana*) diseases cause significant yield losses to rice production across the world. In this study, we made an attempt to evaluate endophytic bacteria that form symbiotic association with rice plants for their abilities to manage both of these diseases. Endophytic bacteria were isolated from rice plants grown under conventional and organic cultural systems at various locations in Texas and Louisiana. A total of 227 bacterial isolates (173 from Texas and 54 from Louisiana) were isolated from rice roots, leaves and stems at the heading stage and tested them in dual culture for their abilities to suppress *R. solani* and *C. janseana*. Among them, 24 isolates showed clear zones of inhibition at the point of contact of *R. solani* and suppressed its radial growth. These endophytic isolates were further evaluated against *C. janseana.* Six of these isolates suppressed the mycelium growth of C. *janseana*.

Correlation between Leaf and Neck Blast Diseases in Arkansas Commercial Rice

Wamishe, Y., Belmar, S., Kelsey, C., Moldenhauer, K., and Gebremariam, T.

Arkansas grows nearly 50% of the USA rice. Blast caused by the fungus *Magnaporthe oryzae,* is one of the economically important diseases of rice. *M. oryzae* produces airborne spores that infect different parts of young rice plants. Lesions from infected leaves often serve as sources for additional inoculum that may infect leaf collars, nodes and panicles of rice plants. Leaf blast in Arkansas is often managed with adequate flood depth; however, the more destructive type is blast on nodes and panicles and it often requires supplementary chemical protection. Therefore, a fungicide application is used on susceptible varieties to protect the necks and when grown in fields with a history of blast. Hybrid and a few conventional rice varieties have overall field resistance to blast. Field observations and experience with blast epidemics in the last few years have yielded three possible outcomes. The variety is more susceptible to leaf blast than to neck blast such as Jupiter. The variety is susceptible to both leaf and neck blast as in CL151. The variety often shows low leaf blast but severe neck blast similar to Roy J. The objective of this study was to evaluate the characteristic response of a select group of Arkansas conventional rice varieties and determine the correlation of leaf and neck blast. The following four races of *M. oryzae,* common to Arkansas, were tested: IB-1, IB-49, IC-17 and IE-1. Races were individually used to inoculate 3-week-old seedlings in a greenhouse. The experiment was repeated twice in three replications. A mixture of these same races was also used to produce field inoculum using sterilized cracked corn and ryegrass. A disease nursery was established in early May at Pine Tree Research Station (PTRS), University of Arkansas System near Colt, AR. The field test consisted of six replications of test entries planted in hill plots. Spreader rows consisted of very susceptible varieties (M201, M206, Francis, and Fanny) were planted throughout the nursery with the purpose of aiding in the development of a local blast epidemic. Test entries and spreader rows were inoculated by spreading the inoculum twice, in late July and August. Prior to each inoculation, the field was drained to allow the plants to grow under upland conditions. The standard visual rating scale of 0 to 9 was used to rate leaf blast in greenhouse. In the field, the number of panicles with neck blast were counted in proportion to the total number of panicles in a hill plot. The mean values were used for correlation analysis. When the values for all four races of greenhouse tests are combined, the correlation between neck blast and leaf blast was 0.45; while with individual races, the correlation between neck blast and leaf blast were 0.51 with IB-49, 0.46 with IE-1, 0.41 with IB-1 and 0.28 with IC-17. Although this analysis showed some levels of positive correlation between leaf and neck blast, it clearly indicates the inadequacy of associating greenhouse leaf blast data to fully indicate field blast resistance. Knowledge of such characteristic response to the leaf and neck blast in rice varieties is beneficial for breeders in their effort to producing durable resistant lines. Rice producers can also benefit from such information on their integrated disease management approach and decision on fungicide application.

Amistar® Top: A New Fungicide for Use in Rice

Eure, P.M., Hadden, J.F., Black, B.D., Jackson, R.E., and Moore, S.R.

Amistar® Top is a broad-spectrum fungicide registered for use in rice that contains two active ingredients and modes of action - azoxystrobin (FRAC Group 11) and difenoconazole (FRAC Group 3). This combination offers both preventative and curative disease control of many rice diseases. Results from rice trials conducted in the United States demonstrate that Amistar® Top provides excellent control of sheath blight (*Rhizoctonia solani*), aggregate sheath spot (*Rhizoctonia oryzae-sativae*), sheath spot (*Rhizoctonia oryzae*), brown leaf spot (*Cochliobolus miyabeanus*), narrow brown leaf spot (*Cercospora oryzae*), and other foliar diseases. Federal registration of Amistar® Top for use in rice was granted in 2017 with first product available in 2018.

Management of Second Crop Diseases with Fungicides

Groth, D.E.

Disease pressure, primarily caused by Cercospora, has been increasing in the second or ratoon crop grown in Southern Louisiana. Stubble management, including rolling, cutting or flail mowing, can reduce disease development, but these practices are not always possible due to unfavorable environmental conditions at the time of first crop harvest. Fungicides are a possible solution but little data is available on effectiveness, timing or rate for second crop disease control. The objective of these studies was to develop fungicide efficiency data for second crop disease control.

Three studies were conducted in 2016 and 2017 at the LSU AgCenter H. Rouse Caffey Rice Research Station in Crowley, LA. The first was to see what the effect of applying fungicides to the first crop would have on disease control in the second crop. The second tested which fungicides applied to the second crop were effective at controlling diseases. The third determined what the most effective fungicide application timing was for the second crop. Standard agronomic practices were used to manage both the first and second crops. The Cercospora and sheath blight susceptible variety CL111 was used in all experiments. Plots were inoculated with *Rhizoctonia solani* at late tillering in the first crop. Fungicides were applied with a hand-held CO_2 sprayer at boot in the first crop and from 2 to 8 weeks post-harvest in the second crop.

Spraying the first crop increased the number of productive tillers but did not reduce disease in the second crop. Applying a fungicide to the first crop increased second crop yields from 55 to 880 kg ha^{-1}. Fungicides with Cercospora activity, including propiconazole, fluxapyroxad, and difenoconazole, were most effective in controlling disease in the second crop. Timing of second crop fungicide application was critical for disease control with the optimum period centering around 5 weeks after harvest. However, yield increases due to second crop fungicide applications were very low, ranging from 160 to 330 kg ha^{-1}.

Fungicide Sensitivity among the Isolates of *Tilletia barclayana*, Causal Agent of Rice Kernel Smut

Uppala, S, Liu, B, and Zhou, X.G.

Kernel smut, caused by *Tilletia barclayana* (*Neovossia horrida*), has become an economically important fungal disease of rice in Texas in recent years. Isolates of *T. barclayana* were isolated from the infected grain samples and *in vitro* studies were conducted to evaluate the efficacy of foliar and seed treatment fungicides against these fungal isolates and develop baseline sensitivities to these fungicides. Agar media were amended with propiconazole, azoxystrobin, propiconazole + azoxystrobin, trifloxystrobin + propiconazole, fluxapyroxad, mancozeb, mefenoxam, fludioxonil, metalaxyl and metalaxyl+tebuconazole fungicides at various concentrations and evaluated for their sensitivities to the fungus. EC 50 values differed significantly among the isolates and chemicals evaluated. Foliar fungicides containing propiconazole and seed treatment fungicide with mancozeb as active ingredients were highly effective and showed complete inhibition of all the isolates evaluated at low concentrations.

CruiserMaxx® Vibrance® Rice: The Next Generation Insecticide/Fungicide Seed Treatment for Rice

Black, B.D., Martin, S.H., Jackson, R.E., Eure, P.M., and Moore, S.R.

Syngenta is introducing Vibrance® (sedaxane), a new seed treatment fungicide that provides excellent protection against soil borne *Rhizoctonia solani*. Vibrance® is a new SDHI (succinate dehydrogenase inhibitor) fungicide (Mode of Action Group 7) developed by Syngenta and tested in seedling rice for early season protection against soil borne infection from *R. solani* in U.S. rice production.

CruiserMaxx® Vibrance® Rice is a new insecticide/fungicide from Syngenta. CruiserMaxx® Rice is Syngenta's existing broad spectrum fungicide/insecticide premix combining multiple modes of action for broad spectrum early season disease and insect control in rice. Adding Vibrance® to our existing CruiserMaxx® Rice premix provides additional broad spectrum protection against rice seedling diseases. Multiple field studies, inoculated with *R. solani*, were conducted over several years evaluating the addition of Vibrance® at 0.0002 mg ai/seed to CruiserMaxx® Rice. Results from these studies will highlight differences in rice stands, early seedling vigor, and improvements in rice yields, as well as excellent crop safety across multiple varietal and hybrid rice lines. EPA registration approval is pending.

Value of Insecticide Seed Treatments in Arkansas Rice

Bateman, N.R., Lorenz, G.M., Hardke, J., Taillon, N.M., Clayton, T., McPherson, K., Cato, A., Plummer, A., McCullars, L., and Black, J.

Rice water weevil (RWW) is a major pest of rice in Arkansas infesting almost 100% of Arkansas' rice crop annually. RWW adults feed on rice leaves, leaving longitudinal scars. These feeding scars are not known to cause an economic yield loss in rice, however root pruning caused by RWW larvae can have drastic impact on rice yield. In Arkansas, the most common method for controlling RWW is through the use of insecticide seed treatments. Insecticide seed treatments labeled for rice consist of the neonicotinoids clothianidin (NipSit Inside) and thiamethoxam (Cruiser Maxx Rice), as well as the diamide treatment, chlorantraniliprole (Dermacor X-100). These insecticide seed treatments have been observed to be economically beneficial to rice producers by effectively in controlling RRW.

Insecticide seed treatment studies were conducted throughout the rice growing regions of Arkansas from 2008 through 2017. Stand counts, plant heights, RWW counts, and yield were recorded for each study. RWW samples were taken approximately 21 days after the permanent flood was applied to the rice field. Three 10.2 cm cores were taken from each plot and transported to a laboratory located at the Lonoke Research and Extension Center, Lonoke AR. Core samples were then washed with running water over a No. 40 sieve until all soil was removed from the sample. Samples were then placed in warm salt water and RWW larvae were counted. Yield was recorded using a Wintersteiger Classic combine equipped with a Harvest Master system to record yield. All data from 2008 through 2017 were combined and an ANOVA analysis was conducted to determine the benefits of insecticide seed treatments.

Stand counts were significantly increased in plots with insecticide seed treatments compared to the fungicide only treatment. Clothianidin and thiamethoxam had significantly higher plant stands than chlorantraniliprole and fungicide only plots. No significant differences were observed for plant heights. RWW densities were significantly decreased for all insecticide seed treatments compared to the fungicide only treatment. Chlorantraniliprole had significantly less RWW than the neonicotinoid seed treatments. A significant increase in yield was observed for all insecticide seed treatments compared to the fungicide only treatment.

Fortenza®: A New Seed Treatment Insecticide for Mid-South Rice

Black, B.D., Martin, S.H., Jackson, R.E., Eure, P.M., and Moore, S.R.

Syngenta is introducing Fortenza® (cyantraniliprole), a new seed treatment insecticide that provides broad spectrum insect control for use in mid-south U.S. rice production. Cyantraniliprole is a new anthanilic diamide insecticide (Mode of Action Group 28) developed by Syngenta that in combination with CruiserMaxx Rice provides excellent early-season grape colaspis and rice water weevil protection in rice.

CruiserMaxx® Rice is Syngenta's existing broad spectrum fungicide/insecticide premix combining multiple modes of action for broad spectrum early season disease and insect control in rice. Multiple field studies were conducted over several years evaluating the addition of Fortenza® at 0.03 mg ai/seed to CruiserMaxx® Rice for improved insect protection in rice. Results from these field studies will be presented showing the effect of Fortenza® on improving residual control of grape colaspis and rice water weevil as well as excellent crop safety across multiple varietal and hybrid rice lines. EPA registration approval is pending.

Insecticide Seed Treatment Combinations for Control of Grape Colaspis and Rice Water Weevil

Lorenz, G. M., Bateman, N.R., Hardke, J., Taillon, N. M., Clayton, T., McPherson, K., Cato, A., Plummer, A., McCullars, L., Black, J., Frizzell, D., Castaneda, E., Plummer, W., Lee, G. J., Everett, M., and Crocker, A.

Insecticide seed treatments and combinations of insecticide seed treatments were compared for control of grape colaspis and rice water weevil in studies conducted at the University of Arkansas Pine Tree Experiment Station in 2017. Grape colaspis pressure was extremely high immediately after planting. Severe damage and plant stand were impacted in several plots depending on the seed treatment used. The neonicotinoids (thiamethoxam and clothianadin) provided a superior level of control compared to the diamide treatments. Due to slow growth, plots did not receive the permanent flood until 60-70 days after planting. Subsequently, the rice water weevil population was high and we observed that the neonicotinoid only seed treatments lost control due to the delayed flood timing. The diamide treatments (chlorantraniloprole and cyantraniliprole) provided protection against rice water weevil. Combinations of insecticide seed treatments with a neonicotinoid and either of the diamides provided season long control of both pests. As a result, higher yields were observed for the combination treatments compared to any of the single product insecticide seed treatments. This would indicate that insecticide seed treatment combinations may be an option for growers in areas where both pests are commonly a problem.

Effect of Planting Date on Efficacy of Insecticide Seed Treatments in Rice

McPherson, J.K., Lorenz, G.M., Hardke, J.,Bateman, N.R., Taillon, N.M., Plummer, W.A., Clayton, T.L., Cato, A.J., Black, J.L., and McCullars, L.D.

A study was conducted from 2015-2017 to evaluate the effect of planting date on insect control and yield on current insecticide seed treatments. Planting dates ranged from late-March to mid-June. Grape colaspis and rice water weevil populations were observed throughout the 2015 - 2017 growing seasons. Grape colaspis was present in low levels during 2015 and 2017. In 2015, CruiserMaxx Rice and NipsIt INSIDE controlled grape colaspis while Dermacor X-100 did not. In 2015 and 2016, CruiserMaxx Rice, NipsIt INSIDE, and Dermacor X-100 all reduced rice water weevil numbers compared to the untreated check. In 2017, rainfall delayed fertilizer application and flood timing resulting in the loss of residual control of CruiserMaxx Rice. Subsequently, Dermacor X-100 had fewer rice water weevils than the untreated check while CruiserMaxx rice did not. Treatments provided significant yield increases compared to the untreated control in all years when planted in the March 22-April 21 timeframe.

Insecticidal Seed Treatments vs Seeding Rates

Way, M.O., Pearson, R.A., and Curtice, C.M.

The majority of Texas rice farmers apply an insecticide to their seed rice. They can apply CruiserMaxx Rice (active ingredient thiamethoxam), Dermacor X-100 (active ingredient rynaxypyr) or NipsIt INSIDE (active ingredient clothianidin). Each seed treatment controls a given array of pests but all three target the rice water weevil (RWW), *Lissorhoptrus oryzophilus*, which is the key pest of rice in Texas. CruiserMaxx Rice and NipsIt INSIDE are applied at a given rate per 100 kg seed, regardless of seeding rate. But, Dermacor X-100 is applied at higher rates as seeding rate decreases. Thus, the amount of Dermacor X-100 applied on a per seed basis increases as seeding rate decreases. On the other hand, the amount of CruiserMaxx Rice and NipsIt INSIDE applied on a per seed basis decreases as seeding rate decreases. We hypothesize that the recommended rates of CruiserMaxx Rice and NipsIt INSIDE may provide less control of RWW as seeding rate decreases.

We selected three seeding rates, 22, 56, and 90 kg/ha, which represent typical seeding rates for hybrid, CLEARFIELD/conventional and conventional varieties, respectively. We utilized Presidio for the 22 and 56 kg/ha seeding rates and CLXL745 for the 22 kg/ha seeding rate. Seed treatment rates for CruiserMaxx Rice and NipsIt INSIDE were (1.) Recommended, (2.) High and (3.) Untreated. The High rates of CruiserMaxx Rice and NipsIt INSIDE for 22 and 56 kg/ha seeding rates were equivalent to the amounts applied to seed planted at the 90 kg/ha seeding rate. So, for High rates of CruiserMaxx Rice and NipsIt INSIDE, the amount of active ingredient applied on a per ha basis was the same, regardless of seeding rate.

Experimental treatments were replicated four times in small (6 m x 1.2 m) experimental plots at the Texas A&M AgriLife Research and Extension Center in 2017. RWW and stem borers were sampled using standard procedures. Yields of both main and ratoon crops were recorded.

Basically, recommended rates of both CruiserMaxx Rice and NipsIt INSIDE did not provide as effective control as High rates, but yields were not significantly different between Recommended and High rates.

Potential Exposure of Honey Bees to Neonicotinoid Insecticides in Rice

Taillon, N., Lorenz, G.M., Hardke, J., Bateman, N., Clayton, T., Frizzell, D., Cato, A., Black, J., Plummer, W.A., and McPherson, K.

Pollinator health has been a very important issue in recent years. There is great concern about colony collapse disorder and potential causes; particularly, the neonicotinoid class of insecticides. However, rice producers in the mid-South rely on neonicotinoids for control of grape colaspis and rice water weevil as they are superior to alternative methods such pyrethroids or cultural controls. Neonicotinoid insecticide seed treatments also provide an increase in yield an average of 403.5 kg/ha (8 bu/acre). The purpose of this study was to find if neonicotinoids persist in the rice plant through flowering; and to see how often bees actually occur in flowering rice.

Insecticide seed treatments and foliar clothianidin applications were evaluated 2015-2017 for expression in the flag leaf and floral parts of rice, as well as grain in 2016 and 2017. Data analysis of samples indicated that insecticide seed treatments applied at planting and foliar applications made at pre-flood and post-flood were expressed at very low levels or were non-existent when samples were taken. Also, observations of bees visiting rice indicated extremely low levels of honey bees in rice fields. Although neonicotinoid insecticide seed treatments have been under fire recently for impact on honey bees, these and other studies continue to show concerns are largely unfounded and focus should be placed on the real issues impacting pollinators.

Revision of the Economic Threshold for Rice Stink Bug in Louisiana

Wilson, B.E., Stout, M.J., and Kraus, E.

The rice stink bug, *Oebalus pugnax*, is the primary pest of headed rice across the Midsouth. Stink bug infestations reduce revenue through quantity losses from blanked grains, as well as reductions in rice quality. Quality reductions are the result of rice peck, brown spots where a fungal pathogen infects rice grain which has been injured by stink bugs. The rice stink bug is managed primarily with pyrethroid applications triggered by sweep-net sampling. In Louisiana, the recommendation is that an insecticide application be triggered if there are >3 stink bugs per 10 sweeps during the first two weeks of heading and 10 stink bug per 10 sweeps thereafter. However, this threshold doesn't consider the complex yield loss relationship that includes both quantity and quality reductions. A field study was conducted at the H. Rouse Caffey Rice Research Station in Crowley, LA, in 2016 to investigate the relationship between rice stink bug sweep-net captures and rice yields and quality.

Pyrethroid applications were used to establish plots with varying levels of stink bug infestations. Stink bug populations were monitored weekly with sweep nets to from 25 July 2016 to 18 Aug 2016, and the numbers of empty grains, broken grains, and pecky grains were recorded from 15 panicles per plot at harvest. Linear regression analysis was used to determine the relationship between stink bug sweep-net counts to reductions in rice quantity (percent empty grains) and quality (percent damaged/pecky grains). An increase of one stink bug per 10 sweeps is associated with a 0.3% reduction in yield (quantitative loss) and a 0.3% increase in pecky rice (qualitative loss). Based solely on quantitative losses, the infestation level currently used to trigger an insecticide application (3 stink bugs/10 sweeps) would result in a revenue loss of only $4 (USD) per hectare. However, this level is appropriate to maintain a percentage peck below the 4% required to be considered U.S. rough rice grade #4.

Ongoing analyses are being conducted to better determine the impacts of quality reductions on farm revenue. Additional analyses aim to determine the impact of infestation timing on quality reductions. This work is anticipated to be developed into a refined economic threshold for control of the rice stink bug in Midsouth rice.

Effect of Planting Time after Flooding on Tadpole Shrimp Injury to Rice in California

Espino, L.

Tadpole shrimp (TPS) is a significant problem in California during the initial seedling stages after rice seeding. When fields are flooded, TPS develop quickly and can injure germinating seeds by consuming the coleoptile, the radicle, roots or shoots, or by dislodging seedlings while digging in the mud. Additionally, their digging causes muddy water, which reduces light penetration and slows down the growth or seedlings while they are underwater. Management of TPS relies heavily on pyrethroid insecticides. Currently, around 40,468 ha (100,000 acres) are treated early in the spring targeting TPS. Growers are advised to seed soon after flooding to avoid large TPS that can injure seedlings. Seedlings are thought to be susceptible to injury until they emerge through the water and are well established.

Tadpole shrimp are a challenging pest to manage. They grow quickly after seeding and can cause injury before growers or consultants are aware of their presence. Monitoring is difficult due to their cryptic color and their initial small size. Because of this, no thresholds have been developed. If left untreated or treated too late, they may lay eggs in the soil that can accumulate and result in formation of an egg-bank. The current study was conducted to develop information that can be used to improve monitoring, identify seedling stages that can escape injury, and document stand and yield losses due to TPS.

Several seeding times after field flooding were tested using a split plot design, replicated four times. Main plots consisted in copper sulfate treated and untreated large (5x21 m) basins. Basins were flooded on 8 June 2017. Within each basin, smaller (5x3 m) plots were seeded before flood, day of flood, 1, 2, 3, 4 or 5 days after flood (DAF). TPS density was determined by imposing a 0.07 m^2 PVC ring on the basins and removing TPS within the ring in three scoops of an aquarium net. On each large basin, TPS density and shell length were evaluated for 3 weeks; rice seedling stage in each of the plots was evaluated daily for 2 weeks; stand in each plot was determined 3 weeks after seeding. Yields were obtained using a small plot combine. The experiment was conducted at the Rice Experiment Station in Biggs. All rice management practices were typical for California.

Tadpole shrimp were fist visible 4 days after flood, with an average shell length of 2.2 mm. Initial density was approximately 322 TPS/m^2, but it declined to around 109/m^2 one week after the flood and remained at that level until 20 days after flood. Stand was significantly reduced by TPS when seeding 3 DAF or later. Stand reduction ranged from 31 to 94% when seeding 3 or 5 DAF, respectively. No stand reduction was observed when seeding 2 DAF or earlier. Yields were significantly reduced by TPS only when seeding occurred 4 or 5 DAF. On average, yield was reduced 64%.

The results indicate that seeding before the flood, day of flood, or up to 2 DAF results in seedlings that can escape TPS injury. Data indicates that 2 mm TPS were not able to injure germinating rice seedlings. When TPS shell length reached 4 mm, seedlings that had both coleoptile and radicle escaped injury. When TPS shell length reached 6 mm, seedlings that had a green prophyll escaped injury.

Abstracts of Posters on Plant Protection
Panel Chair: Luis Espino

Hybrid Rice Outperforms Inbred Rice in Resistance against Sheath Blight and Narrow Brown Leaf Spot

Zhou, X.G., Tabien, R.E., Yan, Z., and Wilson, L.T.

Cultivar resistance can be the most effective method to manage sheath blight caused by *Rhizoctonia solani* and narrow brown leaf spot (NBLS) caused by *Cercospora janseana* in rice. The degrees of resistance to either disease in hybrid rice cultivars may be different from those of resistance in inbred cultivars. The objective of this study was to compare differences in resistance against both diseases between inbred and hybrid rice.

A disease nursery was established in Beaumont and Eagle Lake, TX, in 2016 and 2017. This disease nursery had 114 entries that consisted of 49 elite inbred lines from the Texas Rice Inbred Breeding Program, 37 elite hybrid lines from the Texas Hybrid Breeding Program, and 28 promising inbreds and hybrids from Arkansas, Louisiana, Mississippi, and Texas. These entries were arranged in a randomized complete block design with three replications. Each plot was 2.7 m long by 1.2 m wide and was divided into three equal-length sections for disease inoculation. One-third of each plot was inoculated with the sheath blight pathogen. The middle section was kept as a barrier between the two end sections. The final third was left for natural infection of NBLS. Severities of both diseases were rated on a scale of 0 to 9, where 0 represents no symptoms, and 9 represents most severe in symptoms and damage (leaves dead or plants collapsed) at maturity of cultivars.

Sheath blight developed well late in the cropping season in both locations. None of the entries expressed a high level of resistance to sheath blight. Most genotypes were rated susceptible or very susceptible to sheath blight. However, CL272, Rondo, Roy J, Taggart, Wells, RU1303116, RU1603144, the hybrids XL753, XP760, and all but the hybrid line TH555 showed partial resistance to sheath blight, with an averaged disease rating of 4.7. For comparison, all but one hybrid lines showed a higher level of resistance to sheath blight than all elite inbred lines that were evaluated (4.2 vs. 5.7 on average). NBLS severity was considered moderate at both sites. A majority of cultivars and elite lines were highly resistant to NBLS, with no or little (3.0 or less in rating) development of the disease. No symptoms of the disease were observed on CL163, CL272, Rex, Rondo, Joy J, Taggart, Titan, Wells, XL753, RU1303138, RU1303153, RU1303153, RU1503095, RU1503147, RU1603116, RU1603178, and all the hybrid lines. The average rating of NBLS across the sites was 0.1 and 2.7 for the hybrid lines and inbred lines, respectively. The results demonstrate that hybrid cultivars and lines are generally less susceptible to sheath blight and have a higher level of resistance against NBLS than inbred cultivars and lines.

Development of Novel Chemical Compounds for Control of Kernel Smut of Rice

Guo, Z.F., Zhou, X.G., Liu, B.H., and Lei, X.Y.

Fungicides can be an important tool to manage kernel smut caused by *Tilletia barclayana,* a reemerging disease that threatens rice production in Texas and other rice-producing states. However, currently available fungicides are not very effective for control of this disease based on the results of recent field studies. The ultimate goal of this study was to develop new chemistries that would have a different mode of action and a wide spectrum of fungicide activities against *T. barclayana* and other fungal pathogens in rice. Toward this goal, we have designed and synthesized chemical compounds having a potential of systemic mode of action. Their chemical structures were further confirmed by Nuclear Magnetic Resonance (NMR) and High Resolution Mass Spectrometry (HRMS). An in vitro study was initialized to screen these chemical compounds for the inhibition of the growth of *T. barclayana* on potato dextrose agar (PDA). Freshly prepared inoculum suspension of *T. barclayana* was inoculated onto the PDA plates amended with each of the chemical compounds at different concentrations. The propiconazole fungicide (Tilt) served as the positive control. Inhibition of the growth of the fungus was measured at 5 days after incubation at 25ºC. Among 28 compounds evaluated, 11 produced antifungal activities similar to or even stronger than propiconazole. Compound

106D had a significantly higher level of inhibition than propiconazole (0.33 mg/L *vs*. 4.79 mg/Lin EC_{50}). These results demonstrate that compound 106D can be a promising candidate fungicide for further investigation.

Bacterial Endophytes as a Potential for Control of Seedling Disease Caused by *Rhizoctonia solani* AG-11

Gaire, S.P., Uppala, S., Jo, Y.K., and Zhou, X.G.

Rhizoctonia solani AG-11 is a soil borne fungal pathogen causing seedling blight in rice. In this study, we screened eight bacterial endophytes for the suppression of mycelium growth of *R. solani* AG-11in dual cultures and for disease reduction in seedlings of the rice variety Presidio in greenhouse. In the dual culture evaluations, all isolates showed significant inhibition of mycelial growth of *R. solani*, with three isolates having the greatest inhibition zone. The mycelial growth inhibition rate of the fungus ranged from 37 to 52%.The highest inhibition was observed for Isolate 40 (52%) followed by Isolate 60 (44%) and Isolate 1 (39%). These three bacterial isolates were further applied onto seeds as a seed treatment and treated seeds were planted in *R. solani*-infected potting mix. A significant improvement in seed emergence and seedling survival (28 to 38%) was achieved with the endophytic bacterial seed treatments. Shoot length and root length of the treated plants were also significantly increased. Results demonstrate the potential use of the endophytic bacteria for management of rice seedling disease.

Evaluation of Rice Seed Treatments in Delayed Flood Rice Culture

Bell, L., McCoy, J., Mansour, J., and Golden, B.R.

Seed treatments have become a standard agricultural input in most Mississippi row crops with their use in Rice (Oryza sativa L.) cultivation no exception. Seed treatments have been shown to provide significant economic benefits, providing protection of the crop from early season insect and disease pressure. As new treatment packages are brought to market, it is necessary for the producer to be knowledgeable on how these treatments will perform in the field. The objective of this research was to evaluate the efficacy to early season disease pressure of current and new seed treatments for use in rice production in Mississippi.

Experiments were conducted in 2016 and 2017 at the Delta Research and Extension Center, in Stoneville, MS, to evaluate seed treatments influence on plant vigor and grain yield. Treatments evaluated were thiamthoxam (Cruiser), azoxystrobin, fludioxonil, metalaxyl-m, thiamethoxam (CruiserMaxx Rice), azoxystrobin, fludioxonil, metalaxyl-m, sedaxane, thiamethoxam (CruiserMaxx Vibrance Rice), metalaxyl, fludioxonil, clothianidin (Nipsit), and metalaxyl-m, fludioxonil, chlorantriniliprole (Dermacor). Treatments were arranged as a randomized complete block design in both years of testing. Each plot was inoculated with Rhizoctonia Solani in the drill row at planting to encourage early season rice disease pressure. Plots were then managed according to MSU Extension recommendations to ensure highly productive environments and minimize variability except for that of seed treatment. At 14 and 28 days after rice emergence (DAE), plant stand, vigor and plant height was assessed. At maturity a small plot combine was utilized to harvest each plot and collect rough rice yield. Prior to analysis rough rice yield was adjusted to 12% uniform moisture. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

Rice plant stand was influenced by seed treatment in each siteyear. For both siteyears at 14 and 28 DAE CruiserMaxx Rice and CruiserMaxx Vibrance Rice were observed to exhibit similar and the greatest number of plants m^{-1} when compared to other treatments or untreated seed. During 2017, Cruiser and Dermacor produced decreases in plant height when compared to all other treatments, while no differences were observed in plant height among any treatment in 2016. Rice vigor 14 DAE was similar across all seed treatments evaluated during 2017.

Seed treatment significantly impacted rice grain yield at each siteyear. Thiamthoxam (Cruiser), which does not contain a fungicide treatment, exhibited significantly less grain yield than all other seed treatments evaluated in both siteyears. All seed treatments containing a fungicide treatment package (CruiserMaxx Rice, Cruiser Maxx Vibrance Rice, Nipsit, and Dermacor) were observed to perform similarly with respect to mean rice grain yield. Overall, observations from these trials suggest that seed treatments containing an insecticide + fungicide treatment are beneficial to the plant when exposed to Rhizoctonia Solani.

Effects of Dermacor-X-100® Seed Treatment Rates on Rice Insect Pests of Drill-Seeded Rice

Villegas, J.M. and Stout, M.J.

Rice water weevil and stem borers are important rice pests in Louisiana. These pests can cause severe yield losses if not managed appropriately. This experiment was conducted to investigate the efficacy of various rates of chlorantraniliprole seed treatments using Dermacor-X-100® on rice water weevil and sugarcane borer. Field experiments were established in Louisiana using different rates of Dermacor-X-100® (control, 0.25X, 0.5X, 0.75X, 1X and 2X, where X is the standard label rate) in 2016 and 2017. Densities of immature rice water weevil (larvae and pupae) were determined using a metal soil-root core sampler. For sugarcane borer mortality assay, rice stems were collected during vegetative and reproductive stages of rice plants and stems were placed individually in petri dishes. Five sugarcane borer neonates were placed on each stem and left to feed for 72 hours and mortality rate was calculated. Chlorantraniliprole concentrations were also determined for each plant sample. Chlorantraniliprole seed treatment significantly reduced the number of rice water weevil larvae in 2016 and 2017. Weevil larval densities were consistently lower on plots planted with seeds treated with chlorantraniliprole compared to plots with untreated seeds. Furthermore, chlorantraniliprole seed treatment significantly increased sugarcane borer mortality in 2016 and 2017. Sugarcane borer mortalities were generally higher in plants treated with chlorantraniliprole compared to untreated plants in both years. Mortalities were consistently higher on sugarcane borers that were left to feed on stems from plants at the late-tillering stage (vegetative) compared to early-heading stage (reproductive). In 2016, mortalities of sugarcane borer on late-tillering plants ranged from 2.8-75% depending on seed treatment rate, whereas mortalities on early-heading plants ranged from 0-35%. In 2017, mortalities on late-tillering plants ranged from 8.3-73% depending on seed treatment rate, while mortalities on early-heading plants ranged from 11.7-35%.

Effect of Rice Stink Bug, *Oebalus pugnax*, on Yield and Quality in Rice

Clayton, T.L., Lorenz, G.M., Hardke, J.T., Bateman, N.R., Cato, A.J., McPherson, J.K., Taillon, N.M., McCullars, L.D., Frizzell, D.L., Casteneda-Gonzalez, E., Lee, G.J., Plummer, W.J., Plummer, W.A., and Black, J.L.

The rice stink bug, *Oebalus pugnax*, is an economic pest of rice that feeds on developing rice kernels. When feeding occurs during flowering and milk stages, kernels can become shrunken or blank leading to economic yield loss. When feeding occurs during the soft and hard dough stages, an area of chalky discoloration often occurs at the feeding site. This discoloration is known as 'pecky' rice. The rice inspection handbook allows for no more than 0.5% damaged grain in a 500g sample to be considered U.S. grade 1 rice. Grade reductions due to increased amounts of damaged kernels can lead to losses to the value of the harvested grain, with drastic economic impacts occurring at grade 3 rice or 2.5% peck.

The objective of this study was to determine the amount of damage that increasing densities of rice stink bug (RSB) can cause to the different developmental stages of rice. Mesh field cages, 1.8 m by 1.8 m, were used to establish rice plots. Rice stink bug were infested at the flowering, milk, soft dough, and hard dough kernel development stages. Densities of 0, 17, 34, and 68 RSB per 10 sweeps were used for infestation levels. The first infestation timing was initiated at the flowering and milk stage. The cages were infested when the plot reached 50% flowering. A sequential infestation of RSB was made 7 days after the initial application to encompass the milk stage. Infestations were terminated 7 days after the second infestation. This same method was used for the soft and hard dough timing. The metrics used to measure damage were yield, percent whole kernel milled rice, percent total milled rice yield, brown rice damage, and blank kernel.

A trend of decreasing yield with increasing RSB populations was observed in the bloom and milk infestation timing, but there was no significant difference. No yield trend was observed for the soft and hard dough infestation timing. No interaction was observed for infestation timing by infestation density for total damage on brown rice. Differences were observed for total damage on brown rice, with the 68 RSB per 10 sweeps infestation level having higher total damage than the 0 and 42 RSB per 10 sweeps infestation levels. The soft and hard dough timing had higher total damage on brown rice than the bloom and milk timing. No interaction was observed for infestation timing by infestation level for RSB damage. The 68 RSB per 10 sweeps infestation level had more RSB damage on brown rice than the 0, 42, and 84 RSB per 10 sweeps infestation levels. The 84 RSB per 10 sweeps infestation level had more RSB damage than the 0 RSB per 10 sweeps infestation level. The soft and hard dough infestation timing had higher RSB damage on brown rice than the bloom and milk infestation timing. No differences were observed for percent total rice or percent head rice. There was no increase for blank kernels observed for infestation timing or infestation level.

Diversity and Population Dynamics of the Florida Rice Stink Bug Complex in Crop and Non-Crop Hosts

VanWeelden, M.T. and Cherry, R.

The rice stink bug complex in Florida is the most diverse in United States rice production. As of 2017, this complex includes the common rice stink bug, *Oebalus pugnax* (F.) and two invasive species, *O. ypsilongriseus* (DeGeer) and *O. insularis* (Stal). In 2017, a study was conducted to determine the abundance and population dynamics of the three stink bug species in rice agroecosystems. Sweep net sampling was conducted in susceptible rice fields in July, September, and October to determine abundance of each stink bug species. In addition, sampling was conducted in graminaceous, non-crop hosts adjacent to rice fields to determine population fluctuations within commercial rice production.

Comparing Rice Stink Bug Sampling Methods: University vs Consultants

Way, M.O., Pearson, R.A., Curtice, C.M., and Crane, G.L.

The rice stink bug (RSB), *Oebalus pugnax*, is a key pest of rice in the South. We developed economic thresholds for this pest of grain based on sweep net sampling. However, our sampling method now differs from sweep sampling employed by Texas rice crop consultants, primarily due to the continuing adoption in Texas and the South of very high yielding varieties (i.e. hybrids). Our sweep net sampling is based on 10 consecutive sweeps (1 sweep per step with no interruption between sweeps) of a 38 cm diameter net attached to a 91 cm handle passed through the heads of the rice so that the top of the net coincides with the top of the panicles. Each sweep encompasses a 180 degree arc. Because of denser canopies associated with high yielding varieties, it is physically very difficult to take 10 consecutive sweeps without tripping or falling which clearly affects the number of RSBs collected. In dense canopy fields, we have observed RSBs flying away from areas to be sampled due to the disturbances caused by operators trying to take consecutive sweeps without interruption. Thus, most crop consultants now take 1 sweep, walk 3 paces and take another until 10 sweeps have been taken. In between sweeps, they pinch the net or dip the net in the flood water to prevent escape of the RSBs They cover more distance than when employing our method, but the area sampled by the sweep net is approximately equal.

In 2017, we compared our sampling method (A&M) to that of the crop consultants' (CC) in an array of Texas commercial rice fields planted to various varieties in heading to dough stages of maturation. Fields on both sides of Houston were sampled. Two operators were employed; 1 performing A&M and the other performing CC sampling methodology. Operators were opposite one another but separated by at least 9m to avoid interference with the RSBs in each sampling transect. Sampling methods were performed simultaneously. Fifty-four comparison samples were performed counting both nymphs and adults. Preliminary evaluations indicate CC sampling collected more RSB nymphs and adults than A&M sampling, particularly when populations were relatively high.

Rice Stem Borers (Lepidoptera: Crambidae) in the Everglades Agricultural Area of Florida

Beuzelin, J., VanWeelden, M., Roldán Salazar, E., Karounos, M., and Cherry, R.

Three stem borer species, the sugarcane borer (*Diatraea saccharalis*), rice stalk borer (*Chilo plejadellus*), and Mexican rice borer (*Eoreuma loftini*) infest rice produced in the U.S. Gulf Coast Region. These three stem borer species occur in Florida and could threaten rice production in the Everglades Agricultural Area (EAA). *D. saccharalis* infests sugarcane in the EAA and *C. plejadellus* is thought to occur in the EAA. *E. loftini* is a newly detected invasive species in Florida that is a severe pest of rice in Louisiana and Texas. However, this invasive species is not thought to have become established in the EAA. Thus, a project initiated in 2017 aimed to address the threat of stem borers in rice of the EAA to ensure management actions can be implemented if necessary.

Thirty commercial rice fields were selected throughout the EAA to represent a geographically diverse sample during the 2017 growing season. One *E. loftini* pheromone trap was placed near the edge of each field in late May. Pheromone traps were monitored every two weeks until late August for the presence of *E. loftini* adults. No *E. loftini* adults were collected, suggesting that the invasive species has not become established in rice fields of the EAA.

When each field was between the milk and early maturation stage, between June 8 and September 19, sampling was conducted to determine levels of stem borer injury and infestation. Ten locations were selected approximately 50 m apart along the edge of each field, approximately 20 m from the edge. At each location, all plants within three 1-m^2 quadrats were observed. Plants injured by stem borers were observed in eleven fields. The number of plants exhibiting stem borer injury averaged 0.024/m^2 (i.e., 99 injured tillers/acre). Stem borer infestation levels averaged 0.008/m^2 (i.e., 33 borers/acre), with only *D. saccharalis* being observed. Seven *D. saccharalis* immatures collected from plants in the quadrats, as well as two *D. saccharalis* immatures collected outside sampling locations, were reared in the laboratory until adult eclosion, parasitoid emergence, or death. The solitary parasitoid *Alabagrus stigma* parasitized 33% of those *D. saccharalis* immatures.

These results suggest that rice is a source of *D. saccharalis* populations in the EAA, but also a source of parasitoids. However, the areawide contribution of rice to *D. saccharalis* pest and beneficial populations is likely minor.

The Roles of Arbuscular Mycorrhizal Fungi in Trophic Interactions between Rice and Herbivores

Bernaola, L. and Stout, M.

Arbuscular mycorrhizal fungi (AMF) are fungal endophytes that form a mutualistic associations with the roots of many terrestrial plants. AMF provide plants with nutrients in exchange for carbon. While AMF usually have strong, positive influences on plant growth, their role in plant defense is more varied. Associations with AMF have been shown to both increase or decrease resistance to herbivory in different crop systems. Understanding the roles of arbuscular in plant-insect interactions is essential for optimizing their use in pest management programs. This study investigated whether the effects of AMF can stimulate rice yields and/or tolerance to rice water weevil (RWW, *Lissorhoptrus oryzophilus*) injury. In particular, we hypothesize that rice growth and yield losses from RWWs would be smaller in the presence of AMF. Four seed treatments (untreated control, Nipsit inside, AMF, and Nipsit + AMF) with 10 replications each were used in field experiments over two years. Nipsit inside is a neonicotinoid seed treatment. Our results showed that mycorrhizal treatments did not reduce population densities of RWW relative to untreated control. Insecticidal seed treatment and the combination of insecticidal seed treatment and mycorrhizae significantly reduced weevil densities. AMF benefited rice biomass and a clear but non-significant increase in yield was observed. In all experiments, mycorrhizal seed treatments showed the highest AMF colonization. In conclusion, AMF mediate plant interaction by influencing plant biomass, and rice inoculated with Nipsit + AMF may provide an effective method for weevil control and for increasing rice yields.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Kassim Al-Khatib

Efficacy of a Rinskor™ Active Plus Cyhalofop-butyl Premix in U.S. Mid-South Rice

Perry, D.H., Ellis, J.M., Lovelace, M.L., Morell, M., and Walton, L.C.

Rinskor™ active is a new herbicide by Dow AgroSciences for broad-spectrum weed control in a variety of crops. Rinskor belongs to the new arylpicolinate synthetic auxin class of herbicides that is characterized by low use rates and extremely low volatility. Loyant™ herbicide with Rinskor active is registered in the U.S. for control of key weeds in Mid-South rice including, but not limited to, barnyardgrass (*Echinochloa crus-galli*), broadleaf signalgrass (*Urochloa platyphylla*), rice flatsedge (*Cyperus iria*), yellow nutsedge (*C. esculentus*), Palmer amaranth (*Amaranthus palmeri*), and hemp sesbania (*Sesbania herbacea*). Cyhalofop-butyl is a graminicide commonly used in rice production for controlling *Echinochloa* spp. and *Leptochloa* spp., among other grass species. Dow AgroSciences is currently characterizing an experimental pre-mixture (GF-3479) containing Rinskor active and cyhalofop-butyl for use in U.S. rice. GF-3479 is formulated as an EC with 160 and 12 g ai L^{-1} of cyhalofop-butyl and Rinskor, respectively.

In the summer of 2017, seven studies were conducted across 4 states evaluating efficacy and tolerance of GF-3479. Treatments included 6 herbicide treatments (Loyant applied at 30 g ai ha^{-1}, Clincher SF® (cyhalofop-butyl) applied at 313 g ai ha^{-1}, Loyant at 30 g ai ha^{-1} + Clincher SF at 313 g ai ha^{-1}, Loyant at 25 g ai ha^{-1} + Clincher SF at 333 g ai ha^{-1}, GF-3479 (Rinskor + cyhalofop-butyl, applied at 358 g ai ha^{-1} and RebelEX (214 and 30 g ai L^{-1} of cyhalofop-butyl and penoxsulam, respectively) applied at 357 g ai ha^{-1}) by 2 application timings (3-5 days preflood and 7-10 days postflood) and an untreated check. Treatments were applied utilizing standard small-plot methods and equipment at each location. Each study was arranged in a randomized complete block design with 4 replications. Since treatments were applied either mid- or late-postemergence, trials received a pre-emergence broadcast application of clomazone with rate based on soil type to reduce initial weed pressure. Weed spectrum and rice variety differed among locations.

Barnyardgrass (BYG) control was similar across four locations. Loyant alone and Loyant + Clincher at the high rate 3-5 days preflood provided 95% BYG control 4-5 weeks after application (WAA). All other preflood treatments provided 89 to 91% BYG control 4-5 WAA. All postflood treatments provided 85 to 89% BYG control 4-5 WAA. Rinskor-containing preflood treatments controlled all broadleaves (*Aeschynomene* spp., *Amaranthus palmeri, Commelina diffusa, Ipomoea lacunosa* and *Sesbania herbacea*) > 98% 4-5 WAA. All Rinskor-containing postflood treatments provided 93 to 96% control 4-5 WAA. At 2 locations, all treatments containing 30 g ai ha^{-1} Rinskor, provided 100% rice flatsedge control, while all treatments containing 25 g ai ha^{-1} Rinskor controlled rice flatsedge 95-96%. Rice exhibited excellent tolerance to all treatments. All treatments caused <1% rice injury 2 and 4 to 5 WAA.

Rinskor at 25 to 30 g ai/ha in combinations with cyhalofop-butyl provided excellent broad-spectrum weed control in preflood and postflood application timings. The cyhalofop-butyl component of GF-3479 is intended to broaden the grass spectrum control and increase the speed of control on key grasses, while maintaining the excellent broadleaf and sedge control. The majority of the grass weeds present in this study were controlled by Rinskor alone, therefore, the full grass control capability of GF-3479 was not realized. Further GF-3479 characterization studies are warranted to demonstrate the robustness of this new herbicide premixture.

Gambit® Herbicide for Sedge and Broadleaf Weed Control in Mid-South Rice

Sandoski, C.A., and Strano, S.D.

Gambit® herbicide was developed by Gowan USA for use on rice in the Mid-South USA and was registered in late 2017. The product is a 79% DG formulation consisting of halosulfuron (50%) and prosulfuron (29%). Use rate for the product is 55 - 110 g ai/ha. Application timing for the product ranges from pre-plant to post-flood. The weed spectrum for Gambit includes all sedges and broadleaf weeds commonly encountered in Mid-South rice.

Butte®-Based Herbicide Programs in California Water-Seeded Rice

Godar, A.S., Brim-DeForest, W.B. and Al-Khatib, K.

Butte® herbicide, a co-formulated granular mixture of 3% benzobicyclon + 0.64% halosulfuron-methyl developed by Gowan Company, is a recently-introduced into-the-water applied herbicide for use in California water-seeded rice. The former component of Butte® is a new mode of action (HPPD-inhibitor) to the herbicides in California rice. Given the proliferation of herbicide-resistant weeds in California rice, the addition of a new mode of action will assist in resistance management. During the 2016 and 2017 rice growing seasons, Butte®-based programs were tested under a continuous flood system (10 cm water depth). All experiments were conducted in the field under controlled conditions at the California Rice Experiment Station, in Biggs, CA. Treatments consisted of Butte® applied alone at seeding or 1 leaf stage of rice (lsr) or in a program with several follow-up POST herbicides applied at 1 tiller stage of rice. Evaluations were made for crop tolerance and yield, and control of common California rice weeds. Application of Butte® (at 250 + 52.2 or 303 + 63 g ai/ha, benzobicyclon and halosulfuron-methyl, respectively) caused minimal crop injury (stand reduction and stunting) and provided complete control of ricefield bulrush (*Schoenoplectus mucronatus* L.) Palla) and smallflower umbrella sedge (*Cyperus diformis* L.) regardless of the rate and application timing. Late watergrass (*Echinochloa oryzicola* (Vasinger) Vasinger) control with the Butte® alone applications was also good (85-88% control). A follow-up application of cyhalofop-butyl (280 g ai/ha + 2.5% v/v COC), bispyribac-soduim (37 g ai/ha + 2.0% v/v UAN + 0.2% v/v NIS), propanil + triclopyr (6726 + 58 g ai/ha + 1.25% v/v COC) or penoxsulam (40 g ai/ha + 2.25% v/v COC) following Butte® applied at 1 lsr improved late watergrass control and resulted in excellent control of all the weed species evaluated. Butte® followed by POST-applied herbicide combinations caused no or little crop injury and provided higher crop yield (10.6 t/ha) compared to Butte® alone applications (9.4 t/ha). This research shows that Butte® herbicide offers excellent crop safety and has a great potential to control several important weeds in California water-seeded rice. The choice of an appropriate follow-up application may largely depend on the weed population pressure and/or resistance status of the weeds in the field.

Field Performance of an Indica x Tropical Japonica Rice Mapping Population under AWD Stress

Gealy, D.R. and Rohila, J.S

Alternating-wetting-drying (AWD) is an emerging rice irrigation management system that has the potential ability to reduce both irrigation water use and emissions of the greenhouse gas, methane. Based on preliminary experiments, 15 (F10) recombinant inbred lines (RILs) showing diversity for root and shoot traits were selected for this study from a mapping population of ~330 RILs that was derived from a high-tillering, weed-suppressive indica (PI 312777) x a low-tillering, non-suppressive southern long grain tropical japonica (Katy). The selected RILs were evaluated in the field for their potential tolerance to ‘severe’ AWD stress conditions, with the goal of identifying RILs with AWD tolerance. The experiment was a split plot design with four replications. The main plots were conventionally flooded (FLD) or AWD irrigation, and subplots were the 15 diverse RILs and the parents. Seeds were planted 2 cm-deep in Dewitt silt loam soil in plots 4-m-long with 6, 18-cm-wide rows on May 9, 2017 near Stuttgart, AR. Weeds were controlled in all plots using commercially-available herbicides. All genotypes emerged on May 23rd. Plots were fertilized with 110 kg/ha N as urea and flooded on June 20th. After permanent flood had been established in all plots, drain cycles were initiated in the AWD bays. Due to unusually rainy and cloudy conditions in 2017, there were only two AWD drain/reflood cycles. These cycles occurred July 14/July 21-24 and July 28/Aug 25. Leaf gas exchange parameters (photosynthesis, Pn; transpiration, E; and stomatal conductivity, C) in both AWD and FLD plots were measured using an infrared gas analyzer system when soil volumetric water content (VWC) had reached ~20-30% (less stress) or ~16-26% (more stress) in the AWD plots. Plots were then reflooded and the new AWD cycle begun. Agronomic measurements including plant height, and leaf area index (LAI) were recorded. Plots were harvested Oct. 4-17 and grain yields were determined. The RILs and parents were designated as stress-susceptible or stress-tolerant based on their relative yield reduction in AWD compared with FLD. In the first AWD cycle, at a time when visual stress symptoms were largely absent (July 21, 2017), AWD reduced C by up to 70% in stress-susceptible lines such as Katy and RIL90, compared with more stress-tolerant lines such as PI 312777 and RIL401, which were reduced by less than 40%. In the second AWD cycle, after susceptible plants had begun to exhibit visual stress symptoms such as wilting or curling leaves, large reductions also were observed for Pn in Katy, RIL90, and RIL15 (up to 80%) compared with the more tolerant genotypes, RIL401 and PI 312777 (less than 40%). Interestingly, the VWC of soil in plots of the highly AWD-stress-susceptible Katy parent was greater compared with that of AWD-tolerant genotypes such as the PI 312777 parent, and suggests that Katy may be relatively less able to extract water from soil as water deficits increase, and may be partly responsible for a negative correlation (r= -0.29 to -0.37) observed between VWC and gas exchange parameters. Root data gleaned from preliminary experiments appeared to be helpful in identifying some AWD-tolerant genotypes. The PI 312777 parent had spreading roots with numerous, long root hairs, and very high root mass (>2X) when compared with the Katy parent. The AWD-susceptible RIL90 had very few root hairs. The AWD-tolerant RIL401 had moderately hairy and spreading roots, and AWD-tolerant RIL12 had very high root mass (≥ that of PI 312777). AWD reduced the LAI and final height at harvest by 11% and 13%, respectively. Yields over all genotypes were 39% lower in AWD compared with FLD plots, and there was a genotype x irrigation interaction in which tolerant genotypes such as PI 312777, RIL401, and RIL12 had statistically similar yields in AWD and FLD, whereas yields of susceptible genotypes such as Katy and RIL15 were reduced by as much as 70% in AWD compared with FLD. Yield in AWD was positively correlated with leaf Pn and E (r= 0.21 to 0.44) under AWD stress, apparently reflecting the reduced leaf gas exchange values (and possibly other physiological conditions) that accompany AWD. Thus, leaf gas exchange may be very useful as an early indicator of yield-altering stress in AWD irrigation management. Overall, several RILs were identified as potential AWD-tolerant genotypes and will be explored in greater detail in subsequent experiments.

Genetic Characterization of California Weedy Red Rice Reveals Multiple Possible Origins

De Leon, T.B., Andaya, C.B., Andaya, V.C., McKenzie, K., Al-Khatib, K., Espino, L., Blank, T., Mutters, R., Leinfelder-Miles, M., Linquist, B., and Brim-DeForest, W.

Weedy red rice is a very close relative of rice that belong to the same species *Oryza sativa*. Several hypotheses were proposed for the origins of weedy red rice. Recent studies of a strawhull weedy red rice collected in 2006 from California indicated the possible reversion of cultivated rice varieties into weedy type. Since weedy rice is an important weed of rice, a genetic study was conducted to understand the genetic profile and possible origin of California weedy red rice collected in 2006 and 2016. A total of 96 samples including 44 CA weedy red rice, 20 weedy red rice from the Southern USA, 8 wild rice, and 7 temperate japonica, 3 tropical japonica, 5 indica, 5 aus and 4 specialty rice were grown in the greenhouse. For genotyping, DNA samples were extracted from leaf tissues and amplified using 100 SSR markers and 1 primer pair for *Rc1* gene. PCR products were resolved in 6% polyacrylamide gel using the ABI 377 DNA sequencer. A total of 521 alleles were generated and scored as 1 or 0 in the presence or absence of alleles, respectively. Phylogenetic analysis was employed in DARwin v.6 using the UPGMA hierarchical cluster analysis, and bootstrapped 1000 times. Quality assessment of the genetic tree indicated that two distinct subgroups were detected that separated the japonica rice from indica. Furthermore, the tropical and temperate japonicas were differentiated well by the markers. In general, CA weedy red rice were genetically distinct but closely related to the weedy red rice from the Southern US. Type 1 clustered with Southern blackhull weedy rice and aus. The group of type 2 weedy rice clustered with Southern strawhull weedy rice from which type 3 and 4 likely diverged. However, type 5 clustered with japonica rice, demonstrating possible recent hybridization of weedy rice with cultivated rice. Additionally, some specialty rice grouped in type 2 and type 5, thus, indicating multiple possible origins of CA weedy red rice.

Weedy Rice in California: Addressing an Emerging Pest through Outreach and Research

Espino, L., Brim-DeForest, W., Al-Khatib, K., Blank, T., and De Leon, T.

There are many references in the literature that confirm that weedy rice was present in California soon after commercial rice production began in the state until the 1950s. Around this time, the use of certified seed was widely adopted and is credited, together with the flooded culture system, with almost eliminating weedy rice infestations. In the early 2000s, weedy rice was identified in six fields in two rice producing counties. The University of California Cooperative Extension (UCCE) worked with growers managing the infested fields to address the infestations and prevent the spread of weedy rice. In 2008, a visual survey showed no expansion of the infestations into neighboring fields. Since then, only a handful of new infested locations were identified.

In 2016, UCCE farm advisors and specialists received numerous calls regarding suspect weedy rice infestations. By the end of the year, five different weedy rice types had been identified infesting approximately 10,000 acres. Infestations in most cases were small, with just a few plants or patches in the field. During conversations with affected growers and consultants, it became clear that in some cases infestations started after using contaminated, non-certified rice seed.

Currently, UCCE, with support from the rice industry, is working intensively to educate growers and consultants about the threat of weedy rice to the rice industry in California. Our objectives are to increase awareness of the risks to the California rice industry, identify and monitor infested fields, provide management options for those fields, and stop the spread of weedy rice into new fields. Our long-term objective is to greatly reduce or eliminate weedy rice from the state. To this aim, many outreach activities were conducted during 2017, such as consultant and grower meetings, workshops, and field days. Outreach materials such as identification guidelines, best management practices, newsletter articles, blog posts, e-newsletters, and videos were developed. A new website, caweedyrice.com, was created as a repository of all outreach materials. Additionally, a phone app, the Weedy Rice Reporter, was developed to aid in reporting suspected samples to UCCE.

Starting in the fall of 2016, several weedy rice research projects were initiated to address the problem. Projects include genetic analyses to determine possible origins, competition studies, soil seedback surveys, shattering and dormancy evaluations, phenotypic characterization, and herbicide screening. Results from these research efforts will be used to improve management guidelines.

Outreach and research conducted so far have resulted in greater awareness among growers and consultants. During 2017, 53 new suspected samples were submitted, with 22 being identified as weedy rice. New seed policy was suggested by the rice industry and adopted by the California Department of Food and Agriculture, requiring all rice growers to use certified seed starting in 2019. For those varieties that cannot be certified, a new Rice Seed Quality Assurance Program was created.

Effects of Weedy (Red) Rice Competition on Early Growth and Yield of California Medium-Grain Rice

Brim-DeForest, W.B., De Leon, T.B., and Al-Khatib, K.

Weedy rice (*Orzya sativa* L.), also known as “red rice” is a major pest of rice worldwide. In California, it was recently discovered to be infesting more than 5,000 ha, or approximately 2% of the state’s rice acreage. A comprehensive survey in 2016 identified five distinct populations of weedy rice, distinguished both genetically and by a set of morphological characteristics. All populations are taller than the widely-grown medium grain California japonica rice varieties, and anecdotal evidence suggests that they have the capacity to tiller more than cultivated varieties. Based on these characteristics, and studies from other rice-growing regions, it is likely that California weedy rice populations will outcompete cultivated varieties and negatively impact yields. Thus, the objectives of this research were: 1) to determine the effect of California weedy rice on the early growth and yield of a widely-grown medium grain rice variety, M-206; 2) to determine if there is a density-dependent effect of weedy rice on cultivated rice early growth and yield; 3) to determine if there are differences between the five California weedy rice populations in terms of their impacts on cultivated rice early growth and yield; and 4) to determine if there are differences between the weedy rice populations in growth or yield.

A greenhouse experiment was started in summer 2017, using the five currently-identified weedy rice populations and medium-grain rice variety M-206. Seeds were pre-germinated and planted in saturated rice-field soil. Soil moisture was maintained at saturation throughout the duration of the experiment. In each pot, M-206 was planted at a constant density of 4 plants per pot in a consistently spaced pattern. Weedy rice was planted at an increasing density of 0, 1, 2, 3, and 5 plants per pot, also in a consistently spaced pattern. Each weedy rice population was planted only with itself or in mixture with M-206; there were no pots with mixed weedy rice populations. The experimental setup was a randomized complete block design (RCBD) with time of planting as the block. The entire experiment was replicated four times, planted approximately every two weeks. Weekly measurements of plant height and number of tillers per plant were recorded up to the 12th week of growth, when vegetative growth slowed. At maturity of the M-206, a final height measurement and final number of tillers per plant was recorded. Yield components consisted of: fresh and dry aboveground biomass, panicle number per plant, grain weight per panicle, and grain weight per plant.

Early growth of M-206 was not significantly affected by weedy rice, neither in terms of tiller number or plant height. Final height of M-206 was only significantly different from the pots with no weedy rice when weedy rice density reached five plants per pot ($p = 0.0091$). Final tiller number of M-206 was the same, regardless of the density of the weedy rice per pot ($p > 0.05$). Grain weight per panicle (gm) was significantly reduced by even one weedy rice plant per pot ($p < 0.0001$), as was number of panicles per plant ($p < 0.0001$). Grain weight per plant was significantly reduced by even one weedy rice plant per pot ($p < 0.0001$), as was fresh and dry aboveground biomass ($p < 0.0001$). Preliminary results suggest that weedy rice population 5 reduces the final height of M-206 the most. Preliminary results suggest that weedy rice populations 2, 3 and 4 reduce the fresh and dry aboveground biomass of M-206 the most. All other effects on yield of M-206 between the weedy rice populations appear to be non-significant, but results are still preliminary.

Final average height of weedy rice population 4 was significantly shorter than the other four populations ($p < 0.0001$). Final average tiller number per plant of weedy rice populations 2, 3 and 4 were the highest with averages of 11.8, 12.5 and 16.3 tillers per plant, respectively. Tiller number of population 1 and 5 were 9.0 and 7.3, respectively. Both population 1 and 5 were not significantly different in tiller number from M-206. Average fresh and dry aboveground biomass was greatest for weedy rice population 3 (significantly different from the other populations), and lowest for weedy rice population 5 (significantly different from the other populations). Populations 1, 2 and 4 were not significantly different from each other in fresh or dry aboveground biomass.

Registration Update and Proposed Use Directions for Benzobicyclon in the Mid-South United States

Sandoski, C.A., Holmes, K.A., and Takahashi, A.

Benzobicyclon is a novel herbicide that is currently under development by Gowan for use on rice in the Mid-South 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 250 – 370 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 registered in California and the Mid-South registration is expected in the next few years.

Community Efforts to Detect and Manage Herbicide Resistant Weeds in California Rice

Al-Khatib, K., Godar, A.S., and Brim-DeForest, W.B.

In California, over 200,000 ha of flooded rice are annually planted in a water-seeded system with little to no crop rotation. Rice growers in California rely heavily on herbicides for weed control with up to 97% of rice fields treated with herbicides at least once in the growing season. Weed resistance to herbicides is currently a major problem in California rice production. Further complicating weed management is the relatively few modes of action herbicides available with majority of these herbicides belong to ALS-inhibitors. Herbicide resistance was first confirmed in CA rice in 1993 in smallflower umbrella sedge (*Cyperus difformis* L.) to an ALS-inhibitor, bensulfuron-methyl. As of 2016, resistance has been confirmed in nine species and to five modes of action, with several species resistance to multiple modes of action.

Since 2009, the University of California has provided a service to rice growers and Pest Control Advisers (PCAs), allowing them to submit seeds from weed species' suspected to have herbicide resistance. Seed collections are made by growers or PCAs in the fall. The collected seeds are then subjected to dormancy breaking treatments and are grown in a greenhouse and subjected to a whole plant bioassay, screening with the field use rate of the appropriate rice herbicides for that species. Growers and PCAs are then provided with a diagnosis of resistance and given recommendations of herbicides or modes of action to use for the following season. The number of species has grown over the years, from just two species when the program began, to seven species as of 2017.

We compiled submissions from 2012 to 2017 to gauge participation in the program. From 2012-2015, the submissions came from four to five of the nine rice-growing counties. In 2016, submissions came from eight of the nine rice-growing counties whereas in 2017 samples came from all nine counties. The number of samples submitted has been steadily increasing since the beginning of the program. In 2012, 23 samples from six species were submitted. In 2016, the total number was 117, also from six species. In 2017, the total number increased to 232 samples including eight weed species and samples came from all counties. The increase may be due in part to increased extension efforts, but may also be due to spreading herbicide resistance. Smallflower umbrella sedge, sprangletop (*Leptochloa fusca* (L.) Kunth var. *fascicularis* (Lam.) N. Snow), late watergrass (*Echinochloa phyllopogon*) and barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) submission numbers have been increasing since 2012, whereas ricefield bulrush (*Schoenoplectus mucronatus* (L.) Palla), early watergrass (*Echinochloa oryzoides* (Ard.) Fritsch), and redstem (*Ammannia auriculata* Willd.) submissions have remained relatively constant. In 2016, we were able to accurately identify resistance in the field in 100% of early watergrass (*E. oryzoides* (Ard.) Fritsch) samples, 85% of late watergrass (*E. oryzicola* (Vasinger) Vasinger) samples, 93% of barnyardgrass samples, and 30% of sprangletop. Accuracy in identifying resistance in the sedges was also relatively high: 94% for smallflower umbrella sedge and 100% for ricefield bulrush (*Schoenoplectus mucronatus* (L.) Palla).

Abstracts of Posters on Weed Control and Growth Regulation
Panel Chair: Kassim Al-Khatib

Antagonism of Quizalofop Activity on Barnyardgrass and Weedy Rice in ACCase-Resistant Rice

Rustom, S.Y., Webster, E.P., McKnight, B.M., Telo, G.M., Webster, L.C., and Osterholt, M.J.

Imidazolinone-resistant (IR) rice (*Oryza sativa* L.) was introduced in 2002 as a tool for red rice control (*O. sativa* L.) with postemergence herbicides while producing a rice crop. Reports have indicated this technology has naturally outcrossed with red rice resulting in IR red rice. In addition, IR-hybrid rice seed has dormancy characteristics and can become weedy when allowed to establish in succeeding growing seasons.

Barnyardgrass becoming resistant to several different modes of action has also become an issue in rice producing areas throughout the southern United States. These herbicides include propanil, quinclorac, clomazone, imazethapyr, and imazamox. Reports of herbicide-resistant barnyardgrass continue to increase and the potential exits for the spread of these biotypes.

In 2017, BASF released a new herbicide-resistant rice called Provisia™. Quizalofop is the herbicide targeted for use and will also have the trade name Provisia™. Quizalofop is an ACCase-inhibiting herbicide with activity on annual and perennial grass weeds and little to no activity on broadleaf and sedge weeds. Quizalofop has been used to control red rice and other grass weeds in soybean production at rates of 35 to 85 g ai ha^{-1}.

Herbicides applied in mixtures have proven to be beneficial to producers with regards to broadening the weed control spectrum and maximizing economic returns. Mixtures can result in one of three interactions: synergistic, antagonistic, and neutral; however, ACCase herbicide activity is often antagonized when applied mixed with other herbicides. The focus of this research was to determine the responses of weedy rice and barnyardgrass when treated with quizalofop mixed with synthetic auxin or contact herbicides commonly used in rice production.

In 2015 and 2016, two separate studies were conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station to evaluate quizalofop activity when applied alone or in mixtures with herbicides containing synthetic auxin or contact activity. Applications for the contact study were applied when ACCase-resistant rice was at the three- to four-leaf growth stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha. Applications for the auxin study were applied postflood, when the rice was at the one- to two-tiller growth stage. Plot size was 5.1 by 1.5 m with eight, 19.5 cm drill-seeded rows planted as follows: 4 rows of ACCase-resistant 'PVL024B' rice, 2 rows of IR 'CL-111' rice, and 2 rows of IR-hybrid 'CLXL-745' rice. Awnless red rice was broadcast in the research area at 50 kg ha^{-1}. The CL-111, CLXL-745, and red rice were planted to represent a weedy rice population. The research area was also naturally infested with barnyardgrass.

The experimental design for each trial was a randomized complete block with a factorial arrangement of treatments with four replications. Factor A for each study was quizalofop applied at 120 g ai ha^{-1} or no quizalofop. Factor B for the synthetic auxin study was 2,4-D applied at 1,330 g ai ha^{-1}, triclopyr at 280 g ai ha^{-1}, quinclorac at 420 g ai ha^{-1}, or no mixture herbicide. Factor B for the contact study was bentazon at 1,050 g ai ha^{-1}, carfentrazone at 18 g ai ha^{-1}, propanil at 3,360 g ai ha^{-1}, saflufenacil at 25 g ai ha^{-1}, thiobencarb at 3,360 g ai ha^{-1}, or no mixture herbicide. Control data were subject to Blouin's modified Colby's analysis by calculating an expected response based on the activity of each herbicide applied alone and comparing with the observed control to determine mixture interactions.

For the synthetic auxin study, an antagonistic response occurred for barnyardgrass control for each synthetic auxin herbicide mixed with quizalofop at 14 and 28 DAT. Observed control for barnyardgrass treated with quizalofop mixed with 2,4-D did not exceed 24% at 14 or 28 DAT, compared with an expected control of 91 and 98%. In addition at 28 DAT, the same mixture controlled red rice, CLXL-745, and CL-111 37 to 38%, compared with an expected response of 98 to 99%. Antagonistic responses were also observed at 14 DAT for CL-111 treated with quizalofop mixed with triclopyr or quinclorac; however, these mixtures indicated neutral responses at 28 DAT.

For the contact study, an antagonistic response occurred at both 14 and 28 DAT for barnyardgrass treated with quizalofop mixed with propanil. Observed control for barnyardgrass treated with quizalofop mixed with propanil did not exceed 38% at 14 or 28 DAT compared with an expected control of 92 to 93%. In addition, quizalofop activity on barnyardgrass was antagonized by saflufenacil at 14 DAT; however, by 28 DAT, the same mixture indicated a neutral response for barnyardgrass control. Antagonistic responses for red rice, CLXL-745, and CL-111 treated with quizalofop plus propanil occurred at 14 and 28 DAT, and observed control did not exceed 75%, compared with an expected control of 92 to 95%.

Do Adjuvants Have the Ability to Overcome Antagonism of Quizalofop Plus ALS Herbicide Mixtures?

Webster, L.C., McKnight, B.M., Webster, E.P., Rustom, S.Y., Telo, G.M., and Osterholt, M.J.

Imidazolinone-resistant (IR) weedy rice (*Oryza sativa* L.) and barnyardgrass (*Echinochloa crus-galli* L.) resistance prompted BASF to develop an acetyl coenzyme A carboxylase (ACCase) resistant (ACCase-R) rice (*O. sativa* L.) to be sold under the tradename of Provisia. Quizalofop, a group 1 herbicide, is the herbicide to be used in Provisia rice with a single application rate of 92 to 155 g ai ha^{-1}, not to exceed 240 g ha^{-1} per year. ACCase-R rice will allow quizalofop to be applied postemergence (POST) in cultivated rice for control of annual and perennial grasses, including IR weedy rice and barnyardgrass.

Herbicides are often applied in a mixture to broaden the weed control spectrum, to save time, and to save application costs. Herbicide interactions may result in one of three responses: synergistic, antagonistic, or additive/neutral. ACCase herbicide antagonism for grass weed control is commonly observed when applied in a mixture with a broadleaf or sedge herbicide. Quizalofop is often antagonized for control of weedy rice and barnyardgrass by many ALS herbicides that are labeled for use in rice production. In research conducted in Louisiana, bispyribac has been shown to be one of the least compatible ALS herbicides in a mixture with quizalofop. Adjuvants may have the ability to overcome this antagonism due to their ability to alter the physical and chemical properties of herbicides and modify herbicide activity. The objective of this study was to evaluate the influence of different adjuvants in overcoming the antagonism of quizalofop when mixed with ALS herbicides. A BASF-supplied crop oil concentrate (COC-BASF) (Dash, BASF, Research Triangle Park, NC), a crop oil concentrate (COC-Helena) (Agri-Dex, Helena Chemical Company, Collierville,TN), and a silicon-based adjuvant (SBA) (Dyne-A-Pak, Helena Chemical Company, Collierville, TN) were evaluated for their potential to overcome antagonism of quizalofop.

A study was conducted in 2017 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana. Plot size was 1.5 by 5.1 m with eight, 19.5 cm drill-seeded rows of ACCase-R 'PVL01-B' long-grain rice. In addition to PVL01-B, eight, 19.5 cm drill-seeded rows of IR 'CLXL-745' and 'CL-111' were planted perpendicular to the PVL01-B at 84 kg ha^{-1}. Awnless red rice was broadcasted at 50 kg ha^{-1} across the research area, and the area was naturally infested with barnyardgrass.

The study was a randomized complete block with a two-factor factorial arrangement of treatments with four replications. Factor A consisted of POST applications of quizaolofop at 0 and 120 g ha^{-1}, bispyribac at 0 and 34 g ai ha^{-1}, or a mixture of quizalofop at 120 g ha^{-1} plus bispyribac at 34 g ha^{-1}. Factor B consisted of no adjuvant, COC-Helena, COC-BASF, or a SBA. All adjuvants were applied at a rate of 1% v v^{-1}. All herbicide applications were applied when the rice was at the three- to four-leaf rice growth stage. Visual evaluations for this study included barnyardgrass, red rice, CL-111, and CLXL-745 control at 14 and 28 days after the treatment (DAT). Rice yield was obtained and adjusted to 12% moisture.

At 14 DAT, quizalofop plus COC-Helena controlled barnyardgrass 91% at 14 DAT and 94% at 28 DAT. At 14 DAT, barnyardgrass treated with quizalofop plus bispyribac with COC-Helena or SBA was controlled 25 and 54%, respectively, and control increased to 33 and 64% at 28 DAT for the same mixtures. However, by substituting COC-BASF as the adjuvant, the quizalofop plus bispyribac mixture controlled barnyardgrass 80 and 88% at 14 and 28 DAT, respectively. No reduction in control was observed for red rice, CL-111, and CLXL-745 control when bispyribac was mixed with quizalofop plus all adjuvants evaluated at 14 and 28 DAT. ACCase-R rice treated with bispyribac mixed with quizalofop plus COC-BASF yielded 4,790 kg ha^{-1}, which did not differ from the ACCase-R rice treated with bispyribac mixed with quizalofop plus COC-Helena or SBA.

In conclusion, antagonism of quizalofop activity on barnyardgrass was observed when applied in a mixture with bispyribac plus COC-Helena or SBA; however, a neutral response was observed for red rice, CL-111, and CLXL-745 control when bispyribac was mixed with quizalofop plus all adjuvants evaluated. Preliminary results indicate that COC-BASF can reduce antagonism to a neutral response when bispyribac is mixed with quizalofop for control of barnyardgrass. Yield data for ACCase-R rice and control data for barnyardgrass, red rice, CL-111, and CLXL-745 treated with bispyribac mixed with quizalofop plus COC-BASF indicate a potential herbicide/adjuvant combination to be used in ACCase-R rice.

Rice Cultivar Tolerance to Florpyrauxifen-Benzyl

Corban, N.G., Bond, J.A., Golden, B.R., Sanders, T.L., Lawrence, B.H., and Edwards H.M.

Florpyrauxifen-benzyl, which is a new postemergence rice (*Oryza sativa L.*) herbicide developed by Dow Agrosciences, LLC, received registration in late 2017. It will be sold under the tradename Loyant™ with Rinskor™ and will offer a new herbicide mode of action for control of herbicide-resistant weeds in rice. The inconsistent response of rice cultivars to herbicides can be an issue for producers. An understanding of rice cultivar tolerance to florpyrauxifen-benzyl is essential for integrating this herbicide into southern U.S. rice production. Therefore, research was conducted to characterize the response of commercial rice cultivars to sequential POST applications of florpyrauxifen-benzyl applied at different rates.

The study was conducted from 2015 through 2017 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS. Treatments were arranged as a two-factor factorial within a randomized complete block experimental design with four replications. Factor A was rice cultivar and included 'Caffey,' 'CL151,' 'CL163,' 'CLXL745,' 'Jupiter,' and 'Rex.' Factor B was florpyrauxifen-benzyl treatment and consisted of florpyrauxifen-benzyl at 0.026 and 0.053 lb ai/A applied to rice in the two- to three-leaf (EPOST) followed by four-leaf to one-tiller (LPOST) growth stages. A nontreated control was included for each cultivar. Visual estimates of rice injury were recorded at 7, 14, and 28 d after the LPOST application. The number of days to 50% heading was recorded as an estimate of rice maturity. Plant heights and rough rice yields were collected at maturity. Height and rough rice yield data were converted to a percent of the control for the respective cultivar in each replication. All data were subjected to ANOVA and estimates of the least square means were used for mean separation at $\alpha=0.05$.

For all rice cultivars except CLXL745, injury 14 and 28 d after the LPOST application was similar with florpyrauxifen-benzyl at 0.026 and 0.053 lb/A. Injury to CLXL745 was 12 and 7% greater 14 and 28 d after LPOST application, respectively, when the florpyrauxifen-benzyl rate was increased from 0.026 to 0.053 lb/A. The higher application rate injured CL163 and CLXL745 more than other cultivars 14 and 28 d after the LPOST application.

Rice maturity, determined by the number of days to 50% heading, was delayed 2 to 3 d for CL151, CL163, and CLXL745 when the florpyrauxifen-benzyl rate was increased from 0.026 to 0.053 lb/A. Following applications of florpyrauxifen-benzyl at 0.026 lb/A, maturity was delayed for CL163 and CLXL745 compared with other cultivars. Maturity was delayed more for CL151, CL163, and CLXL745 than for Caffey, Jupiter, and Rex following applications of the higher florpyrauxifen-benzyl rate. Florpyrauxifen-benzyl application rate did not influence mature rice height. Pooled across florpyrauxifen-benzyl application rates, mature height was lower for Caffey and Rex than for CL151, CLXL745, and Jupiter. Additionally, CL163 mature height was greater than that for Caffey.

Pooled over rice cultivar, rough rice yield was reduced 6% following sequential applications of florpyrauxifen-benzyl at 0.053 compared with 0.026 lb/A. Rough rice yields for CL163 and CLXL745 were lower than for Caffey, CL151, Jupiter, and Rex regardless of florpyrauxifen-benzyl application rate. Although it was 96% of the nontreated control, rough rice yield of Rex was reduced compared with CL151 and Jupiter.

Current labeling only allows florpyrauxifen-benzyl to be applied at 0.026 lb/A. However, in commercial fields, variability in growth stages and irregularities in florpyrauxifen-benzyl application may occur that would make application rates exceed that specified on the label under some commercial field situations. Therefore, applications of florpyrauxifen-benzyl to CL163 and CLXL745 should be avoided, and caution should be exercised with applications to Rex.

Florpyrauxifen-benzyl on Grass Weeds Found in Louisiana Rice Production

Teló, G.M., McKnight, B.M., Webster, E.P., Rustom, Jr., S.Y., Webster, L.C., and Osterholt, M.J.

Florpyrauxifen-benzyl is a synthetic auxin and new postemergence herbicide for control of broadleaf, grass, and sedge weeds in rice (*Oryza sativa* L.). Many broadleaf, grass, and sedge weeds can be found in rice production, and the weeds can result in yield losses. Grass weeds are common in Louisiana rice production, and many can be difficult to control, especially in south Louisiana where annual and perennial grasses can be serious weed problems. Individual studies were conducted to evaluate the activity of florpyrauxifen on brook crowngrass (*Paspalum acuminatum* Raddi), fall panicum (*Panicum dichotomiflorum* Michx.), Nealley's sprangletop (*Leptochloa nealleyi* Vasey), rice cutgrass (*Leersia oryzoides* L.), southern watergrass (*Luziola fluitans* Michx.), and water paspalum (*Paspalum modestum* Mez).

A study was established in a glasshouse in November 2016 and repeated in February 2017 on the Louisiana State University campus in Baton Rouge, Louisiana. The experimental design was a two-factor factorial in a completely randomized design with five replications. Factor A consisted of florpyrauxifen applied at 0 or 30 g ai ha^{-1}. Factor B, for each grass evaluated, consisted of application timings at two growth stages, 1) three- to four-leaf; 2) one- to two-tiller. Individual plants of each grass were planted in 6.9- by 17.8-cm Ray Leach™ cone-tainers, and cones were placed into racks suspended above a 67-L water reservoir to allow for sub-surface irrigation. Florpyrauxifen was applied at 30 g ai ha^{-1} with a CO_2-pressurized backpack sprayer calibrated at 145 kPa to deliver 140 L ha^{-1} of solution, a methylated seed oil was added at 1% v/v. Weed control and leaf number were evaluated at 5, 10, 15, and 21 days after treatment (DAT), and plant total fresh weight was taken at 21 DAT. Data were analyzed using mixed procedure of SAS, and Tukey's test was used for mean separation at the 5% probability level ($p \leq 0.05$).

At 21 DAT, Nealley's sprangletop control was 82 and 78%; and leaf number was reduced 41 and 40% when treated with florpyrauxifen at the three- to four-leaf and one- to two-tiller growth stage, respectively. Plant fresh weight was reduced 73 to 75% when Nealley's sprangletop was treated with florpyrauxifen compared with the nontreated.

Fall panicum treated with florpyrauxifen at three- to four-leaf stage was controlled 91% at 21 DAT, compared with 72% control with the later application timing. Fall panicum leaf production ceased following florpyrauxifen treatment across all evaluation dates. A plant fresh weight reduction of 60% was observed when fall panicum was treated with floryrauxifen compared with the nontreated, indicating overall plant growth of fall panicum ceased when treated with florpyrauxifen.

Brook crowngrass, rice cutgrass, southern watergrass, and water paspalum control did not exceed 71, 12, 56, and 36%, respectively. Consequently, plants treated with florpyrauxifen compared with the nontreated did not greatly differ for leaf number and plant fresh weight. Results from this glasshouse study indicate that florpyrauxifen provides suppression of Nealley's sprangletop at 82% control and fall panicum at 91% control when treated at the three- to four-leaf stage.

Surveying the Level of Herbicide-Resistant Weeds in Texas Rice

Liu, R., Zhou, X.G., and Bagavathiannan, M.V.

Barnyardgrass (*Echinocholoa crus-galli*), weedy rice (*Oryza sativa*) and Nealley's sprangletop (*Leptochloa nealleyi*) are dominant weed species in Texas rice production. Postemergence herbicides, Propanil (Riceshot®), quinclorac (Facet®), fenoxaprop (Ricestar®), and imazethapyr (Newpath®) are frequently used for weed management. However, repetitive use of the same herbicides can lead to the development of herbicide-resistant weeds. To determine the current status of herbicide resistance in Texas rice weeds, late-season field surveys were conducted in the 2015 and 2016 growing seasons. Greenhouse screening experiment was conducted following a completely randomized design. Seedlings were germinated in trays and thinned to 20 seedlings per tray, with three replications for each treatment, two runs. A total of 40 barnyardgrass populations, 11 weedy rice populations, and 30 Nealley's sprangletop populations were evaluated in this study. Herbicides were applied following standard application procedures at 2-3 leaf weed stage, with recommended rates, using an automated spray chamber. Percent survival and percent weed injury were assessed at 21 days after treatment. Results showed that 33, 25, 19, and 25% of the barnyardgrass populations had individuals with high resistance (<25% injury) to propanil, imazethapyr, quinclorac, and fenoxaprop, respectively. Among these barnyardgrass populations, six had cross-resistance to all the four herbicides evaluated in this study. Seven weedy rice populations also showed resistance to imazethapyr with an injury level of <25%. Nealley's sprangletop showed low to moderate resistance to both propanil and imazethapyr with injury rate between 26-90%. The findings of this study revealed the level of herbicide resistance in Texas rice weeds and can help Texas rice growers develop effective management practices to combat against herbicide-resistant weeds.

Bearded Sprangletop Adaptation to Flooding in California Rice

Driver, K.E., Godar, A., Ceseski, A., Lee, M., and Al Khatib, K.

Bearded sprangletop (*Leptochloa fusca* (L.) Kunth ssp. *fasicularis* (Lam.) N. Snow) is a problematic weed in California rice production. Flooding was thought to suppress bearded sprangletop growth, however, after many years of continuous rice production, anecdotal evidence suggests that bearded sprangletop populations can tolerate flood pressures. A study was conducted in 2016 at the Rice Research Station in Biggs, CA to test the flooding tolerance of two populations against three irrigation depths. The study implemented a split block factorial design with four replications with sprangletop population being factor 1 and irrigation method being factor 2. The irrigation methods were 1) 10-cm continuous flood, 2) 20-cm continuous flood and, 3) 5-cm flood. The two bearded sprangletop populations tested consisted of one clomazone resistant and one susceptible population. Seed were planted in PVC rings with rice and flooded in the field. Emergence, height, tiller number, panicle per plant, seed per panicle, and rice yield were recorded. There was no emergence of bearded sprangletop in the 20-cm flood depth of either population. With a continuous 10-cm flood, only the resistant population survived flooding pressure and produced significantly more tillers and seed than any other treatment- population combination tested. This suggests that there may be a fitness advantage related to clomazone resistance, however, further testing is needed to confirm this.

Cyperus difformis ALS-Inhibitor Cross Resistance is Common in California Rice Region

Ceseski, A., Driver, K., Godar, A.S., and Al-Khatib, K.

Control of smallflower umbrella sedge (*Cyperus difformis* L.) in California rice has relied heavily on acetolactase synthase (ALS) inhibiting herbicides for more than two decades. As a result, smallflower populations resistant to ALS inhibitors are found throughout California's rice growing region.

The present study illustrates the current extent of smallflower resistance to ALS herbicides in California rice. Sixty-two grower-submitted smallflower samples collected in 2015 and 2016 were screened for resistance to four ALS herbicides: bensulfuron-methyl (Londax), halosulfuron-methyl (Halomax 75), bispyribac-sodium (Regiment CA), and penoxsulam (Granite SC). Plants were grown in a greenhouse at the Rice Experiment Station in Biggs, California, and sprayed with each herbicide at two rates: labeled field rate (1x) and 3x the field rate.

Only one population was susceptible (S) to all treatments; in the remaining 61 populations, six major resistance (R) patterns emerged. All of the 61 R populations exhibited some resistance to bensulfuron, with 58 showing significantly reduced mortality at the higher rate. Resistance to more than one herbicide was apparent in 59 populations, confirming that smallflower cross-resistance to ALS herbicides is widespread in the region. Of note, 18 populations were R to bensulfuron but S to halosulfuron, both of which are sulfonylurea-based herbicides. This may not be fully explained by a change to the ALS enzyme target site; a combination of enzyme insensitivity and enhanced herbicide metabolism may be present in these populations. Furthermore, one population was strongly resistant to all treatments, suggesting that a substitution for tryptophan at residue 574 of the ALS enzyme may be the mechanism of resistance for that biotype, as that particular mutation is known to confer resistance to all ALS herbicides.

Weedy or Not? Phenotypic Characterization of California Weedy Red Rice

De Leon, T.B., Al-Khatib, K., Blank, T., Espino, L., Mutters, R.,
Leinfelder-Miles, M., Linquist, B., and Brim-DeForest, W.B.

Rice is one of the most important crops in California. More recently, the presence of weedy red rice was observed in some growers' fields and therefore posed a threat to the quality and yield productivity of California rice. In this study, we characterized the CA weedy red rice collections for morphological and physiological characteristics to understand the existing weedy red rice and so as to identify traits that will help in identification and differentiation of weedy red rice from cultivated rice. The plants were grown in the greenhouse until maturity with five plants per accession. Several morphological traits such as plant height, leaf sheath, node, ligules, grain type, hull color, awn, and pericarp color were noted. Chlorophyll content, heading date, seed shattering and seed dormancy were evaluated. At least five ecotypes of weedy red rice were identified and differentiated based on hull color, grain size, and presence of awn. Type 1 is a short grain, straw hull, without awn; type 2 is medium grain, bronze hull, without awn; type 3 is medium grain, straw hull, with long awn; type 4 is short grain, black hull, with long awn; and type 5 is a mixture of medium grain and long grain straw hull and partially awned. All weedy rices had red pericarp and showed lower chlorophyll content as compared to cultivated California rice varieties. Seeds of type 1, 3, and 4 were high shattering and highly dormant while type 2 and 5 were partially dormant and less shattering. Based on multivariate analyses, CA weedy red rice ecotypes were phenotypically distinct from cultivated rice varieties.

Assessment of Crop Response and Weed Control with Different Use Rates and Timings of Foliar-Applied Penoxsulam Following Early-Applied Butte®

Godar, A.S. and Al-Khatib, K.

Penoxsulam is a relatively newer ALS-inhibiting herbicide for weed control in California rice. Butte®, a newly registered herbicide, is a mixture of two active ingredients; 3% benzobicyclon + 0.64% halosulfuron-methyl. The former component of Butte® is a HPPD-inhibitor and the later is an ALS-inhibitor. During the 2016 and 2017 rice growing seasons, field experiments were conducted to assess rate and timing flexibility of foliar-applied penoxsulam in a Butte®-based weed control program. Treatments included Butte® (250 + 52.2 g ai/ha, benzobicyclon and halosulfuron-methyl, respectively) applied at 1 leaf stage of rice (lsr) with a follow-up application of penoxsulam at a rate of 35, 42 or 49 g ai/ha applied at 3 lsr, 5 lsr or 1 tiller stage. A Butte® alone and weedy check treatments were included for comparison. All experiments were conducted in the field under controlled conditions at the California Rice Experiment Station, in Biggs, CA. Crop response (stand reduction and stunting) and weed control were evaluated 7, 14 and 21 days after foliar treatment and at 40 and 60 days after planting (DAP). Butte® alone provided an excellent season-long control of ricefield bulrush (*Schoenoplectus mucronatus* L.) Palla) and smallflower umbrella sedge (*Cyperus diformis* L.) and a good control (<90%) of late watergrass (*Echinochloa oryzicola* (Vasinger) Vasinger. Penoxsulam applications following Butte® greatly improved late watergrass control regardless of the rates and timings. In general, all the penoxsulam treatments caused slight transitory crop injury (<10%) which completely disappeared by 60 DAP. Crop yield was similar among the penoxsulam rates and timings and the yield averaged 10.4 t/ha. In conclusion, foliar-applied penoxsulam as a follow-up option offers a broad application window and flexibility in its use rate in Butte®-based herbicide programs in California water-seeded rice. However, use of a full recommended rate of penoxsulam is suggested unless the herbicide program also includes a late-season application that also targets a broad spectrum of weed control.

Response of Drill- and Water-Seeded Rice Varieties to Post-Flood Benzobicyclon Application

McKnight, B.M., Webster, E.P., Telo, G.M., Rustom, S.Y., Webster, L.C., and Osterholt, M.J.

Benzobicyclon is a new active ingredient for U.S. rice production. This herbicide works by inhibiting 4-hydroxyphenylpyruvate dioxygenase (HPPD) and typical symptoms on susceptible weeds include bleached plant tissue followed by necrosis and eventual plant death. This product has been labeled for use in rice production in Japan since the early 2000s and is currently labeled for use in California rice production. Past research has concluded that benzobicyclon must undergo a hydrolysis reaction to render the active herbicide, benzobicyclon-hydrolysate. Water-seeded rice plantings are common in Louisiana and account for approximately 35% of planted hectares. The unique water activity of benzobicyclon has a fit in a Louisiana water-seeded production system and early-flooded drill-seeded rice where ducksalad and other aquatic weeds can become early-season pests. Crop safety is an important component to the development of new herbicides, and the scope of this research is to evaluate herbicide tolerance of benzobicyclon to several common commercial lines grown in Louisiana.

Two field studies were conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, in the 2017 growing season. Both field studies were a split-plot design with whole plot consisting of herbicide rate and subplot consisting of rice variety. In the first study, two different rates of a pre-packaged mixture of benzobicyclon plus halosulfuron were evaluated under a drill-seeded commercial system. Rice cultivars ‘Diamond,’ ‘Cheniere,’ ‘CL111,’ CL272,’ and ‘PVL01-B,’ were drill seeded at 78 kg ha^{-1} and ‘CLXL745’ hybrid rice was drill-seeded at 50 g ha^{-1} on April 10, 2017 into individually-leveed bays 6 m wide by 83 m long. The 1X rate of the pre-packaged mixture consisted of 246 g ai ha^{-1} benzobicyclon plus 36 g ai ha^{-1} halosulfuron-methyl, and the 2X rate consisted of 492 g ha^{-1} benzobicyclon plus 72 g ha^{-1} halosulfuron-methyl. The permanent flood was established at the two-to three-leaf growth stage and herbicide treatments were applied 24 h following flood establishment. In a second study, the previously mentioned rice lines were water-seeded into 6 m wide by 83 m long, individually-leveed bays. One treated bay was managed as a pinpoint flood and another treated bay was not flooded until rice was at the three-to four-leaf growth stage. Herbicide treatment of the 2X rate of benzobicyclon plus halosulfuron were applied in each of these bays 24 h after establishment of the pinpoint or three-to four- leaf. Applications in both field studies were made by spraying the entire plot area with one pass utilizing a CO_2-pressurized backpack sprayer calibrated to deliver 93 L ha^{-1} spray solution, and a 6 m wide, two-man, handheld spray boom equipped with 12 flat fan 11001 nozzles.

In the drill-seeded study Diamond, Cheniere, and CL272 treated with the 2X herbicide rate were injured 61, 63, and 55% at 21 DAT, respectively. Phytoxicity ratings for CLXL745 plants treated with the 1X or 2X rate were 14 and 19% at 21 DAT, respectively. CL111 rice injury ratings were similar at 21 DAT for plants treated with both the 1X and 2X rate with 25 and 19% visual injury, respectively. All rice treated with the 1X herbicide rate yielded greater than 90% of the nontreated check except CLXL745 which yielded 84% compared with the nontreated. The grain yield of Diamond, PVL01-B, Cheniere, CL111, CL272, and CLXL745 treated with the 2X rate was 59, 63, 104, 78, 49, and 65% of the nontreated, respectively.

In the water-seeded field study, herbicide injury did not exceed 30% in any rice treated in the pinpoint flood bay except for 46% injury of Cheniere at 35 DAT. Injury of Diamond, Cheniere, and CL111 at 21 DAT was 30, 39, and 33%, respectively. By 49 DAT, herbicide injury of Cheniere was 21% and all other varieties were injured less than 20%. CL111, Diamond, Cheniere, and CLXL745 grain yield was greater than 100% of the nontreated in both, pinpoint flood and delayed flood timing. CL272 grain yield was 82% of the nontreated when treated 24 h after pinpoint flood establishment; however, grain yield was 144% of the nontreated when the herbicide was applied at the later timing, the three- to four-leaf flood. PVL01-B grain yield was 87 and 82% when herbicide was applied following the pinpoint flood and three-to four-leaf flood, respectively.

These field studies indicate acceptable crop safety on several commonly grown commercial rice lines and one hybrid to herbicide mixtures containing benzobicyclon in drill- and water-seeded production systems. Excessive injury can occur to drill-seeded rice when treated with a 2X rate of benzobicyclon plus halosulfuron. Careful and accurate applications should be exercised by applicators in order to avoid increased injury of rice. Excellent control of troublesome aquatic weeds observed in previous research, along with the level of crop safety observed in this study indicates benzobicyclon will be a useful option for weed control in Louisiana rice production.

Performance of Preplant Applications of Glyphosate-Based Herbicide Mixtures

Edwards, H.M., Sanders, T.L., Lawrence, B.H., Peeples, J.D., Corban, N.G., and Bond, J.A.

Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] is one of the more problematic weeds in southern U.S. soybean production. Barnyardgrass is the most common and troublesome weed of rice in Mississippi, and populations of barnyardgrass in the state have evolved resistance to photosystem II inhibitors, synthetic auxins, acetolactate synthase inhibitors, and/or acetyl CoA carboxylase inhibitors. Glyphosate is included with all PRE treatments in rice to control emerged barnyardgrass. Suspected glyphosate-resistant barnyardgrass samples have been evaluated in Mississippi, but none have tested positive for resistance. However, complaints about the level of barnyardgrass control with glyphosate-based herbicide mixtures are common in Mississippi. Research was conducted to evaluate barnyardgrass control with herbicide mixtures containing different rates of glyphosate and applied at different application timings.

The experiment was conducted in 2017 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, at a site containing a natural barnyardgrass population. The soil texture was a Sharkey clay with a pH of 7.5 and 2.4% organic matter. Individual plots were 6.67 feet wide and measured 15 feet in length. Treatments were arranged in a three-factor factorial within a randomized complete block design with four replications. Factor A was application timing and included an early application to barnyardgrass that was 3 inches in height and a late application to barnyardgrass that was 12 inches in height. Factor B was glyphosate rates of 0, 0.77, and 1.16 lb ae/A. Factor C was herbicide mixture and consisted of no mixture, 2,4-D amine at 1 lb ae/A, dicamba at 0.5 lb ae/A, fomesafen at 0.35 lb ai/A, saflufenacil plus clomazone at 0.045 plus 0.5 lb ai/A, and saflufenacil at 0.045 lb/A. The glyphosate formulation utilized was packaged with a surfactant so no additional adjuvants were included. Treatments were applied with a CO_2-propelled backpack sprayer and hand-held boom equipped with flat-fan nozzles and set to deliver 15 gallons per acre. Barnyardgrass control was visually estimated at 7, 14, and 21 days after treatment (DAT). All data were subjected to ANOVA and estimates of the least square means were used for mean separation at $p \leq 0.05$.

Barnyardgrass control 7 DAT was greatest with glyphosate alone (0.77 and 1.16 lb/A) or glyphosate at 1.16 lb/A plus 2,4-D amine or saflufenacil applied at the early application timing. For applications at the late timing, increasing glyphosate rate increased barnyardgrass control with glyphosate plus dicamba or fomesafen. For all application timing and glyphosate rate combinations, the addition of fomesafen to glyphosate reduced barnyardgrass control 7 DAT compared with glyphosate alone. Pooled across glyphosate rates, barnyardgrass control 14 DAT was reduced following the early application timing with all herbicide mixtures compared with no mixture. Following the late application timing, fomesafen and saflufenacil plus clomazone reduced barnyardgrass control 9 to 15% compared with the treatment containing no mixture. With the exception of 2,4-D amine mixed with the highest glyphosate rate, the addition of any herbicide to glyphosate reduced barnyardgrass control 14 DAT compared with glyphosate alone. Pooled across glyphosate rate and herbicide mixture, barnyardgrass control 21 DAT was greater with applications at the early vs. the late application timing. Pooled across application timings, barnyardgrass control 21 DAT increased when glyphosate rate was increased from 0.77 to 1.16 lb/A for mixtures with 2,4-D amine, fomesafen, and saflufenacil plus clomazone. Reductions in barnyardgrass control 21 DAT with the addition of a herbicide mixture to glyphosate was only observed when saflufenacil plus clomazone was added to glyphosate at 0.77 lb/A and when fomesafen was added to glyphosate at 0.77 and 1.16 lb/A.

Across the different evaluations, barnyardgrass control varied with different combinations of application timings, glyphosate rates, and herbicide mixtures. At all evaluations, and for each combination of application timing and glyphosate rate, the addition of fomesafen reduced barnyardgrass control compared with glyphosate alone. Because of the inconsistencies in barnyardgrass control, glyphosate-based herbicide treatments should include glyphosate at 1.16 lb/A with applications to barnyardgrass ≤ 3 inches. Additionally, mixtures of glyphosate with fomesafen should be avoided where the primary target is barnyardgrass.

Phytotoxicity of Sulfonylureas on Clearfield (CL) Rice

Marchesi, C.E., and Saldain, N.E.

Currently, available generic sources of sulfonylureas (SU) as metsulfuron and pyrazosulfuron are inexpensive compared to a ton of rough rice in Uruguay. Thus, it is very difficult to avoid overuse of such herbicides during rice production. Farmers and technicians have observed that metsulfuron applied close to seeding date can injure conventional rice, showing low tillering and growth detention, especially on tropical *japonica* type rather than *indica* type. This fact usually happen when a higher than recommended rate of metsulfuron is applied, due to excessive overlapping during spraying, or non-appropriate weather (high winds or thermic inversion phenomenon). Metsulfuron can cause damage in rice or rotational crops, depending on soil texture, organic matter, pH, herbicide doses, use frequency, and environmental conditions. Furthermore, there are reports about pyrazosulfuron causing some damage on rice, when it is repeatedly used. In addition to this, it is known the persistent soil activity of the imidazolinone herbicides (IM), and the carryover effects on susceptible species. Reports of damage by SU herbicides used on fallow, over IMI resistant crops after imazethapyr use can be find. Rice varieties CL and hybrids CL occupied a small but consistent area in Uruguay (25% of 160,000 has). In our country, the use of herbicide tank-mixes and sequences are extensive, so we are working to acquire more information about possible interactions of SU and IMI to prevent yield loses.

We carried out two experiments in 2016-2017, with CL rice on different locations (East and North). In the East, over a silty-clay texture, 5.5-pH soil, three metsulfuron rates (0, 3 and 6 g ai ha^{-1}), and two fallow lengths (28 and 14 days before sowing, DBS) were tested over three CL cultivars. Those were CL 212 (*indica* type) and CL 933 (tropical *japonica* type) varieties, that have the AHAS mutation $Ser_{653}Asp$ (two alleles, homozygous), and Titan CL (*indica* type) hybrid, that has the mutation $Ala^{122}Thr$ (one allele, heterozygous). Overall experiment, a pre-formulated mix of imazapyr + imazapic was applied on pre emergence, and on early post emergence (73.5 + 24.5 g ai ha^{-1}, respectively). The combination of factors and levels gave a factorial arrangement of treatments and those were displayed under a completely randomized block design (CRBD) with three replications. In the North, over a clay texture, 5% OM and 6.2-pH soil, with 20 DBS metsulfuron application at 3 g ai ha^{-1}, the use of two rates of pyrazosulfuron post emergence (0 and 38 g ai ha^{-1}), plus a pre-formulated mix of imazapyr + imazapic IM were assessed over a CL 212 (*indica* type) variety. Variables measured included population (plants m^{-2}), plants height (cm) and phytotoxicity (visual score), as well as flowering time (days after emergence), yield (kg ha^{-1}) and yield components, as panicle number (panicles m^{-2}), grain number (grains $panicle^{-1}$) and grain weight (1000 grains weight). The design was a RCBD with three replicates, and statistical analysis was performed to tests the individual effects and possible interactions between factors. In the light of the last year interesting results, two similar experiments are currently ongoing in the East and North field.

In the East experiment, only plant population (averaged over fallow length, CL cultivar and blocks) was affected by metsulfuron rate (p =0.0785). We found a trend of plant population reduction at the highest metsulfuron rate used, from 193 to 167 plants m^{-2}. Otherwise, we observed an interaction between fallow length and cultivar (p=0. 0111). Whereas Titan CL rice yield was higher than varieties average yield, in the long fallow the difference was higher than in the short one (difference of 3,362 kg ha^{-1} with SU application at 28 DBS, vs 1,946 kg ha^{-1} at 14 DBS). In the North experiment, we did not detected differences on rice growth or cycle. Nevertheless, we measured an important reduction in grain yield (16%) when both SU, metsulfuron and pyrazosulfuron, were used over the CL variety with IM application. Both higher persistence of SU and high phytotoxicity of IM have been reported in high pH soils. Nevertheless, the North soil pH is around 6, and has an important amount of OM (5%) and clay (45 %), properties that induce high adsorption of these herbicides and therefore, a low probability of phytotoxicity. Still, rice flooded conditions make such chemical changes at the soil level, that it is not well known yet the dissipation rates of some herbicides.

More data related to this matter should be analyzed, not only for the rice crop cultivated immediately after the SU and IM use, but also for the better understanding of the possible carry over effects in a rotation, where many problems have been reported with Clearfield systems. It appears to be rational form this point of view, along with the prevention of resistance, to use non-ALS inhibitors other than IM in Clearfield systems, before, during or after the rice crop season.

Efficacy of Preflood Applications of a Halosulfuron Plus Prosulfuron Mixture

Peeples, J.D., Edwards, H.M., Lawrence, B.H., Sanders, T.L., Corban, N.G., and Bond, J.A.

Although grass species are often the most troublesome weeds of rice (*Oryza sativa* L.) in the midsouthern United States, broadleaf weeds species can also be problematic. Halosulfuron (Permit) has been the primary treatment for sedge control in rice, but it also controls some broadleaf weed species. Halosulfuron, along with other herbicides targeting broadleaf weeds, has been used extensively in recent years, and resistance is becoming problematic. Halosulfuron plus prosulfuron (Gambit) is an acetolactate synthase (ALS) herbicide from Gowan Company that will be marketed for broadleaf and sedge control in rice. Research was conducted to (1) identify the optimum rate of a prepackaged mixture of halosulfuron plus prosulfuron for broadleaf weed control in rice and (2) compare the efficacy of a prepackaged mixture of halosulfuron plus prosulfuron to that of other herbicides targeting broadleaf weeds in rice.

Two studies were conducted at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate halosulfuron plus prosulfuron in rice. For both studies, the experimental design was a randomized complete block with four replications. The first study (Rate Study) evaluated rates of halosulfuron plus prosulfuron and was conducted from 2015 to through 2017. Treatments included halosulfuron plus prosulfuron at 0.037, 0.049, and 0.074 lb ai/A, and halosulfuron plus thifensulfuron (Permit Plus) at 0.035 lb ai/A. Treatments were applied when rice was at the two- to three-leaf growth stage. The second study (Broadleaf Herbicide Comparison) compared the efficacy of halosulfuron plus prosulfuron to other common broadleaf herbicides and was conducted in 2017. Treatments included halosulfuron plus prosulfuron at 0.049 and 0.099 lb/A, florpyrauxifen-benzyl (Loyant) at 0.026 lb ai/A, penoxsulam plus triclopyr (Grasp Xtra) at 0.25 lb/A, halosulfuron plus thifensulfuron at 0.035 lb/A, and saflufenacil (Sharpen) at 0.022 lb ai/A. Treatments were applied when rice was at the three- to four-leaf growth stage. Visual estimates of rice injury and weed control were recorded 7, 14, and 28 d after treatment (DAT). Data were subjected to ANOVA and estimates of the least square means were used for mean separation.

In the Rate Study, all rates of halosulfuron plus prosulfuron controlled hemp sesbania and ivyleaf morningglory ≥ 96% 14 DAT. Control of hemp sesbania with halosulfuron plus prosulfuron was greater than with halosulfuron plus thifensulfuron 14 DAT. The highest rate of halosulfuron plus prosulfuron (0.074 lb/A) was required for ivyleaf morningglory control greater than that with halosulfuron plus thifensulfuron 14 DAT. Volunteer soybean cultivars were glyphosate- and ALS-resistant. All rates of halosulfuron plus prosulfuron controlled volunteer soybean ≥ 93% 14 and 28 DAT, respectively. No differences in Palmer amaranth control were detected 7, 14, or 28 DAT.

In the Broadleaf Herbicide Comparison, hemp sesbania was controlled ≥ 97% with all treatments 14 DAT. Ivyleaf morningglory control 14 DAT was greater with saflufenacil than with either rate of halosulfuron plus prosulfuron. Both rates of halosulfuron plus prosulfuron, florpyrauxifen-benzyl, penoxsulam plus triclopyr, and saflufenacil controlled volunteer soybean ≥ 94% 14 DAT. Florpyrauxifen-benzyl, penoxsulam plus triclopyr, and saflufenacil controlled Palmer amaranth better than both rates of halosulfuron plus prosulfuron and halosulfuron plus thifensulfuron 14 DAT.

Halosulfuron plus prosulfuron at all rates evaluated controlled more hemp sesbania and volunteer soybean than halosulfuron plus thifensulfuron. Halosulfuron plus prosulfuron at 0.074 lb/A controlled more ivyleaf morningglory than halosulfuron plus thifensulfuron in the Rate Study; however, in the Broadleaf Herbicide Comparison, halosulfuron plus prosulfuron offered no advantage in ivyleaf morningglory control over halosulfuron plus thifensulfuron. The efficacy of halosulfuron plus prosulfuron compared with penoxsulam plus triclopyr, florpyrauxifen-benzyl, and saflufenacil was species specific. Halosulfuron plus prosulfuron at 0.099 lb/A can serve as an alternative broadleaf herbicide for rice when hemp sesbania or volunteer soybean are the primary targets.

Postemergence Herbicide Options for Ducksalad (*Heteranthera limosa*) Management

Sonnier, J.J., Webster, E.P., McKnight, B.M., Rustom, Jr., S.Y., Teló, G.M., Webster, L.C., and Osterholt, M.J.

In south Louisiana, ducksalad [*Heteranthera limosa* (Sw.) Willd.] is often a common weed problem early in the growing season, and it is often a problem at planting, especially under water-seeded production. In south Louisiana, rice growers often hold water during the winter months to reduce pumping costs in the spring when preparing fields for water-seeding, and another benefit to holding water is a reduction in winter vegetation. Producers will also hold water during the winter months to improve waterfowl habitat, and continue to hold the water in preparation for water-seeding rice. Crawfish producers will also hold water for extended periods, and this continuous flood usually occurs from October through June. These fields under extended flood conditions are a perfect habitat for early season ducksalad growth and infestations.

A field study was conducted during the 2017 growing season at the LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, Louisiana. The research area was not planted with rice in order to promote ducksalad infestation and growth. The area was treated as a water-seeded production system by flooding the area for 48 hours to simulate planting and draining. The research area was drained for 5 days and the permanent flood was established to simulate a pin-point system. Immediately after flooding, a 1-m diameter ring was placed in the center of each 1.5- by 5-m plot. The herbicides evaluated were: 1) bentazon at 873 g ai ha^{-1}, 2) bensulfuron at 28 g ai ha^{-1}, 3) bensulfuron at 14 g ai ha^{-1} plus halosulfuron at 26 g ai ha^{-1}, 4) benzobicyclon at 246 g ai ha^{-1}, 5) bispyribac at 28 g ai ha^{-1}, 6) florpyrauxifen-benzyl at 29 g ai ha^{-1}, 7) halosulfuron at 53 g ai ha^{-1}, 8) imazosulfuron at 210 g ai ha^{-1}, 9) orthosulfamuron at 80 g ai ha^{-1}, 10) orthosulfamuron plus halosulfuron at 87 g ai ha^{-1}, 11) orthosulfamuron plus quinclorac at 490 g ai ha^{-1}, 12) penoxsulam at 40 g ai ha^{-1}, 13) penoxsulam plus triclopyr 403 g ai ha^{-1}, 14) quinclorac 420 g ai ha^{-1}, 15) saflufenacil at 25 g ai ha^{-1}, 16) triclopyr at 750 g ai ha^{-1}, and 17) a nontreated was added for comparison. A crop oil concentrate (Agri-dex, Helena Chemical, Memphis, TN) at 1% v v^{-1} was added to all herbicides except bispyribac which received a silicon-based adjuvant at 1% v v^{-1} (Dyne-A-Pak, Helena Chemical, Memphis, TN). Visual control was evaluated at 42 days after treatment (DAT).

At 42 DAT, benzobicyclon, bispyribac, florpyrauxifen-benzyl, penoxsulam, and penoxsulam plus triclopyr controlled ducksalad 95 to 98%. Ducksalad treated with orthosulfamuron, orthosulfamuron plus halosulfuron, and orthosulfamuron plus quinclorac was controlled 75 to 85%. However, all other herbicides evaluated controlled ducksalad less than 45%. This research indicates that the new herbicides benzobicyclon and florpyrauxifen can be useful herbicides when an early-season ducksalad infestation occurs.

Rice Varietal Differences in Photosynthetic Response to Protoporphyrinogen Oxidase-Inhibitor

Tarpley, L. and Mohammed, A.R.

Oxidative stress is a common component of abiotic stresses. A study was conducted to develop a novel method for nondestructively and rapidly analyzing rice (*Oryza sativa* L.) crop response to oxidative stress. As part of this method-development study, a protoporphyrinogen oxidase-inhibitor (PPOi) herbicide was applied to easily impose an oxidative stress. The PPOi are herbicides that damage plants by promoting oxidative stress damage, especially of cell membranes in leaf tissue, thereby negatively affecting leaf integrity and function. As part of method development, a range of cultivars and elite breeding lines (varieties) of interest to Texas were used as a source of genetic variation. Different varieties were likely to respond to the herbicide differently, with variation in leaf penetration of active ingredient, in cellular sequestration, and in metabolism of active ingredient among possible differences not directly related to the oxidative stress response. Therefore, differences due to exogenous application of the PPOi in certain physiological parameters, including leaf-level net photosynthesis, were determined for each variety. The varieties' relative differences in the physiological response were then related to the nondestructive measure being developed. Reported here, wide variation within Texas germplasm in relative photosynthetic response to PPOi application exists, suggesting that good tolerance to oxidative stress, thus possibly abiotic stress, exists in Texas germplasm.

Twelve rice varieties of interest to Texas were grown using usual practice, including imposing flood at the six-leaf stage. Herbicide was applied to the individual varieties at boot stage at a rate targeting 10% damage to photosynthesis (actual damage averaged 6.5%) and was applied as a small canopy (app. 1 square meter) spray. Half of the plants of each variety were sprayed with the PPOi and half with adjuvant only.

Losses in leaf photosynthetic activity due to PPOi application when measured at 7 days post treatment ranged from -2% (i.e., a slight increase) to 16% among these cultivars and promising rice lines for use in Texas. Using 10% photosynthetic loss as a common threshold for possible economic loss, then establishing the responses of current cultivars and promising lines to PPOi herbicides is justified. The use of protoporphyrinogen oxidase-inhibitor herbicides as a tool for imposing oxidative stress in trials when used in conjunction with measurement of physiological responses has potential value.

Weed Control and Crop Injury of Herbicides in Rice

Zhou, X.G. and Samford, J.

Herbicides are an essential tool to the effective control of weeds in both conventional and Clearfield® rice. However, various herbicides often have different modes of action, target weeds, and timings and methods of application. Improper selection and use of herbicides may result in crop injury, causing significant rice grain yield and quality loss. Rice farmers need information about different herbicide programs that are not only effective for control of target weeds but also safe to the rice crop. The objective of this study was to evaluate the impact of herbicide programs on weed control efficacy, crop injury, and yield in conventional and Clearfield® rice under Texas environments.

A field trial was conducted as split plot design with variety as main plots and herbicide program as subplots at Eagle Lake, Texas, in 2016 and 2017. This trial was evaluated on the two conventional varieties Mermentau and XL753 and the two Clearfield® varieties CL111 and CLXL729 (2016) or CLXL745 (2017). Eight (2016) or 10 (2017) herbicide programs, consisting of Command alone or in combinations with Sharpen or League applied at preemergence followed by the two or three combinations of Aim, Bolero, Facet, Grasp, Obey, Permit, Regiment, RiceBeaux, Rice Starr HT, Rogue Plus, Stam, and Strada applied at mid-postemergence, were evaluated on the conventional varieties. Eight (2016) or 10 (2017) herbicide programs, consisting of Command alone or in combinations with Newpath or League applied at preemergence followed by the two or three combinations of Newpath, Clearpath, Bolero, Facet, Grasp, Loyant, Permit, Regiment, RiceBeaux, Rogue Plus, Stam, and Strada XT2 applied at early- and mid-postemergence were evaluated on the Clearfield® varieties. The treatments were arranged in a randomized complete block design with four replications. Percent plant injury caused by herbicides was visually rated. Percent control of broadleaf signalgrass, barnyard grass, carpet weed, and yellow nutsedge was rated. Rice was harvested using a plot combine at maturity of each variety. Grain yield and milling quality (% head rice and % total milled rice) were determined.

All herbicide programs provided excellent control of broadleaf signalgrass, barnyard grass, and yellow nutsedge. Facet, Regiment and Grasp were safe for use to control weeds in conventional inbred and hybrid varieties. Facet, Regiment, Grasp, Newpath and Clearpath also were safe to Clearfield® rice varieties. Command and Sharpen might cause some degree of injury to conventional and Clearfield® rice varieties. However, treated plants with command or Sharpen could recover with time, resulting in no significant, negative impact on grain yield and milling quality.

Interactions of RiceOne and Individual Herbicide Components Mixed with RiceBeaux

Osterholt, M.J., McKnight, B.M., Webster, E.P., Telo, G.M., Rustom Jr., S.Y., and Webster, L.C.

Dry-seeded rice (*Orzya sativa L.*) production in the state of Louisiana has risen to approximately 65% of the planted rice area which is up from approximately 25% prior to the release of imidazolinone-resistant (IR) rice in 2002. With more hectares going to dry-seeded planting, farmers are relying more on preemergence (PRE), delayed preemergence (DPRE), and postemergence (POST) residual herbicides to help manage weeds prior to the permanent flood establishment. RiceOne is a pre-packaged mixture of clomazone (Group 13) and pendimethalin (Group 3) at 128 and 307 g ai L^{-1}, respectively. RiceBeaux is a pre-packaged mixture of propanil (Group 7) and thiobencarb (Group 8) at 360 and 360 g ai L^{-1}, respectively. Because of the residual activity of both RiceOne and RiceBeaux the two products combine for a total of four sites of action (SOA), and this could greatly benefit dry-seeded rice production by providing extended residual control of troublesome early-season weeds. The objective of this research was to evaluate early season grass control between early-POST (EPOST) applications of RiceOne, clomazone, or pendimethalin mixed with RiceBeaux for early-season weed management.

A field study was conducted during the 2017 growing season at the LSU AgCenter H. Rouse Caffey Rice Research Station (RRS) near Crowley, Louisiana. Treatments were arranged as a two-factor factorial in a randomized complete block design with four replications. Factor A consisted of EPOST applications of RiceBeaux at 0, 2,520, or 5,040 g ai ha^{-1}. Factor B consisted of EPOST applications of clomazone at 223 or 336 g ai ha^{-1}, pendimethalin at 537 or 807 g ai ha^{-1}, or RiceOne at 760 or 1,020 g ai ha^{-1}. Clomazone and pendimethalin rates were applied at the equivalent rates formulated in RiceOne. Rice was in the two- to three-leaf stage at the EPOST timing. IR 'CL-111' rice was planted at 84 kg ha^{-1} in eight, 19-cm rows. Herbicide applications were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 190 kPa. Visual weed control ratings of barnyardgrass [*Echinochloa crus-galli (L.) P. Beauv*], were recorded at 35 and 49 days after treatment (DAT). Rough rice yield was obtained for the primary crop with a small plot combine harvesting the center four rows of each plot. Grain yield was adjusted to 12% moisture and calculated based on kilogram per hectare.

At 35 DAT, barnyardgrass treated with clomazone at 223 or 336 g ha^{-1} or RiceOne at 760 or 1,020 g ha^{-1} mixed with RiceBeaux at 2,520 or 5,040 g ha^{-1} was controlled 86 to 93%. An increase in control of barnyardgrass was observed when treated with multiple SOA compared with the individual herbicides applied alone. Data indicates that pendimethalin applied with either rate of RiceBeaux provided less control of barnyardgrass compared with clomazone or RiceOne mixed with RiceBeaux.

At 49 DAT, both the higher and lower rates of clomazone or RiceOne mixed with RiceBeaux at 2,540 g/ha resulted in 76 to 83% control of barnyardgrass. The high rates of clomazone or RiceOne evaluated mixed with RiceBeaux controlled barnyardgrass 90 to 95%. Rice treated with RiceOne at 760 g/ha mixed with RiceBeaux at 5,020 g/ha yielded 7,260 Kg/ha. No differences in yield was observed with rice treated with RiceOne at 760 or 1,020 g/ha mixed with both rates of RiceBeaux or rice treated with clomazone at 336 g/ha mixed with 5,040 g/ha of RiceBeaux.

The addition of clomazone, pendimethalin, with RiceBeaux provides both residual and POST activity on barnyardgrass. This case of multiple SOA herbicide mixtures can be a useful tool to help manage and delay herbicide resistance.

Abstracts of Papers on Rice Culture
Panel Chair: Randall (Cass) Mutters

Measuring Mid-season Nitrogen in Rice Using Remote Sensing

Dunn, B.W., Dehaan, R., Dunn, T.S., and Robson, A.

In the Australian rice industry the application of nitrogen at panicle initiation is an important practice that impacts grain yield and profitability. Rice growers have been utilizing a tissue test service where they physically collect plant samples at panicle initiation (PI), which are then analyzed for nitrogen using NIR spectroscopy. The biomass weights and nitrogen concentrations are used to provide nitrogen topdressing recommendations to growers based on the results from many years of nitrogen experiments. Only 30% of growers/agronomists currently utilise the free service with many growers saying the requirement to physically sample the crop is a major reason why they do not use the test. Remote sensing offers a potential opportunity to determine PI nitrogen uptake with reduced or potentially no physical sampling while also identifying variability in nitrogen uptake across the field.

Each year a series of experiments were established with a range of nitrogen rates applied across several commercial rice varieties, to create rice plots with a large range of nitrogen uptake levels at PI. The plots are scanned at PI using several remote sensing instruments including Worldview, Sentinel and RapidEye satellites and Parrot Sequoia, MicaSense RedEdge and SlantRange sensors mounted on drones. At the start of the project a handheld hyperspectral sensor (SVC 1024) was also used. On the same day as the remotely sensed data is collected, physical plant samples are taken from all the plots and measured for biomass and nitrogen concentration. The relationship between the remotely sensed data and the physically measured nitrogen uptake at PI has been investigated for each sensor. Multi-season correlations have been developed between the sensor data and actual measured PI nitrogen uptake for several multispectral systems.

The PI nitrogen uptake prediction obtained from three years of hyperspectral data was very encouraging with PI nitrogen uptake able to be predicted with an $r^2 = 0.86$ and RMSEP of 16.46 kg N/ha. As there are currently no hyperspectral sensors available that are commercially viable for scanning rice fields the research has focused on available multispectral sensors.

Data collected with the micaSense RedEdge camera was used to develop relationships between both Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE) and PI nitrogen uptake. At PI N uptake levels above 75 to 80 kg N/ha, NDVI saturates, with its response to increased PI N uptake diminishing, as a result NDVI is of little value for predicting PI N uptake above these levels. NDRE however, which uses the red edge waveband (710–740 nm) has a stronger relationship with PI N uptake and does not saturate until around 100 kg N/ha. For some rice varieties that have a lower nitrogen requirement NDRE is suitable for direct prediction of PI nitrogen topdressing rates without physical sampling however for many varieties some physical sampling is still required to accurately determine optimal crop PI nitrogen requirements. Research is continuing into sensors that may provide the ability to remove the requirement for physical sampling for all rice varieties.

Nitrogen Cycling Under Alternate Wetting and Drying Cycles in Arkansas Rice

Olk, D.C., and Anders M.M.

Rice is commonly grown in the U.S. under continual flood from early vegetative growth until shortly before harvest. Alternate wetting and drying (AWD) cycles offer potential savings in water use while reducing both greenhouse gas emissions and also grain arsenic content. In a three-year (2011-2013) field study near Stuttgart, AR, one-third of a field previously grown to soybean was brought into continuous rice production during three consecutive years, enabling within-season comparison of first-year rice versus second-year rice (2012) and also versus third-year rice (2013) while avoiding differences in annual weather patterns. Within each year's rice area, season-long AWD (with drying to 60% of soil water-holding capacity) was compared to season-long AWD to 40% of field moisture capacity and to AWD (drying to 40%) only during vegetative growth stages followed by maintained flood during reproductive growth stages. The AWD treatments began 14 days after the initial flood. The control was permanent flood throughout the growing season. All nitrogen (N) fertilizer was applied in a single pre-flood application. In the second and third years, N cycling was investigated through ^{15}N micro-plots imbedded within three of the four field replicates. Rice uptake of ^{15}N estimated crop uptake of fertilizer N, and rice uptake of ^{14}N estimated crop uptake of soil N.

AWD improved water use efficiency (kg grain m^{-3} water applied) by 22 to 43%. It also reduced in-season greenhouse gas emissions by 38 to 90% depending on cropping history (continuous rice or first-year rice) and duration of drying cycles (vegetative growth only versus season-long). Methane emissions fell by 43 to 94%, and N_2O emissions rose only slightly due to coordination of AWD with the timing of N fertilizer inputs. Grain yield decreased by 5% with season-long AWD (drying to 60%) compared to the flood control, and any N uptake decrease was insignificant. With AWD drying to 40%, grain yield and N uptake were limited by water stress; this treatment will not be discussed further. For continuous rice, grain yield did not decrease in the treatment having AWD during vegetative growth followed by maintained flood during reproductive growth, which we attribute to a late-season increase in available soil N as measured in the ^{15}N micro-plots. At harvest, continuous rice had taken up 20 to 47 kg N ha^{-1} more in this treatment than in the season-long AWD or the continuous flood control, due mostly to the late-season soil N flush. The size of this N flush grew during the three years of continuous rice cropping, possibly reflecting a gradual accumulation of higher quality soil organic matter resulting from more aerobic decomposition of crop residues. The aeration treatments had no clear effect on N cycling or yield trends for first-year rice. All aeration treatments for first-year rice had greater grain yield and N uptake than did all continuous rice treatments, especially for third-year rice.

The evolution of this yield gap during second- and third-year rice cropping was driven by decreasing crop uptake of soil (^{14}N) nitrogen, consistent with our earlier research on an observed yield gap between continuous rice versus rice-soybean cropping. Details will be provided on the biochemical composition of the soil organic matter, including phenol levels which our earlier work associated with the inhibition of soil N cycling under continuous rice. Combinations of crop rotation and AWD offer growers a range of options to meet their desired balance of grain yield, water savings, and reduction of greenhouse gas emissions. They also provide producers with strategies to better use available soil N.

Breaking Yield Barriers of Uruguayan Rice Farmers

Deambrosi, E., Zorrilla, G., Lauz, M., Terra, J., Blanco, P., Castillo, J., Méndez, R., Perez, F., Macedo, I., Uraga, R., Gonnet, D., Rovira, G., Marella, M., Stirling, E., and Zorrilla, H.

The costs of rice cultivation in Uruguay increased significantly in recent years. Higher crop yields and more efficient use of resources and inputs are needed to maintain or increase producers' profit. Average farm yields in a region or country are smaller than Yield Potential (Y_p) because achieving it requires a perfect management of soil and crop that could affect plant growth and development along its cycle. Best farmers sometimes can get that objective, but in general it is not profitable. Given that the average productivity obtained in Uruguay is already high and that the yield gap among farmers has decreased in recent years, it has been questioned if there are opportunities to increase it more and in a sustainable way through new integrated crop management proposals.

A project was initiated in 2013 with the objective of testing the feasibility of increase yields at least 10% over the best farmers, integrating available technologies and practices of crop management. Thirty-nine rice farmers who belonged to the top yield quintile during the period 2009-2013 in the Eastern Region of Uruguay were identified, from industry records. All of them were interviewed to identify the most important practices that contribute to this maximum regional productivity. Based on the environmental characteristics three sub-regions were characterized resulting in 3 groups of producers. Twenty technologies for integrated management of rice cultivation associated with these producers were recorded, and the relative frequency of use of different options, was analyzed within each group. From this study, a baseline technology from best farmer´s on each three sub-regions was defined.

Four factors were proposed as alternative practices for increasing yields, to be evaluated in 2014-15 and 2015-16 experiments: 1) cultivar (high yield potential/Blast disease resistance), 2) crop installation (seed treatments/number of plants to be installed per unit area), 3) fertilization management (basal and split/ macro and micro-nutrients applications), 4) disease protection (only one fungicide application plus aggregates of potassium phosphate and silicon).

Twelve treatments arranged in a RCB Design with 3 replications were tested in 4 locations. Plots of 6.12m wide by 20m long were installed. The first treatment corresponds to the top farmer technology (TFT); in each of the following five treatments (2 to 6), one of the factors is substituted by their proposed alternative. In a similar, but reverse way, in treatment 7 all alternative practices in the four factors were used. In each of the remaining treatments (8 to 12), on factor at a time was substituted by the original on treatment 1. In summary, the objective was to evaluate if at least one of the 11 combined treatments (2 to 12) in each location, was able to obtain a 10% yield increase over the treatment 1, trying to exploit the positive interactions among several factors.

Eight experiments were performed in 2014-15 and 2015-16 growing seasons (GS), with statistical coefficients of variation ranging between 2.4 and 5.3. Top farmer´s treatments (Trt.1) yielded 12.8 Mg ha^{-1} and 13.9 Mg ha^{-1} in Rincon de Ramírez; 11.5 Mg ha^{-1} and 12.3 Mg ha^{-1} in 7ª Section. - San Francisco Treinta y Tres; 9.4 Mg ha^{-1} and 12.1 Mg ha^{-1} in Cebollatí; and 11.6 Mg ha^{-1} and 12.2 Mg ha^{-1} in India Muerta (first and second year, respectively). Productivity percent increments over treatment 1 of 16.4 - 6.2 - 15.1 - 9.3 in 2014-15, and 0 - 7.7 – 7.1 – 11.5 in 2015-16 GS, were obtained with some of the alternative treatments. Significant statistical differences between treatments and locations were detected within a growing season analysis, and also between years and location within the same place.

The last year of the project was devoted to validation of experimental results in large areas in farmer´s fields. Two paired plots of 4-5 ha each were installed in six commercial farms along the three sub-regions and they were completely managed by the rice farmer. In one of the plots the baseline technology of top farmers was applied (treatment 1 of previous experiments) and the best resulting treatment from the two-year experiment was used in the other plot. Yield average of improved technology plots was 10.5 Mg ha^{-1} (range 9.3 to 12.2 Mg ha^{-1}), obtaining 14.5% increase over the average of plots with the best producer's management (TFT: mean 9.2 Mg ha^{-1} range 8.6 to 10.1 Mg ha^{-1}). These results suggested there is no yield ceiling for Eastern Uruguayan rice farmers and bring opportunities to improve yields and profit.

Soil Health Evaluation of Flooded Rice Cultivation in South Florida

Bhadha, J.H., Khatiwada, R., Galindo, S., and Capasso, J.

Flooded rice (*Oryza sativa L.*) in South Florida is grown commercially in rotation with sugarcane and vegetables. From 2008 to 2015, rice production has increased more than 80%. During the spring-summer, more than 50,000 acres of fallow sugarcane land is available for rice production. In 2017, approximately 28,000 acres of rice were planted in the region. The net value of growing rice in the Everglades Agriculture Area (EAA) as a rotation crop far exceeds its monetary return. In addition to being a food crop in Florida, production of flooded rice provides several benefits to the agroecosystem. By flooding fields, growers greatly reduce the negative impacts from issues related to soil subsidence, nutrient depletion, and insect pests. This, in turn, enhances the subsequent sugarcane crop and maximizes the longevity of the soil by reducing soil loss due to oxidation. Our objective was to evaluate soil quality parameters before and after rice cultivation and compare them against two other common summer farming practices of fallow fields and flooded fallow.

The soil health parameters that were tested as part of this study included soil pH, bulk density, water holding capacity, cation exchange capacity, organic matter, nutrient content, and carbon microbial biomass. Quantifying these changes and comparing them to flooded fallow or fallow field practices will help assess the impact of rice cultivation on soil health parameters. Six 40-acre fields were considered for each land-use practice. The goal of the study was to evaluate rice cultivation from a soil health perspective.

Results indicated a slight increase in soil pH, and a significant reduction in soil bulk density as a result of rice cultivation. Water holding capacity increased significantly under all flooded land use practices compared to fallow fields. Cation exchange capacity significantly increased when sugarcane fields were cultivated with rice and ratoon rice, nearly doubled from 58 to 101 cmolc/kg. Small, yet significant 3% increase in organic matter was observed when sugarcane fields were cultivated with ratoon rice. Almost 16 g/kg of active C is being generated within fallow soils, whereas no more than 8 g/kg of active C under flooded practices. From a soil sustainability point of view what this means is that loss of carbon via oxidation processes can be halved by keeping the soils flooded during the hot and humid South Florida summer months.

Aerobic Rice Production System in Water-Scarce Areas in Cagayan Valley, Philippines

Balderama, Orlando F.

ART is a new water-saving technology for rice production which involves growing drought and disease tolerant, high yielding and short-duration rice varieties in non-flooded and non-puddled soil in water-scarce areas such as rain fed lowland and upland and tail-end portions of gravity irrigation systems. The project aimed to improve eco-system based rice farming system through appropriate water-saving technologies to increase rice production and farmers' income through innovative research and extension modalities.

As a result, farmer-managed on-farm trials yielded 4-6 tons per hectare across climate types and variation of varieties, ecosystem, planting dates and planting methods. The water use efficiency obtained 2.2 grams per kg as compared with the traditional flooded rice production practice which has only about 0.4 g/kg. The financial viability of ART is also promising. For a yield of 4.2 tons per hectare will give the following: cost of production is P34,135.20; gross sales at prevailing rate is P84,000; net income of P49,864.8; with return of investment at 1.46.

Extension work activities such as training of trainors to agricultural extension workers & farmer leaders, farmer participatory trial & field day, and production & distribution of brochures & training manuals were conducted to enhance the information dissemination and adaption of technology. Upscaling of Aerobic Rice Technology was pursued through the conduct of National Aerobic Rice Conference and organization of ASEAN network.

Understanding Grain Yield and Economic Results of Sub-Optimum Stand Densities in Rice

Hardke, J.T., Frizzell, D.L., Plummer, W.J., Castaneda-Gonzalez, E., Lee, G.J., Clayton, T.L., and Mulloy, R.B.

Earlier planting dates and difficult early-season weather conditions have made rice stand establishment increasingly difficult in Arkansas. Replant considerations due to low plant stands should include an evaluation of yield potential as well as the economics associated with replanting or managing the current plant stand. Field studies were conducted in 2017 to evaluate the grain yield potential and net return associated with sub-optimum stand densities in rice for both varieties and hybrids. Based on results from traditional seeding rate trials and field observations, it has generally been recommended to replant rice fields when stand densities fall below 3 plants per square foot for hybrids and below 5 plants per square foot for pureline varieties. However, the yield potential of the existing stand, combined with current economic investment and any subsequent costs associated with a replant must be considered when making these decisions.

Trials were conducted at the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (RREC) near Stuttgart, AR; the Pine Tree Research Station (PTRS) near Colt, AR; and the Northeast Research and Extension Center (NEREC) near Keiser, AR. The variety LaKast was planted at rates of 32, 65, 129, 258, and 323 seed/m^2. The hybrid XP753 was planted at rates of 11, 22, 43, 75, and 111 seed/m^2. The recommended seeding rates for LaKast and XP753 are 323 and 111 seed/m^2, respectively, and all lower seeding rates were chosen to simulate suboptimal plant stands. Preflood nitrogen (N) rates also varied at each location based on Nitrogen Soil Test for Rice (N-STaR) recommendations. Single preflood N rates used were 101, 135, and 168 kg N/ha at RREC; 112, 146, and 179 kg N/ha at PTRS; and 146, 179, and 213 kg N/ha at NEREC.

At NEREC, 323 and 258 seed/m^2 for LaKast and 111 and 75 seed/m^2 for XP753 resulted in significantly greater grain yield compared to lower seeding rates. In addition, optimum N rates of 179 kg N/ha and above were needed to achieve optimum grain yield for both LaKast and XP753. At PTRS, 323 and 258 seed/m^2 for LaKast resulted in significantly greater grain yield compared to lower seeding rates; and optimum N rates of 146 kg N/ha and above were needed to achieve optimum grain yield. However, for XP753, 111, 75, and 43 seed/m^2 resulted in significantly greater grain yield compared to lower seeding rates; and only the highest N rate of 179 kg N/ha resulted in the highest grain yield. At RREC, for LaKast there was a significant interaction between seeding rate and nitrogen rate with regard to percent lodging. The highest seeding rates of 258 and 323 seed/m^2 and the highest N rate of 179 kg N/ha resulted in significantly greater lodging compared to all other treatments. For LaKast there was no significant difference between any seeding rate or N rate treatments for grain yield. For XP753, the highest seeding rates of 111, 75, and 43 seed/m2 resulted in significantly greater lodging and grain yield compared to all other seeding rates. The optimum N rate of 146 kg N/ha and above was needed to maximize grain yield for XP753.

Reductions in seeding rates and nitrogen rates overall resulted in significantly lower grain yields. Reductions in N rate did not succeed in achieving maximum grain yield in low stand density situations, suggesting that optimum N rates must still be used to achieve maximum yield potential even when stand densities are lower than recommended. Evaluation of net return in this study is dependent on preflood N rate as the only cost changing variable. Direct comparisons between this data and an actual replant situation are needed to identify actual yield potential and changes in input costs for a replant situation.

Evaluations of an Experimental Urease Inhibitor on Ammonia Volatility, NUE and Rice Yield

Harrell, D.L., Schwab, G., Kongchum, M., and Adotey, N.

Ammonia volatilization can occur when urea nitrogen (N) fertilizer is left exposed on the soil surface for an extended period of time. Fertilizer N losses can be quite large if it takes more than 5 days to flood a field. Research has shown that treating urea with a urease inhibitor that contains the active ingredient NBPT and/or NPPT can significantly reduce volatilization losses. KOCH Agronomic Services is currently filing for an EPA registration for a new urease inhibitor (ANVOL) which contains a new active ingredient that is made by combining NBPT, urea, and formaldehyde in an undisclosed process. The objectives of the following experiments were to 1) evaluate the volatility of ANVOL treated urea 2) determine rice yield potential when using ANVOL treated urea as compared to untreated urea and other treated urea fertilizers.

Trial 1 evaluated urea, ANVOL treated urea and Agrotain Advanced treated urea in a laboratory setting on both a Crowley silt loam and Mowata silt loam soil over a 15-day period of time. Trial 2 consisted of a yield trial which contained 3 N sources (urea, Agrotain Advanced-urea and ANVOL-urea) and 4 application timings (15-, 10-, 5-, and 1-days preflood). An unfertilized control was also included. Trial 3 was a field volatilization trial which utilized the semi-open chamber method and the same treatments included in trial 2.

In trial 1, cumulative volatile N loss from urea (25.9%) was significantly greater than Agrotain Advanced-urea (7.1%) and ANVOL-urea (6.8%) on the Crowley soil. Cumulative volatile N losses from urea (32%) was significantly greater than Agrotain Advanced-urea (10.5%) and ANVOL-urea (11.3%) on the Mowata soil. In trial 2, mean rice yield was significantly greater for Agrotain Advanced-urea (6,692 kg ha^{-1}) and ANVOL-urea (6,496 kg ha^{-1}) as compared with urea (3,885 kg ha^{-1}) when applied 15-days preflood. Mean rice yield was significantly greater for Agrotain Advanced-urea (9,022 kg ha^{-1}) and ANVOL-urea (9,014 kg ha^{-1}) as compared with urea (6,397 kg ha^{-1}) when applied 10-days preflood. Rice yield was not significantly different between N sources when applied 5- or 1-days preflood. In trial 3, cumulative ammonia volatilization losses from urea (26.7%) were significantly greater than both Agrotain Advanced-urea (7.7%) and ANVOL-urea (6.8%).

Significant fertilizer N losses can occur due to ammonia volatilization when N is left unincorporated on the soil surface for more than 5 days. Treating urea with a urease inhibitors like Agrotain Advanced or ANVOL can reduce cumulative N losses and increase rice yield in situations where it may take more than 5 days to flood a rice field.

Effect of Nitrogen Fertilization and Variety Selection on Organic Rice Production

Dou, F.

Soil fertility is a key component in achieving high yields that will make organic farming systems economically viable. Essentially all rice in the USA is produced under flooded conditions as a means of controlling weeds and stabilizing yields. Nutrient availability is very different under anaerobic (flooded) conditions typical of rice production as compared to dryland, or row cropping, systems. In addition, rice is typically grown in heavy clay soils or those with a shallow hardpan in order to sustain field flooding. Thus, organic nutrient management methods that have been developed for other crops may have limited use in rice and few studies have been conducted in flooded-rice systems using organic-based fertilizers.

A field experiment was conducted at the Texas A&M AgriLife Research and Extension Center near Beaumont, Texas, U.S.A. The soil was a League clay soil (fine, montmorillonitic, Entic Pelludert) with 28% silt, 58% clay, 1.2% organic matter, and pH 5.5. Mean annual temperature for 2015 was 20^0C for the Beaumont Center.

The cropping system has been one-year rice and one-year fallow for more than five years. A randomized factorial design with four replications was used for the study. The two factors were rice variety (hybrid XL753 vs. inbred Tesani 2) and nitrogen fertilization rate (0, 50, 100, 150, 200, and 250 kg/ha). Rice was dry seeded around 1 cm in depth using a planter with a seeding rate of 323 and 162 seedlings m^{-2} for inbreds and hybrids, respectively. The rice was grown with flush irrigation until the two- to three-leaf growth stage and then a permanent flood (2-5 cm above the tip of rice leaves) was imposed and maintained until five-leaf stage to control weeds. After five-leaf stage, a 5-10 cm floodwater was maintained until maturity. Nature safe (13-0-0) as the nitrogen source was manually applied at plating. At maturity, a small plot combine was used to harvest each plot individually for assessment of rice grain yield. The harvested rice grains were weighed, analyzed for moisture content, and the reported grain yields adjusted to a uniform moisture content of 120 g H_2O kg^{-1} before statistical analysis.

Rice grain yield was a positive, linear function of N rate, regardless of variety, increasing as N rate increased and followed the general order of 250 > 200 > 150 > 100> 50 > 0 kg/ha. Both Tesanai 2 and Hybrid XL753 had good yields of 8,371 and 7,890 kg/ha, respectively. For all tested nine varieties, both hybrids, XL753 and CLXL745 had highest grain yields and Seria had lost the yield due to severe weed pressure.

N-Stabilizers and Temperature Effect on NH3 Volatilization and N2O Emissions from Poultry Litter

Dodla, S., Adotey, N., Meng, Y., Harrell, D., Kongchum, M., and Wang, J.J.

Poultry litter (PL) is used as a multi-nutrient fertilizer, which supplies both macro and micro plant nutrients, in the rice cultivation. Relatively low levels of nitrogen (N) combined with significant N-losses through ammonia (NH3) volatilization, nitrous oxide (N_2O) emissions and leaching of NH_4^+ and NO_3^- requires large quantities of PL to provide adequate N, which increases production costs. There is a need to identify ways to minimize N-losses from PL applied soils. Similar to inorganic fertilizers, it is possible to minimize N-losses or improve N use efficiency (NUE) of PL applied soil by the use of N-stabilizing compounds such as NBPT, and DCD. A three-year study in corn and cotton to evaluate the efficacy of NBPT and DCD to improve NUE in PL applied soils gave contrasting results. While N-stabilizers improved NUE in cotton crop, no improvement of NUE was observed for corn. Due to differences in seasonal temperatures for corn and cotton, this indicated possible effects of temperature on the efficacy of N-stabilizers to minimize N-losses from PL applied soils. To determine the effect of temperature on the efficacy N-stabilizers to minimize N-losses, a three-week laboratory incubation study was conducted with a hypothesis that temperature will have significant on the efficacy of N-stabilizers.

The study had two temperatures 23 and 30°C as main treatments and 3 N-stabilizers, NBPT, DCD and K32 (a formaldehyde based compound) along with a control (PL only) as sub-treatments. N-stabilizers were applied at one rate that decreased N-losses in our field studies. For the incubation study: 500 g of a silty loam soil was weighed into a 1L jar followed by the surface application of PL at 180 kg N ha^{-1}, addition of DI water to bring the soil moisture to 60% of the field capacity, and application of N-stabilizers. Jars were placed in temperature-controlled chambers at 23 and 30°C followed by sealing the jars with lids that have rubber septa to collect headspace gas samples and to continuously flush hydrated NH_3 free air to flush out the NH_3 released from the jars into an acid trap. The incubation study was conducted for 4 weeks. Acid traps were replaced every day with new solutions, while the collected acid traps were analyzed for NH_3, trapped from each incubation jar, using flow injection analyzer. At the selected intervals, flushing of jars was stopped for 4 hours to monitor the N_2O emissions by collecting headspace gas samples at time 0 and 4 h. The headspace gas samples collected in to pre-vacuumed vials were analyzed using a GC equipped with ECD detector.

The results revealed that NPBT and K32 compounds did not affect NH_3 losses at 23°C, while DCD lead to 29% increase compared to the control. This could be attributed to suppression of NH_4^+ ion oxidation by DCD leading to losses of N as NH_3. On the other hand, incubation at 30°C, significantly increased NH_3 emissions. At 30°C, NH_3 emissions from control increased by 73% compared to control at 23°C. At 30°C, NBPT and K32 decreased NH_3 losses by 33 and 20%, respectively, compared to control. Similar to 23°C treatment, DCD application led to higher NH_3 losses compared to control at 30°C.

Increase in temperature from 23 to 30°C significantly increased the N_2O emissions in all sub-treatments. At 23°C, NBPT and K32 increased N_2O emissions by 101 and 76%, respectively, compared to control. However, application of DCD significantly decreased N_2O emissions by 95% compared to control. Similar to 23°C treatment, N-stabilizers NBPT and K32 increased N_2O emissions by 3.9 and 4.1 times, respectively, compared to control, while DCD decreased N_2O emissions by 31%. These results prove that DCD was very effective to suppress nitrification in PL applied soils, similar to inorganic-N fertilizer applied soils, leading to lower N-losses as N_2O. The effectiveness of DCD was lower at higher temperature. Additional research is needed to understand the increased N-loss as N_2O by NBPT and K32. The study revealed that temperature significantly effects the N-losses as NH_3 and N_2O. While N-stabilizers can minimize N-losses from PL applied soils, they were more effective at minimizing NH_3 losses at the higher temperature. Though DCD is effective in reducing N-loss as N_2O, its efficacy was lower at the higher temperature.

Effect of Nitrogen Source and Rate on Soil Microbial Community Structure during Rice Production

Li, X., Dou, F., Guo, J., Velarca, M.V., Chen, K., Gentry, T., and McNear, D.

Selections of nitrogen source, rate and cropping system are important management practices to meet increasing demand in rice yield. Soil microbial community structure shifts with changes in management practices and varies at different rice growth stages. A greenhouse trial was conducted to study effects of rice cultivation (XL753), cropping system (organic system received Nature Safe, and conventional system received Urea), and nitrogen rate (0, 50, 100, 150, 200, and 250 kg N ha^{-1}) on PLFA profiling of microbial community structure at four growth stages of rice (Day 8 germination, D39 maximum tillering, D55 heading, and D111 after harvest). Total microbial biomass (TMB) was significantly ($P < 0.0001$) higher in soils with rice cultivation than control and significantly ($P < 0.0001$) affected by growth stages, which was dramatically higher at D111 (261 nmol g^{-1}, in average) than at D8 (72.4 nmol g^{-1}), D39 (61.9 nmol g^{-1}), and D55 (71.0 nmol g^{-1}). Of TMB, General FAME (average 30.5%) > G+ or G− bacteria (25.7%, 24.9%) > Actinomycetes (12.8%) > Fungi or Arbuscular Mycorrhizal Fungi (2.5%, 2.8%) > Protozoa (0.9%). Rice growth stages significantly ($P < 0.001$) affected all individual PLFAs; nitrogen rate only had significant ($P < 0.05$) effect on fungal PLFAs; while neither N source nor cultivation had significant effect ($P > 0.05$) on any individual PLFAs. Bacterial PLFAs, rather than fungal, dominated the community with a mean bacterial / fungal ratio of 11.3 – 13.8, which was significantly higher ($P < 0.0001$) at heading than other stages, higher ($P < 0.05$) in Control than XL753, and higher in Urea than Nature Safe. The result indicated that the capacity of soil to sequester C, reflected by B/F ratio, was lower at heading than other stages, lower in control soils than soils with rice cultivation, and lower in conventional system than organic system.

Yield Gap Analysis and Prognosis of Yield Increase of Irrigated Rice in Uruguay

Carracelas, G., Grassini, P., Guilpart, N., Cassman, K., and Zorrilla, G.

The Uruguayan rice sector has become one of the most successful and most integrated agricultural industries in the country, which has contributed to increased yields at one of the highest rates worldwide (145kg^{-1} ha^{-1} yr^{-1} from 2000 to 2017). However, this yield trend has shown a marked slowdown in recent years, which may be indicating that average rice yields are approaching the biophysical yield ceiling. A robust yield gap analysis was conducted to distinguish between a temporary or permanent yield plateau and determine if would be possible to further increase yields in Uruguay. For this purpose rice yield potential (Yp) and current exploitable yield gaps (Yg) were estimated at local farm-level to regional and national scales, and a comparative analysis with other rice countries included in the Global Yield Gap Atlas (GYGA) was conducted. Estimation of rice Yp and Yg is essential to identify opportunities for future yield gains. Also unknown was if the rapid rate of increase in Uruguayan rice yields since 2000 was associated with favorable climate change.

Methodology developed by GYGA (www.yieldgap.org) was followed to select data sources, define the agro-climatic zones, simulate rice Yp and estimate Yg at reference weather stations (RWS) within Uruguay. Data on current farm yields (Ya) were collected from the Uruguayan rice Industry database. The crop simulation model Oryza (v3) was used to simulate Yp over a period of 18 years for each of the 7 selected RWS. Two independent datasets were used for model calibration and validation. Comparison of simulated flowering and maturity dates against measured collected data from experiments and yield validation indicated good agreement between simulated and observed values giving confidence in model performance for rice in Uruguay.

The *exploitable* Yg was calculated as the difference between 80% of Yp and average Ya over five years (2010-2014). Estimated national average Yp was 14 t ha^{-1} (14% moisture) with a relatively small range across RWS of 13.0-14.7 t ha^{-1}. Average Ya across RWS was 8 t ha^{-1} ranging from 7.7 to 8.5 t ha^{-1}, which gives a national Yg = 3 t ha^{-1} with a range of 1.9-4.1 t ha^{-1}. The lack of significant trend in the average yield potential in Uruguay during the 18 years analyzed ($P<0.05$) indicates there was no significant effect of climate change on the rate of rice yield increase for most regions in Uruguay. Because current Ya is only 57% of Yp, it should be possible to continue improving rice yields and close much of the existing Yg. An additional 0.5 million metric tons of rice production would be possible if average farm yields reached 80% of Yp. Comparing these results with that for rice in other countries included in the GYGA, shows that it would be possible to maintain or increase yields within existing rice production areas, which will contribute to meet the growing demand for rice worldwide.

Effect of Long-term Potassium Fertilization on Rice Yield and Mehlich 3 Extractable Potassium

Jones, G.T., Slaton, N.A., Norman, R.J., Roberts, T.L., DeLong, R.E., and Liyew, Y.D.

Potassium (K) is important in dry matter production, stalk strength, and other plant health components that contribute to yield in rice [*Oryza sativa (L.)*]. In the mid-South, rice is most commonly grown in rotation with soybean [*Glycine max (L.) Merr.*], which has a high demand for K. A long-term trial has been conducted on a Calhoun silt loam for the previous 18 years to determine the effect of five fertilizer-K rates (149, 112, 75, 37 and 0 kg K ha^{-1}) on rice and soybean yields and Mehlich 3 extractable soil K. Regression analysis was performed to determine crop yield and extractable soil K trends among K rates over time.

Rice yield was a quadratic function across time that was dependent upon annual K rate. When averaged over nine rice crops (years), rice yields averaged 7044, 8102, 8499, 8677, and 8887 kg ha^{-1} for the 0, 37, 75, 112, and 149 kg K ha^{-1} rates, respectively. Rice yields were not significantly different in the first year of the study. Since the third year of rice (year 5 of the study), rice yields in the 0 kg K ha^{-1} have been significantly lower than all other treatments with relative yields ranging from 75 to 85% of the maximum yields produced by rice receiving fertilizer K. Also, since the third rice crop, rice fertilized with 37 kg K ha^{-1} has produced yields significantly lower than rice fertilized with 75 to 149 kg K ha^{-1}. Maximal numeric rice yields have been produced by rice fertilized with 149 kg K ha^{-1}, but the predicted yields have been greater than the yields of rice fertilized with 75 and 112 kg K ha^{-1} rates in four (112 kg K ha^{-1}) or six (75 kg K ha^{-1}) of the nine rice crops. Numerical relative yield differences among the 75 to 149 kg K ha^{-1} $year^{-1}$ rates have ranged from 0 to 8%. Mehlich 3 extractable K was dependent on annual K rate and responded linearly across time. Soil test K values were 91, 94, 96, 103, and 101 ppm in 0 to 149 kg K ha^{-1} plots after the first year of rice production. The 2017 soil test K results showed mean soil-test K values of 43, 54, 65, 78, and 92 ppm for the five annual K rates in increasing order, respectively, with all treatments being significantly different from each other for the past 10 years. This trial shows that on the loamy soils used for rice and soybean production in Arkansas, long-term omission or application of below optimal K rates results in reduced rice yields and low soil-test K values. It should be noted that for soil receiving the greatest annual K rate, soil-test K has remained nearly constant across time despite a large positive K balance (input greater than removal).

Does Moist Soil Analysis Improve Soil-Test Based Potassium Fertilizer Recommendations for Rice?

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

Mehlich-3 extractable potassium (K) has been shown to be a relatively good predictor of soil K availability for flood-irrigated rice (*Oryza sativa* L.) produced in Arkansas. The standard method for processing soil for routine soil testing is oven drying so that soil samples can be mixed and subsampled for extraction without having to account for differences in water content. Research has shown that oven drying soil influences the amount of K extracted and that K extracted from field-moist soil is a better predictor of corn (*Zea mays* L.) and soybean [*Glycine max* (L) Merr.] response to K fertilization. Our research objective was to evaluate whether Mehlich-3 K extracted from field-moist or oven-dry soil was a better predictor of flood-irrigated rice response to K fertilization. Rice K rate trials were conducted at 23 site-years to evaluate rice yield response to fertilizer-K rate. Composite soil samples (0-10 cm depth) collected from each no fertilizer-K control were wet sieved to homogenize and divided into two subsamples with one sample being oven-dried and the other sample refrigerated in the moist state with a subsample used to determine soil moisture content. Rice whole, aboveground plant K concentration at R3-R4 stage and grain yield (expressed as yield increase and relative yield) were determined and each regressed against field-moist or oven-dry soil-test K using a quadratic model.

Oven-dry, Mehlich-3 K of the 23 soils ranged from 37 to 260 mg K kg^{-1} with a median value of 84 mg K kg^{-1}. In comparison, field-moist Mehlich-3 K of the 23 soils ranged from 25 to 145 mg K kg^{-1} with a median value of 65 mg K kg^{-1}. The differences (ΔK = dry – moist) in Mehlich-3 extractable K due to soil moisture status at the time of extraction ranged from -13 to 149 mg K kg^{-1}. Clayey-textured soils showed the greatest difference in extractable K with 50 to 149 mg K kg^{-1} more K extracted from oven-dry soil than field-moist soil. The ΔK range for silt loam soils was -13 to 26 mg K kg^{-1}. The oven-dry to field-moist soil K ratio of loamy-textured soils gradually decreased as oven-dry soil-test K increased being around 1.0 at 100 mg K kg^{-1}. Whole-plant K concentration, relative yield, and yield increase all showed significant quadratic relationships with field-moist and oven-dry soil-test K. The coefficient of determination of the final models were similar for relative yield [R^2 = 0.68 (dry) vs 0.68 (moist)], yield increase [R^2 = 0.66 (dry) vs 0.64 (moist), and whole plant K concentration [R^2 = 0.80 (dry) vs 0.81 (moist)].

These results suggest that field-moist and oven-dry soils are both excellent predictors of rice plant K concentrations and relative yield response to K fertilization. The major difference was that extraction of K from field-moist soil was much lower and on a similar scale as the loamy soils. Field-moist soil might be a more accurate predictor of soil K availability in geographic areas with a more diverse range of soil clay contents or clay types that have vastly different amounts of K.

Irrigation Advancements in Furrow Irrigated Rice

Henry, C.G., Mane, R., Kandpal, V., and Pickelmann, D.M.

Furrow irrigated rice provides an opportunity to increase the profitability of rice production, but growers are successful and sometimes less successfully producing rice under furrow irrigation. Much work is necessary in the areas of irrigation, variety selection, nitrogen forms, amounts and application, weed management, pathology, and insect management.

Field experiments for furrow irrigated rice were conducted on a 16.18 hectare (40 acre) field at the Rice Research and Extension Center in Stuttgart, Arkansas, on a Dewitt silt loam using a novel variable flow tail water recovery system. Yield differences were observed in the varieties. All hybrid rice varieties performed significantly better than the conventional rice varieties. Highest yield of 9,532 kg ha^{-1} (189 bu/ac) was obtained from XL753. Average yield from all hybrid rice varieties was 8,776 kg ha^{-1} (174 bu/ac) while 6,556 kg ha^{-1} (130 bu/ac) was measured for conventional rice varieties.

A total of 2.72 ML ha^{-1} (11 ac-in/ac) of water was applied from irrigation, 2.22 ML ha^{-1} (9 ac-in/ac) of rainfall was received, and 1.73 ML ha^{-1} (7 ac-in/ac) of water was lost as runoff which includes runoff from high rainfall events. Annual average water use on contour or precision grade rice systems reported from the Arkansas Rice Research Verification Program has been reported in previous work to be 7.91 ML ha^{-1} (32 ac-in/ac). Thus 2.72 ML ha^{-1} (11 ac-in/ac) of irrigation in a furrow irrigated rice system is a substantial reduction in water use. On-farm comparisons used an average of 4.74 ML ha^{-1} (19.2 ac-in/ac) on furrow irrigated fields, so this is a reduction of about half using the novel system.

The study also evaluated nitrogen source differences. Using a rate of 75 units urea, an additional 75 unites was applied to replicated treatment of; 150 total units urea pre-plant, split urea 50 days after planting, Environmentally Safe Urea of 75 units at day 50 after planting, and 32% UAN fertigated at day 50 after planting. No yield differences were found between the nitrogen source treatments. Normalized Difference Vegetation Index (NVDI, Trimble Green Seeker™) was used to ensure adequate nitrogen was available in the study, according to University of Arkansas recommendations, using reference areas in the top and bottom of the field. NVDI values were significantly higher for plants in the middle and bottom position along the furrow length in comparison to plants at top position ($p<0.0001$).

However the ratio of the readings to the reference value did not indicate any additional nitrogen was needed (<1.15). Yield decreased from the bottom of the field (data not shown) by on average 408 to 612 kg (20-30 bushels).

Twelve paired comparisons of production fields on farmer managed fields comparing furrow irrigated rice and conventional flooded rice was conducted in 2016 and 2017. There was no significant difference in average yield of furrow irrigated rice was 171 bpa and flooded rice was 181 bpa (p=0.15). There was no significant difference in water use between furrow irrigated rice and flooded rice (p=0.71). Water use in furrow irrigated rice was found to be 19.1 ac-in/ac but was highly variable with a high of 15.57 ML ha^{-1} (63 ac-in/ac) and a minimum of 2.77 ML ha^{-1} (11.2 ac-in/ac) compared to an average water use for flooded levees of 5.02 ML ha^{-1} (20.3 ac-in/ac), with a maximum of 13.00 ML ha^{-1} (52.6 ac-in/ac) and a minimum of 3.53 ML ha^{-1} 14.3 ac-in/ac.

In summary, there appears to be a need for recommendations on water and fertilizer management that are specific to furrow irrigated rice. These findings show that there is an opportunity to substantially reduce water use on furrow irrigated rice. The findings also indicate that other forms of nitrogen can be used which can reduce the production cost of furrow irrigated rice.

Evapotranspiration and CO_2 Dynamics in AWD Irrigated Rice Production

Runkle, B.R.K., Reba, M.L., Suvočarev, K., and Reavis, C.

Water saving irrigation strategies are recommended and incentivized in order to reduce water use, decrease field methane emissions, and save energy costs associated with agriculture. One useful method, the Alternate Wetting and Drying (AWD) irrigation practice, suggests multiple 3-10 day periods of non-inundated conditions followed by re-flooding the rice field. In this talk we discuss the changes that AWD irrigation may provoke in evapotranspiration (ET) and CO_2 flux dynamics. Such an analysis provides: first, a valuable assessment of whether AWD creates drought stress responses in the rice crop, as seen either through canopy photosynthesis or water use; second, quantification of the major part of the growing season water balance; and third, quantification of the growing season carbon balance. The carbon balance in a rice field under AWD conditions is particularly important as the method is often used to reduce field methane emissions and a more complete accounting is needed to place this reduction in a broader context. Additionally, as soil organic matter is crucial for plant productivity and for methane production, quantifying the carbon balance helps constrain estimates of change in organic matter.

This work is presented from a pair of adjacent, production-sized rice fields where measurement and comparisons took place during the 2015 to 2017 growing seasons using the eddy covariance method on each field. Gaps in the eddy covariance time series are filled with an artificial neural network model associating various meteorological and crop-growth parameters to ET and CO_2 fluxes. The studied fields, in Lonoke County, Arkansas, have poorly-drained Perry silty clay soils and have been zero-graded. The fields were alternately treated with continuous flood (CF) and AWD irrigation.

Our initial findings show no evidence that AWD changes seasonal ET or CO_2 fluxes, suggesting that AWD does not provoke a stress response in either of these terms. These results are consistent with yield data taken from GPS-enabled combines across the production fields, where no significant differences in the harvest yield of rice with respect to irrigation treatment have been found. While we see relatively minor increases in respiration rates during some dry periods in AWD applications, from either a soil-carbon or a global-warming perspective, these increases are negligible compared to the concurrent reduction in CH_4 emissions.

Agronomic, Physiological and Biochemical Evaluations of Rice under a Water-Deficit Irrigation System

Rohila, J.S., Henry, C.G., Zhao, H., Lorence, A., and McClung, A.M.

The sustainability of conventional flood irrigation management in rice is a concern worldwide considering the uncertain patterns of precipitation and depletion of aquifers used for irrigation. This same concern is shared in USA rice producing areas and, thus, development of rice varieties that can tolerate water-deficit irrigation (such as alternate-wetting-and-drying, AWD) practices without a penalty on grain yield and quality is highly desired.

A multi-year study was conducted to evaluate rice cultivars and germplasm under precise deficit irrigation regimes using a subsurface drip irrigation system. The goal of this investigation was to identify cultivars that possess water-deficit stress tolerance with minimum yield penalty and to understand the biochemical and physiological nature of selected germplasm. Field trials were conducted using a randomized complete block design at DBNRRC/UofA research farm (N 34.46286°, W 91.39944°) for three years (2014-2016). A total of 15 rice cultivars representing a diverse genotypic range (indica, japonica, long grain, and medium grain) were evaluated in a replicated trial using four soil moisture regimes: Treatment 1: fully saturated (field capacity, FC), Treatment 2: 30% deficit, Treatment 3: 70% deficit, and Treatment 4: just above the wilting point. Two-row plots were drill planted each year (May-June) in such a way that the buried drip tape was between the two rows in the plot. To prevent water exchange between the treatments, 4 buffer rows of rice (cv. RoyJ) were planted between the irrigation treatments. Fertilizer and herbicide was applied according to local rice agronomic practices. Plots were thinned to a uniform plant stand and two-four seedlings were selected in the middle of the row and tagged for season-long defined measurements. Plots were fully irrigated until the V5 stage when irrigation treatments were initiated. To target certain soil moisture levels for each treatment, the irrigation valves were automatically controlled based on Acclima water moisture sensors, which were placed in rhizosphere of each treatment at 20 cm depth. Throughout the season actual soil moisture was monitored on each plot through a portable soil moisture sensor.

On average, the total amount of irrigation applied in the most saturated treatment was 68.98 ha-cm compared to 36.34 ha-cm in the greatest water deficit treatment. Overall water-deficit stress treatments reduced plant height (91 cm to 79 cm), delayed heading dates (89 days to 93 days), and reduced grain yield per plant (26.5 g to 14.4 g) compared to the FC treatment. Regression analyses of the data support the developing hypothesis that the yield under water-deficit environment could be governed by thousand kernel weight trait. The cultivars were ranked for yield per se, and for yield stability across the four water regimes. In the final year of the study, foliar ascorbic acid (AsA) measurements were determined approximately 17 days before heading to evaluate the association between AsA and water-deficit stress tolerance. A selected set of genotypes were evaluated for net photosynthesis, stomatal conductance, and evaporation at this same stage. Based on the results an association was established between AsA, stomatal conductance, and yield under water-deficit stress tolerance and will be presented. The data supports that SDI is a viable and effective method for germplasm evaluation at a targeted water-deficit stress level. The study revealed that two mapping populations available at DBNRRC (PI 312777 x Katy, and Lemont x Teqing) are the best choices to screen under 20-40% water deficit conditions, while Rondo x Francis mapping population could be an excellent choice for higher water-deficit stress conditions and to look for transgressive variants among the mapping population.

Strategies to Minimize Water Used While Maintaining Grain Yields in Uruguayan Rice Systems

Carracelas, G., Hornbuckle, J., Riccetto, S., and Roel, A.

Water is a limiting factor for the expansion of rice crops as a high proportion of rice irrigation in Uruguay is done with water stored in dams. Irrigation management practices that increase water productivity (more or equal rice produced per volume of water used), would lead to an increase of rice planted area per year. Moreover, a reduction of water used to irrigate rice would allow to allocate water to irrigate other crops in a crop rotation and could reduce pumping irrigation costs. Improving water use efficiency would also allow farmers to irrigate properly the entire rice planted area during all the crop cycle, while minimizing risks and securing rice yield potential. The aim of this study was to determine irrigation management practices and field layout techniques that increase Water Productivity (WP) allowing a reduction in water used without negatively affecting grain yield. A summary of the joint analysis results of experiments carried out during three seasons (2011-2014) in three rice growing regions: East (Treinta y Tres), North (Artigas) and Center (Tacuarembó) are presented in this work.

A split plot experimental design trial was conducted in North and Central regions. Treatments included two types of systematization with different vertical (VI) interval between levees (big plots): I. Conventional (VI-8cm) and II. Alternative (VI-4cm), and three irrigation management practices (small plots): 1.Continuous (C), 2.Intermittent until panicle initiation (IP) and 3.Intermittent during all crop cycle (I). A complete randomized block design was conducted in the East region. A total of five treatments were evaluated; three continuous flooding treatments: flooding at 15, 30 (control) and 45 days after emergence (C15, C30 and C45) and two controlled irrigation treatments: intermittent irrigation (IP) and alternate wetting and drying (AWD). In C a water layer of 10cm is maintained after flooding throughout all the crop cycle. In IP and I the water layer is allowed to decrease and is re-established when the soil is still saturated. The AWD, alternates wetting and drying periods until panicle initiation, allowing a 50% depletion percentage of the available soil water in the first 30 cm depth (equivalent to 25 mm of water for this Brunosol soil), determined through a water balance using information from a weather station and soil tensiometers installed in the experimental area.

Intermittent irrigation (IP and I) led to a significant savings in water inputs in both North and Central regions (38%-5,567 m^3water ha^{-1} and 35% -2,798 m^3 water ha^{-1} respectively)) and a significant increase in water productivity. Considering only water from irrigation, WP was: 0.57(c), 0.73(b) and 0.88(a) (kg grain m^3 of $water^{-1}$) for C, IP and I respectively in the North. In the Central region WP was 0.99(c), 1.31(b), 2.00(a) kg grain m^3 of $water^{-1}$ for C, IP and I respectively (P< 0.05). Intermittent irrigation (IP and I) affected negatively industrial quality in both regions while grain yield was reduced (950 kg rice ha^{-1} less) only in the North. However, grain yield was not affected in low-infiltration rate soils (planosols) of Central Region (average = 7713 kg rice ha^{-1}). Regarding systematization, there were no significant differences in any of the parameters evaluated between treatments in the North and Central regions (P <0.05). The higher yields registered in the East region were obtained in the treatments CF15, CF30 and IP (10,592(a), 10,454(a) y 10,189(ab) kg ha^{-1}, respectively), followed by CF45 and AWD (9,653(bc) y 9,287(c) kg ha^{-1}, respectively) (P< 0.05). Mean irrigation water productivity was 1.31 kg of rice m^{-3} ranging from 1.18 (CF45) to 1.46 kg m^{-3} (AWD). Mean irrigation water used was 6150, 8044 and 10968 m^3 ha^{-1} in the Central, East and Northern region respectively.

This study helped to identify irrigation management practices that reduce water used while achieving high water productivity values. Intermittent irrigation (IP) during vegetative phase until panicle initiation in low infiltration soils (East and Center), reduced water used without affecting grain yield. Further research and validation is required in order to evaluate water Management strategies that maintain soil water depletion in a range that does not reduce rice grain yields and quality in both, experimental conditions and commercial farms.

Subsurface Water Losses: Seepage and Percolation in California Rice Fields

LaHue, G.T., and Linquist, B.A.

California rice fields receive 135 cm of applied water on average, more than almost any other crop grown in California. However, the evapotranspiration or consumptive water use by rice is similar to many other crops (approximately 85 cm). This discrepancy between applied water and consumptive water use is due to variable tailwater drainage as well as seepage and percolation losses. Here we define percolation as downward water movement below the root zone and seepage as lateral water movement at the borders of a rice field. Given the growing pressure to reduce agricultural water use, it is important to understand and quantify these subsurface water loss pathways.

In this study, we quantified seepage and percolation using (1) direct measurements of water loss from replicated percolation rings installed in eight fields, (2) direct measurements of water loss from nested three-sided metal seepage frames installed in different levee types at six fields, and (3) complete water balances for three commercial rice fields. Our results show that percolation is consistently low throughout the Sacramento Valley, ranging from less than 0.75 cm per season to approximately 5 cm per season. Lateral seepage losses through field border levees were more variable. However, the highest recorded seepage loss was still only 10 cubic meters of water per meter of levee per season (which translates to 5 cm per season for a square 40-ha field). Results from the complete water balances generally corroborated the low seepage and percolation rates seen in the direct measurements, although we were unable to account for 8% of the water on average. Percolation accounted for 0.8 – 2.5% of the applied water based on direct measurements and seepage accounted for 0.9 – 1.8% of the applied water. To our knowledge, the results presented here represent the first direct measurement of seepage and percolation in California rice fields. Our ongoing work seeks to understand the factors influencing these subsurface water losses.

Evaluation of Water Management Practices in a Drill Seeded Rice Production System on NUE, Water Use Efficiency, and Grain Yield

Kongchum, M., Harrell, D., and Adotey, N.

A field experiment was conducted to quantify and compare agronomic benefits of three different water management practices relative to the traditional delayed flood rice production system. Three water management practices including traditional delayed flooding, alternate wetting and drying (AWD), and semi-aerobic management were set as main-plots. Factorial arrangement of two rice varieties (CL153 and CLXL729) and three N application timings were set as sub-plots. Urea was used as nitrogen source at the rate of 168 kg N ha^{-1}. The three N application timings were 1) single 1-day preflood at 168 kg N ha^{-1}; 2) two split applications of 112 kg N ha^{-1} at 1-day preflood and 56 kg N ha^{-1} at panicle initiation (PI); and 3) three split applications of 90 kg N ha^{-1} at 1-day preflood, 39 kg N ha^{-1} at PI, and 39 kg N ha^{-1} at late boot.

Average nitrogen use efficiency (NUE) at the 50% heading growth stage over rice varieties and N application methods was not different by the water management practices (60, 60, and 52% in traditional delayed flooding, AWD, and semi-aerobic). When comparing NUE by rice varieties over N application methods, CL153 had a higher NUE in the single preflood and two split applications than CLXL729, but CLXL729 had a higher NUE than CL153 in the three split applications (90 kg N ha^{-1} at 1-day preflood, 39 kg N ha^{-1} at PI, and 39 kg N ha^{-1} at late boot).

Rice grain yield was significantly different by water management treatments. Average grain yields over two rice varieties and three N application times were 9,753; 9,274; and 5,841 kg ha^{-1} for traditional delayed flooding, AWD, and semi-aerobic. A Single preflood N application of 168 kg N ha^{-1} showed the highest yield (10,317 kg ha^{-1}) followed by two-split applications (10,137 kg ha^{-1}), and three-split applications (9,483 kg ha^{-1}) but there were no significant differences.

Irrigation water use in AWD and semi-aerobic were 31.5 and 36.7% less than the traditional delayed flood. However, yield reductions were 4.5 and 42.8% in the AWD and semi-aerobic treatments for CL153 and 4.1 and 39.5% in the same treatments for CLXL729, respectively. In addition, the average water productivity indexes over rice varieties and fertilizer application methods were 1.04, 1.03, and 1.65 kg m^{-3} in traditional delayed flood, AWD, and semi-aerobic practice.

Even though reducing water use by AWD practice did not show significant yield reduction, the equivalent tradeoff between these two factors should be further investigated. Semi-aerobic was not a good option for drill-seeded cultivation.

Insights into the Operational Mechanisms and Optimization of Multiple-Inlet Rice Irrigation

Massey, J.H., Smith, M.C., Vieira, D.A.N., Adviento-Borbe, M.A., Reba, M.L., and Vories, E.D.

Generalized water-balance equations were used to compare irrigation applications made using single-inlet (SI) or multiple-inlet rice irrigation (MIRI) flood distribution systems for a 16-ha, clay soil, straight-levee field typical of the Lower Mississippi River Valley (LMRV). MIRI distributes irrigation to all paddies of a field simultaneously versus only the top of a field using SI. This relatively simple change from SI to MIRI decreased irrigation applications by an average of 24 ± 2% over an 86-d flood when modeled using 260 site-years of rainfall. It was assumed that irrigation was halted as soon as field runoff occurred. Even in the absence of rainfall, MIRI required 22% less irrigation than SI. Thus, these MIRI irrigation reductions were due mostly to improved distribution uniformity and, thus, could be expected to occur even in the absence of rainfall. This is largely because MIRI negates the need to overfill paddies which SI requires in order to push irrigation water downfield over levee gates. It is this irrigation “overage” that makes SI difficult to control, thereby increasing its propensity to cause runoff.

To study rainfall capture potential, the following Kolmogorov-Smirnov quantiles were calculated for historical daily rainfall measured at nine locations in the LMRV: 50% (5 mm rainfall), 75% (15 mm), 90% (28 mm), 95% (40 mm), and 99% (67 mm). Thus, 99% of daily rainfall over the past 31 years was 67 mm or less at these locations. These values were used as model settings to determine how much rainfall could be captured when these freeboard depths are maintained. Results indicate that 28 mm freeboard was sufficient to reduce irrigation inputs by an additional 9% beyond the 24% MIRI savings achieved without freeboard optimization. According to these analyses, freeboard depths in excess of 28 mm did not, on average, result in significant additional rainfall capture.

Taken together, these results reinforce university extension efforts that stress the importance of proper management in realizing the water-conserving benefits of MIRI. Namely, halting irrigation as soon as (preferably before) runoff occurs and maintaining at least 28 mm freeboard to capture rain. The results also support efforts to automate irrigation monitoring and control as it is not always possible for producers to carefully monitor fields and/or shut off irrigation pumps in a timely manner. By adopting MIRI as the industry standard and managing it in this way, rice irrigation inputs could potentially be reduced by 30% or more relative to SI. In turn, this could help to slow declines in the Mississippi River Valley alluvial aquifer, a resource of national and international significance.

Evaluation of Alternate Wetting and Drying Irrigation for Mid-South Rice Production

Atwill, R.L., Krutz, L.J., Bond, J.A., Golden, B.R., and Walker, T.W.

Rice irrigation currently accounts for the greatest amount of irrigation water applied per acre over corn, soybeans, and cotton in the mid-south. The alluvial aquifer serves as the major source of irrigation water for rice production in Mississippi; however, it is declining at a rate of 37,000 ha-m yr^{-1} and has done so for approximately 35 years. An experiment was conducted at the Delta Research and Extension Center in Stoneville, MS to evaluate the yield and physiological response of rice to alternate wetting and drying (AWD) as compared to a continuous flood.

Three rice cultivars were evaluated in six different rice irrigation treatments that include: a continuous flood, irrigation with water level thresholds at the soil surface, 10 cm below the soil surface, 20 cm below the soil surface, 30 cm below the soil surface, and 40 cm below the soil surface. Water level in each paddy was monitored and irrigation events were triggered at each respective threshold back to a 10 cm flood then allowed to subside until threshold was reached. Rice grain yield response of two AWD treatments were equal to rice grown with a continuous flood. Grain yield increased by 4% when the flood within a paddy was allowed to recede to the soil surface compared to a continuous flood. Grain yield for continuous flood was equal to rice grown with flood receding to 10 cm below soil surface. Reduction of grain yield was observed when the flood receded 20 cm below the soil surface as compared to a continuous flood. Data from this experiment from 2015-2017 suggest that allowing flood to subside to 10 cm below the soil surface does not result in yield loss compared to a continuous flooded system. Additionally, conventional and Clearfield herbicides were applied at different growth stages and evaluated for weed control. Data from this experiment suggest that furrow irrigation for mid-south rice production may be economically feasible, and results of furrow irrigation water management strategies on total water use, rice yield, weed control and economic return will be discussed at length. Water management practices that reduce groundwater withdrawals are a viable option for rice producers in the mid-south.

Evaluation of Flood Timing on Rice Agronomics in a Drill-seeded Delayed Flood Rice Production System

Adotey, N., Harrell, D.L., Kongchum, M., Leonards, R., Fluitt, J., and Hartman, J.

Urea is the most commonly used preflood N fertilizer because of its economic advantage compared to other N fertilizer sources. In the southern United States, where a delayed-flood rice production is practiced, urea is surface broadcast at the 4- to 5-leaf stage of rice development followed by the establishment of a permanent flood. In recent years, there have been rainfall events during the recommended time for urea fertilization. Rice producer have expressed concern on how late they can delay urea application without incurring significant yield losses. Most of the research that has evaluated the effect of urea fertilization and flood time on rice yield used older rice cultivars. There is limited information on the potential yield loss if N is applied earlier or delayed beyond the recommended application time particularly for new rice cultivar with short vegetative growth periods. The objective of this study was to evaluate the effect of different flood timings on rice grain yield in a drill-seeded, delayed flood rice production system.

A three-year field study (2015 – 2017) was conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, to evaluate the influence of flood timings at different rice growing stages on rice grain yield. The trial consisted of seven cultivars: Cheniere, CL111, CL151, CLXL745, Jupiter, Mermentau, and XL753. The cultivars were within an area surrounded by a single levee for flooding at different times resulting in five bays. In 2015 and 2017, the flood timings were 0, 7, 14, 21, and 28 days after CL111 reached the 2-3 leaf stage. In 2016, the flood timings were 0, 7, 14, 21, and 28 days after CL111 reached the first tiller. Urea was surface-broadcast at 135 kg ha^{-1} a day before permanent flood establishment. Individual rice plots were harvested using a Wintersteiger Delta equipped with a HM800 Harvest Master H2 Gauge system.

The mean grain yield pooled across years and flood timings for Cheniere, Mermentau, CL111, Jupiter, CL151, CLXL745, XL753 was 8664, 8739, 8857, 9274, 9849, 10646, and 11346 kg ha^{-1}, respectively. The grain yield of XL753 was significantly greater than other cultivars. The lowest yields were from Cheniere, Mermentau, and CL111 which were all significantly lower than the other cultivars. The predicted maximum relative grain yield from the regression analysis for Jupiter, CLXL745, Cheniere, CL151, CL151, CL111, and Mermentau was 800, 820, 900, 800, 860, and 1100 growing degree days (DD50 heat units), respectively. Based on the results of this study, urea application can be delayed up to 1200 growing degree days (2nd to 3rd tiller) without significant loss in grain yield.

Adoption Rates of Rice Irrigation Practices in the Mid-South

Henry, C.G., Krutz, L., Henggeler, J., Kovacs, K., Huang, Q.Q., and Levy, R.J.

Project Rationale: In 2015, four mid-South states (Arkansas, Mississippi, Louisiana, and Missouri) received a grant from the Mid-South Soybean Board for the purpose of increasing the profitability for soybean growers in the mid-South, specifically through improving their irrigation efficiency. The four-state, county-by-county regional irrigation survey was conducted in 2015 of irrigators regarding a variety of irrigation practices specific to mid-South growers. Direct phone contact was used, affording a good cooperation rate (between 22.8% and 32.3%, with a margin of error of 4.6%); final results represented 0.412 million hectares (1.02 irrigated million acres), or 8% of the acres in the region. Of this reported-on acreage, 20% of it involved rice, making it --behind soybeans (55%)-- the second most reported-on crop. The farmer anticipated rice yields were generally 10% higher than recorded statewide rice yields for the period 2013 to 2015. Of the four states, farmers from MS and MO had smaller percentages of irrigation farmers growing rice (19.6 and 20.8%, respectively), while 39.8 of LA and 68.7% of AR irrigated farmers reported that they grew rice in 2015. Unique among the four states, Louisiana rice was very often (74.3%) grown monoculturally. MS and MO had no rice-only farms, while AR had only 2.9% of the farms growing no other crop but rice. The other investigated crops were corn, cotton, peanuts, and grain sorghum.

Nearly 200 of the survey cooperators grew some amount of rice in 2015. Some queried management practices, primarily associated with rice production, included: land-forming (zero grade, constant slope, warped slope), irrigation method (flood, furrow, pivot), and use of water capture methods (tailwater pits and ponding reservoirs), field application methods. For some of the BMPs, additional information was also collected on reasons why/why not a practice was adopted, funding method, and when the practiced was first begun. Additionally, related socio-economic was collected, including stake-holder status (operator or owner operator), anxiety regarding future water resources, experience level (years) education level, household income, and farm size.

Respondents indicated that 54% of the production systems used was precision grade, with 26% contour levee systems. 8% of the acres reported were using the zero grade system. Surprisingly 10% of the acres were reported to be in furrow irrigated rice and 2% of the acres in sprinkler rice. Respondents report a 23% perceived savings from zero grade rice and a 13% savings from MIRI.

Changes in rice irrigation BMPs adoption and use over time/space within the mid-South are able to be examined. 48% of respondents reported applying Multiple Inlet Rice Irrigation (MIRI) to precision grade fields and 71% to contour levee fields. Most respondents report that they saw the benefit on their farm as the most common reason they implemented MIRI and "it does not work on my farm" as the most common reason they do not implement MIRI.

The source of irrigation water was examined. As an aggregate, almost a quarter of the irrigation in the four states came from non-Ground Water sources. Ground water, the largest water source, supplied 72.2% of the rice irrigation water, then followed by directly tapped streams (14.4%); stream water that was stored on-farm in reservoirs prior to being used supplied 3.8% of the irrigation. Thus, in full, stream water can be credited with supplying 18.2% of the water used, and the actual stream contribution is higher, since unknown amounts of it ended up in tail water pits, later to be used. This joint reservoir-tail pit water was 5.5% of the total. These impoundment structures also were utilized to capture no-outside-source water (3.7%). Water district supplies, only used in AR, provided just 0.3% of the total. Missouri had the highest percent of ground water utilization (98%); followed by MS, LA, and finally by AR with percentages of 84, 74, and 68%, respectively.

Tail Water Systems (TWSs) generally associated with surface irrigation, were found in each state, but more notably in AR and MS than MO and LA. Although farms that grew rice were less than 20% of the total farms, these rice farms had an inordinate number of these TWSs – 67.3% on a farm basis and 73.5% on an aerial basis. Arkansas, by far, had the highest TWSs use, both in reported numbers and area serviced. In AR, the rice farms were replete with TWSs, whereas, farms not growing rice did not make near as much use of them.

Abstracts of Posters on Rice Culture
Panel Chair: Randall (Cass) Mutters

Root Biomass as a Major Means of Affecting Methane Emissions

Kim, W.J., Barnaby, J.Y., Liem, B., Chun, J.B., McClung, A.M., Adviento-Borbe, A., and Pinson, S.R.M.

Human activities are contributing to greenhouse gas emissions. Methane, the second most abundant greenhouse gas, is ~25 times more potent in global warming potential than carbon dioxide, and 7-17% of atmospheric methane comes from paddy rice fields. The purpose of the study was to investigate genetic variation in methane emissions; therefore, five rice cultivars were examined to relate seasonal methane profiles with anatomical and/or physiological characteristics i.e. root and shoot biomass, tiller number, aerenchyma density, plant height, developmental stage, etc. The results showed that root biomass was a major driver that affected total methane emissions. Further quantification of methane emissions was performed with 10 recombinant inbred lines of a bi-parental mapping population segregating for root biomass, and verified root biomass as a trait affecting methane emissions. Further soil microbiome analysis associated with root biomass is under investigation.

The Relations of Root System to Straighthead of Rice under Calcium and Nitrogen Treatments

Huang, B., Li. Y., Singh. S., Pokharel. M., Mahato, G., Ntamatungiro, S., and McClung, A.

The healthier the roots, the bigger the plants and fruits. Plants that have a strong root system have a better chance of producing the quality of produce. Rice straighthead is a physiology disorder that greatly reducing grain yield of rice. This study was to investigate the influence of calcium and nitrogen application on reducing straighthead that may relate to the larger and heather root system developed under the calcium and nitrogen treatments. Both greenhouse and field experiment were conducted to investigate the relationship between root system and the straighthead disorder. The green house experiment was conducted with treatments of calcium and nitrogen. The field experiment was conducted with the treatments of three level of calcium dosages. Root samples were collected from 30-day old seedlings. Root length of all the root samples was analyzed by Root Image Processor Win Rhizo 2012b version. Correlation analysis was done by SAS program version 12.0. Results showed a negative relationship between straighthead and root system. The r value of the greenhouse experiment was -0.708 which is significant at 0.01 level, and the r value of field experiment was 0.293 which also is significant at 0.01 level. Both greenhouse and field experiments showed that the bigger and heather root system developed under the treatments of calcium and nitrogen; and the larger root system developed, the less straighthead disorder occurred.

A Greenhouse Study of Seeding Method for Organic Rice Production Improvement

Bergmann, J.P., Kluge, A., Cody, D., Lundberg, E., Lundberg, J., and Jiang, J.

Rice production in California primarily utilizes presoaked seed, which is then seeded by airplane onto flooded fields. However this method is not available to growers cultivating colored bran rice, as seeding by air presents a contamination risk to neighboring fields. Because of this restriction, colored bran rice is currently ground seeded by broadcasting dry seed onto dry soil. The objective of this study was to investigate the effect of seeding method on weed competition, rice establishment, maturity, and grain yield for a specialty black rice variety 'LBJ-115' under organic culture management.

This study compared five different planting methods: (1) dry seed broadcast onto dry soil, (2) dry seed incorporated 2.5 cm into dry soil, (3) drill seeding 2.5 cm into moistened soil, (4) soaked seed broadcast onto undisturbed flooded soil, and (5) soaked seed broadcast into agitated flooded soil. The replicated drill seeded plots were subsurface irrigated to maintain moisture for 7 weeks before permanent flooding, while all other treatments were replicated and subjected to 24.4 or 30.5 cm deep water to simulate organic field operations for weed control. Significant effects of planting method and water depth were found on yield, plant establishment, weed density, and maturity. Yield did not differ significantly among planting methods 1, 3, 4, and 5 with an average yield of 3,891 kg/ha, however, planting method 2 displayed a significantly reduced grain yield (1,328 kg/ha). The yield reduction was mirrored by a 78% reduction in plant density with planting method 2 (97 plants/square meter), compared to the combined average for all other treatments (430 plants/m^2). Overall, drill-seeded plots had better rice establishment and higher yield than all other treatments, despite more watergrass weed pressure (52.6 watergrass/m^2) than the average of all other treatments (6.6 watergrass/m^2). We also observed delayed maturity in drill seeded plots by approximately 1 week (75 days to 50% heading), compared to 67 days for remaining treatments.

Water depth was found to be negatively correlated with weed pressure, with shallow and deep water treatments averaging 10.5 and 2.8 watergrass/m^2, respectively. However, for LBJ-115, a variety with weak seedling vigor, a shallow water treatment at 24.4 cm produced more grain than a deep water treatment at 30.5 cm, with average yields of 3,887 and 2,546 kg/ha, respectively. Deep water treatments showed a trend toward reduced rice establishment, which may explain the reduced yield observed. These results demonstrated a strong influence of planting method and water management on rice establishment and weed suppression, indicating that organic production of a weak rice variety could be improved by planting pre-soaked seed into flooded fields and using a moderate water depth or using the drill-seeding method for better crop establishment.

Top-Dress Fertilizer Efficacy Trials in Organic Rice

Murray, A.C., Linquist, B.A., and Lundberg, A.

Weed control in organic rice systems is a major problem. In California organic rice systems, aquatic weeds are controlled by draining the field about 1 month after planting and leaving it dry for 3 to 4 weeks. Before reflooding, manure is often applied as a top-dress fertilizer to increase available nitrogen in the fields. Given the management costs and efforts required for this mid-season fertilizer application, it is important to determine the overall efficacy of these applications, as well as compare different application rates and nitrogen sources. We evaluated different N sources and rates at two locations (Woodland and Richvale). The experiment was set up as a randomized block design with six treatments replicated four times. The varieties were S-102 in Woodland and A-202 in Richvale. The manure sources were 12-3-0 (True Organic Products, Inc.), 6-3-2 (True Organic Products, Inc.), and 4-1-4 (Petaluma's Finest). The 12-3-0 was applied at three different rates (22, 45 and 67 kg N ha^{-1}) and the other fertilizers applied at a rate of 45 kg N ha^{-1}. These treatments were all compared to a control that received no top-dress N fertilizer. The pelletized material was broadcasted by hand over 28 m^2 plots just before reflooding the field. Soil and plant nitrogen were evaluated prior to fertilizer application and at harvest. Representative samples from each block were taken for soil (0-15 cm) and plants (above ground biomass) prior to application and evaluated for nitrogen. Harvest occurred approximately 2 months after reflood at both sites at which time representative soil and plant samples were taken from each plot. Extractable soil ammonium and nitrate nitrogen quantities were quantified in all soil samples. At the Woodland site, yield results show that using the 12-3-0 fertilizer resulted in a significant and linear increase in yields with increasing application rates. The regression line coefficient indicates that for every kilogram of N fertilizer applied yield increases by 22 kg N ha^{-1}. At Richvale, CA, there was also a linear response to about 45 kg N ha^{-1} after which yields tended to plateau. The regression line coefficient for N application rates between 0 and 45 kg N ha^{-1} indicates that for every kilogram of N fertilizer applied yield increases by 15 kg N ha^{-1}. 12-3-0 N fertilizers at 45 kg N ha^{-1} at both sites gave higher yields than the control, 4-1-4, and 6-3-2.

Effect of Seeding Rate on Plant Growth, Grain Yield and Yield Components in Organic Rice Production

Li, X., Dou, F., Wang, S., Chen, K., Zhou, X., and McClung, A.

Seeding rate plays an important role in optimizing rice yield and yield components, yet information regarding its effect on organic rice (*Oryza sativa* L.) production is still limited. This study was conducted in an organic field in two continuous years to evaluate the effect of seeding rate (108, 161, 215, 269, 323, 376, and 431 seedlings m^{-2}) and rice cultivar [Presidio (inbred) and XL753 (hybrid)] on plant growth, grain yield, yield components, and weed density. Seeding rate had significant effects on seedling stand density and dry biomass with positive linear correlations; while its effect on plant height was insignificant. Yield increased linearly with increasing seeding rate, which was 3,462 kg ha^{-1} for Presidio and 7,508 kg ha^{-1} for XL753 at 431 seedlings m^{-2}. Panicle number was positively correlated with seeding rate, while the correlation between seeding rate and milling quality was insignificant. Of two cultivars, XL753 had a significantly higher seedling stand density, plant height, dry biomass, panicle number, and filled spikelets $panicle^{-1}$; while Presidio was significantly greater in milling quality and weed density. The effect of seeding rate on grain yield in organic rice production (linear relationship) was different from that in conventional system (quadratic relationship), and the seeding rate recommendation for conventional rice was not transferable to organic rice production system. In organic rice production, a seeding rate of 431 seedlings m^{-2} (94 kg ha^{-1} for XL753, 106 kg ha^{-1} for Presidio) or higher was needed to maximize grain yield for both varieties in organic, direct-seeded rice production.

Evaluating Benefits of Boot Nitrogen Applications for Current Hybrid Rice Cultivars

Plummer, W.J., Frizzell, D.L., Hardke, J.T., Norman, R.J., Smartt, A.D., and Castaneda-Gonzalez, E.

Approximately 40% of Arkansas rice acres is planted in hybrid cultivars each year. Applying 34 kg of nitrogen (N)/ha at the late boot growth stage has remained the standard practice for hybrid cultivars. This practice has been shown to minimize lodging and enhance grain and milling yields. Therefore, a study was conducted in 2016 and 2017 on current hybrid cultivars to determine possible benefits of this application.

The RiceTec hybrids CLXL745 and XP753 were drill seeded at three locations in 2016 and 2017. The locations included were the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, the Pine Tree Research Station, and the Rice Research and Extension Center. There were three different preflood N rates that varied based on the soil type for each location. At each location, all plots received an additional boot N application of 34 kg N/ha or zero kg N/ha at the late boot growth stage (complete exsertion of the flag leaf). The study was conducted in a randomized complete block design with four replications at each location.

There was no year by boot N treatment interaction so the study years were combined. In addition, there was no interaction between preflood N rate and boot N application. The main effect of boot N application averaged across years and preflood N rates resulted in increased grain yield yields and milling yields for both CLXL745 and XP753 cultivars compared to treatments receiving no boot N. The boot N application also significantly reduced lodging for CLXL745 compared to no boot N. Minimal lodging occurred for XP753 and no significant difference was observed between boot N treatments.

The Effects of Agtivate™ and Reduced Nitrogen Rates on Crop Yield in Rice

Samford, J.L. and Zhou, X.G.

Rice producers are continually looking for ways to increase or maintain yield while reducing production costs. Fertilizer expenditures are one of the major costs of rice production. Agtivate is a live algae-based soil amendment being marketed by AlgEternal Technologies at a cost of \$50.51/ha at an 0.85 l/ha rate with claims to positively impact pests, seed germination, plant growth and plant health in almost any crop. Reports from testing in Colorado have shown a 15% yield increase in corn and a 14% yield increase in sorghum. Additionally, testing on vegetables in Texas has reported decreased insect pest and disease problems, decreased fertilizer needs and 10-20% faster maturation. Field research was initiated in 2016 and continued in 2017 to analyze the effects of Agtivate application in conjunction with reduced nitrogen inputs on rice production at the David R. Wintermann Rice Research Station near Eagle Lake, Texas.

A field trial using a randomized complete block design with four replications was conducted in 2016 and 2017. The rice cultivar Presidio was drill seeded at a rate of 78.4 kg/ha in both years. Treatments included a non-treated check (0 Agtivate + 0 nitrogen), a standard fertility program (0 Agtivate + 207.2 kg/ha nitrogen), Agtivate only (0.85 l/ha Agtivate + 0 nitrogen), Agtivate + 25% nitrogen (0.85 l/ha Agtivate + 51.52 kg/ha nitrogen), Agtivate + 50% nitrogen (0.85 l/ha Agtivate + 103.6 kg/ha nitrogen) and Agtivate + 75% nitrogen (0.85 l/ha Agtivate + 155.68 kg/ha nitrogen). Agtivate applications were made pre-plant. All nitrogen applications were made by hand, utilizing a four timing split (27% at pre-plant, 33% at pre-flood, 20% at panicle initiation and 20% at boot). Pre-plant and pre-flood nitrogen applications were made using urea. Panicle initiation and boot nitrogen applications were made using ammonium sulfate. Additionally, 56 kg/ha of both phosphorus and potassium were applied pre-plant in both years. All pre-plant applications of Agtivate and fertilizer were incorporated into the soil. All plots were harvested and rice grain yield was determined in both years.

In 2016, mean yield ranged from 7,813 kg/ha in the non-treated check to 9,723 kg/ha in the Agtivate + 75% nitrogen treatment. Mean yield for the Agtivate alone treatment was 8,314 kg/ha, an increase of 6.4% over the non-treated check. Mean yields for all combinations of Agtivate + nitrogen were within 149 kg/ha of the mean yield for the standard fertility program, with the Agtivate + 75% nitrogen treatment yielding 109 lb/ac more on average. However, none of the treatment yields were significantly different due to large variations in yield among replications.

In 2017, mean yield ranged from 5,778 kg/ha in the non-treated check to 9,242 kg/ha in the Agtivate + 75% nitrogen treatment. Mean yield for the Agtivate alone treatment was 6,875 kg/ha, an increase of 19% over the non-treated check. Mean yields for all combinations of Agtivate + nitrogen were within 853 kg/ha of the mean yield for the standard fertility program, with the Agtivate + 75% nitrogen treatment yielding 86 kg/ha more on average. There was no significant difference found between the standard fertility program and any of the Agtivate + nitrogen treatments. The Agtivate alone treatment had a significant higher yield than the non-treated check.

Results from this study indicate that the application of Agtivate may contribute to increased yields above that of rice receiving no nitrogen inputs, but Agtivate alone does not appear to be a viable alternative to standard nitrogen applications in rice. Data from both years suggest that the application of Agtivate in conjunction with reduced rates of nitrogen fertilizer can be a viable and cost effective rice fertility program.

Potential Use of Nitrapyrin as a Nitrification Inhibitor for Delayed Flood Rice

Mansour, W.J., Golden, B.R., Bond, J.A., and McCoy, J.M.

In the southern United States, urea is the predominant ammonium-forming nitrogen (N) source implemented in a delayed-flood rice production system because of its high N content (46% N) and relatively low cost. Establishing a permanent flood within a few days' post urea application is essential due to potential losses of N through ammonia volatilization and/or nitrification/denitrification. Ammonia volatilization occurs when urea is hydrolyzed to ammonium carbonate [$(NH_4)_2CO_3$] by the urease enzyme and ammonium carbonate decomposes to produce ammonia (NH_3) and carbon dioxide (CO_2). Nitrification is a two-step microbial process in which ammonium (NH_4) is converted into nitrite (NO_2) and lastly into nitrate (NO_3). Denitrification is a microbial facilitated process where NO_3 in the soil is utilized as an electron acceptor under anaerobic conditions resulting in gaseous oxides that are lost to the atmosphere. In order to impede NH_4 losses the use of nitrification inhibitors (NI) allow growers a longer time frame in between fertilizer applications to establishing a permanent flood in rice. Currently, there are several products labeled for use as NI's; however, the focus of this research will pertain to nitrapyrin (as Instinct II). The objectives of this research were to evaluate nitrapyrin in the field as foliar applications versus impregnated on urea, as well as to examine the efficacy of dicyandiamide (NBPT) (as Agrotain) and nitrapyrin alone and in combination on various rates of N fertilizer.

Research to evaluate nitrapyrin efficacy in rice culture was established at the Delta Research and Extension Center in 2017 near Stoneville, MS. One trial evaluated nitrapyrin application method and timing across N rates. Treatments included nitrapyrin applied at 1.97 L ha^{-1} and 4.09 L ha^{-1} at 3-leaf (LF), and pre-flood 5-LF (PF) or nitrapyrin impregnated onto urea and applied at 5-LF. Foliar applications were implemented via pressurized CO_2 back pack sprayer calibrated to deliver a spray volume of 140.31 L ha^{-1} at 262 kPa with Teejet XR 11002 spray tips. At PF, 101 kg N ha^{-1} of was broadcast to all plots except plots that received urea impregnated with nitrapyrin.

A second trial was established to evaluate impregnated nitrapyrin alone or in combination with NBPT. Nitrapyrin and NBPT were both impregnated on urea prills at labeled rates of 1.97 L ha^{-1} and 1.04 L metric $tons^{-1}$, respectively. Urea was broadcast at 5-LF with N rates ranging from 67 to 168 kg N ha^{-1} in incrementing units of 34 kg N ha^{-1}. Each trial was arranged as a randomized complete block design with four replications. At physiological maturity trials were harvested with a small plot combine and grain yields were adjusted to 12% moisture content. Statistical analysis was conducted using PROC Mixed in SAS version 9.2 and means were subjected to analysis of variance implementing Fischer's protected LSD ($P > 0.05$) to compare grain yields among treatments within each trial.

Rice receiving foliar applied nitrapyrin produced greater mean rice grain yield than rice receiving nitrapyrin impregnated on urea. Nitrapyrin followed by urea applied 5-LF at a rate of 1.97 L ha^{-1} significantly increased yield by 23% compared to 1.97 L ha^{-1} impregnated on urea and applied at 5-LF growth stage. In trial two, maximal rice grain yield was obtained when rice received 168 kg N ha^{-1} impregnated with nitrapyrin + NBPT. Urea applied at 168 kg N ha^{-1} + NBPT + nitrapyrin significantly increased relative grain yield over the non-treated control by 45%, respectively. Additionally, the greatest rate of urea at 168 kg N ha^{-1} + NBPT + nitrapyrin resulted in significantly greater grain yield by 8% over 168 kg N ha^{-1} urea + NBPT and 6% over the 168 kg N ha^{-1} urea + nitrapyrin.

Nitrification inhibitors applied at 5-LF as a foliar product increased grain yields by 23% over the impregnated technique. Additionally, greater rates of urea + NBPT + nitrapyrin resulted in the greatest relative grain yield of 8 and 6% when compared to each of the greatest rates of urea + NBPT or urea + nitrapyrin. Foliar applications of nitrapyrin could potentially provide growers tank-mix options with late post herbicides prior to flooding. Furthermore, it is hypothesized that a greater rate of urea + NBPT + nitrapyrin provides growers the greatest efficacy against ammonia volatilization and nitrification/denitrification; due to the greater surface area that is being covered from the high rate of fertilizer in combination with the NBPT + nitrapyrin.

Currently, there is no label for nitrapyrin use in direct seeded, delayed-flood rice culture. Preliminary research suggests that nitrapyrin may be beneficial in the southern United States rice production systems, however, more research is needed to validate these preliminary observations.

Starter Nitrogen Source and Pre-Flood Rate Effects in Rice Grown on Clayey Soils

Martin, L.R., Slaton, N.A., Golden, B.R., Hardke, J.T., Roberts, T.L., and Norman, R.J.

Seedling rice (*Oryza sativa* L.) produced on clayey-textured soils generally grows slowly and requires greater preflood-N rates to produce maximal yield as compared to loamy-textured soils. Farmers often apply 'starter' fertilizer N shortly after rice emergence to stimulate seedling growth. Our research objective was to examine the effects of starter N source and preflood-N rate on the grain yield of rice grown on clayey-textured soils.

Research was conducted on soil mapped as Sharkey and Desha clays at the Rohwer Research Station (RRS) in Arkansas and on a Commerce silty clay loam at the Delta Research Extension Center (DREC) in Mississippi. Four starter N sources including no N (NONE), ammonium sulfate (AMS), diammonium phosphate (DAP), and urea treated with N-(n-butyl) thiophosphoric triamide (UREA) applied at 24 kg N ha^{-1} were made at the 2-leaf stage in combination with five preflood-N rates (0, 56, 112, 168, and 224 kg N ha^{-1}) applied to 5-leaf rice and flooded within 1 day. Two cultivars, CL153 and Rice Tec CL XL745, were grown at the DREC and only CL153 was grown at the RRS. Biomass and N concentration at early heading (R3 stage) were measured to calculate total aboveground N uptake by XL745 grown at the DREC. Grain yield was determined for all three trials.

Aboveground N uptake by XL745 was affected only by preflood-N rate. Aboveground uptake increased with each increase in preflood-N rate. Rice receiving no N contained 48 kg N ha^{-1} at the R3 stage. The fertilizer-N recovery efficiency of rice receiving no starter N and fertilized with 56 to 224 kg preflood-N ha^{-1} ranged from 51 to 61%.

The grain yields of CL153 and XL745 at the DREC were affected by the significant ($Pr < 0.05$) starter-N source by preflood-N rate interaction and were generally maximized (10,394 kg and 12,084 kg ha^{-1}, respectively) by application of 168 and 224 kg preflood-N ha^{-1}, respectively. Starter-N source had the greatest effect on grain yield of rice receiving no preflood N and diminished as preflood N rate increased. Although significant differences occasionally occurred within the preflood N rates ranging from 56 to 224 kg preflood-N ha^{-1}, no single starter N consistently produced greater grain yields than another suggesting the random differences may have been anomalies caused by natural variation among plots within the research area.

The grain yield of CL153 grown at the RRS was affected ($Pr < 0.0001$) only by preflood-N rate, averaged across starter-N sources. Grain yield increased significantly with each increase in preflood-N rate with a maximal yield of 8,295 kg ha^{-1} for rice fertilized with 224 kg preflood-N ha^{-1}.

Based on the three trials conducted in 2017, starter-N had no influence on rice grain yield when optimal preflood-N rates were applied at the 5-leaf stage. The benefit of starter N may be from the stimulation of early season seedling growth (e.g., increasing seedling size) allowing farmers to establish the flood earlier. Research in 2018 will focus more on measuring potential early season growth benefits.

Effects of Water-Nitrogen Interaction on Nitrogen Utilization Characteristics and Yield of Different Genotypes Rice

Zhou, C.C., Wang, S., Dou, F.G., Jia, B.Y., Huang, Y.C., Wang, Y., and Xu, Q.

Water and nitrogen managements play important roles in rice production. A pot trial using a full combination of water regime [continuous flood (W1), saturated soil regime (W2), moderate alternative dry and wet cycling (W3), and severe alternative dry and wet cycling (W4)], nitrogen fertilization [0 kg/ha (N0), 180 kg/ha (N1), and 220 kg/ha (N2)], and two genotypes (one conventional japonica rice, Shendao 47 and one hybrid japonica Jingyou 586) with 12 replications was conducted using a randomized design to determine the optimal water and nitrogen fertilization combination for each genotype. There was no three-way interaction but had a two-way interaction of genotype and N fertilization, variety and water regimes as well. The yield of hybrid rice Jingyou 586 increased significantly under high nitrogen level N2, while N2 had no influence on the yield of Shendao 47. The grain yield under W1 was equivalent to that under W2 and was significantly higher than that under W3, with the lowest under serious water stress W4. Jingyou 586 gained the higher yield under W1, however, the higher yield of Shendao 47 could be gained under W2. There was a three-way interaction effects on N uptake and nitrogen recovery efficiency. For hybrid rice Jingyou 586, with increasing water stress, the effects of nitrogen on increasing N uptake decreased, Shendao 47 adverse, and that on decreasing RE_N intensified. The RE_N increased and then decreased. The AEN and PFPN were affected by the interaction of variety and nitrogen as well as interaction between variety and water regimes. Our study indicated that nitrogen us efficiency and yield can be increased for conventional rice under saturated soil regime combined with moderate nitrogen level and continuous flood combined with high level nitrogen can be suitable for hybrid rice.

Comparison of UAV and GreenSeeker NDVI Vegetative Indices to Estimate Rice Grain Yield Potential

Coker, A., Adotey, N., Harrell, D.L., Hensgens, G., and Kongchum, M.

In order to predict the mid-season nitrogen (N) response to fertilization in rice cropping systems, yield potential, response index, and N response to fertilization must be known. Normalized difference vegetative index (NDVI) is a widely used, well known predictor of yield potential in rice. In the past, the GreenSeeker hand held sensor has been the dominant tool in collecting NDVI readings. This hand held GreenSeeker sensor collects NDVI readings in a rice field on a point to point basis using the devices' own light source. Advances in technology have allowed usage of unmanned aerial vehicles (UAV) to collect NDVI readings. Variation in NDVI readings have been detected because UAV's collect NDVI readings on a whole field basis using natural light as the devices light source. Absorbed and reflected light values are therefore dependent on the sunlight's intensity, angle of the sunlight during readings (time of day), and cloud cover. Those factors must be accounted for during measurement in order for the results to be meaningful. The objectives of this study were to 1) Compare the ability of UAV and GreenSeeker derived NDVI to estimate rice grain yield potential, and 2) Evaluate the relationship between UAV and GreenSeeker NDVI measurements.

Two locations, H. Rice Caffey Rice Research Station in Crowley, LA, and St. Landry Parish in Palmetto, LA, were used to test a group of 10 different varieties and hybrids. The cultivars included Titan, CL153, CL172, Thad, CL272, Diamond, PVL 24A, Aura 115, XL760, and Gemini 214CL. The 10 cultivars were treated with 12 different preflood N treatments (0, 34, 67, 101, 134, 168, 202, and 235 kg ha^{-1}). NDVI readings for all cultivars were taken between panicle initiation and panicle differentiation. Regression analysis across cultivars indicated that approximately 52% of the variation in yield potential at the Crowley location could be explained by GreenSeeker NDVI readings while 11% of the variation could be explained at the St. Landry Parish location in 2017. Regression analysis across cultivars indicated that approximately 31% of the variation in yield potential could be explained by UAV derived NDVI at the Crowley location while 22 UAV and GreenSeeker derived NDVI plant indices were highly correlated at the St. Landry Parish location ($P<0.001$; $R^2=0.70$) and at the Rice Research Station ($P=0.001$; $R^2=0.50$). Further research is needed to determine if the variation between GreenSeeker and UAV NDVI are constant over years in order to improve predictability of mid-season N requirements for rice.

Differential Physiological Response of Diverse Rice Varieties to Ethylene Perception Inhibitor under High Night Temperature

Mohammed, A.R., Mustahsan, W., Thomson, M., and Tarpley, L.

Crop production is experiencing both increases in the frequency and intensity of high night temperatures (HNT) along the United States Gulf Coast and in regions of similar climate. The HNT threatens the sustainability of crop production both currently and in the future. The HNT can alter crop productivity and quality by affecting plant physiology, morphology and phenology. The ethylene perception inhibitor, 1-methyl cyclopropene (1-MCP) can minimize high night temperature (HNT) stress-induced damage to the membranes, thereby preventing loss in the rice yield.

A study was conducted to evaluate the effects of HNT and 1-MCP on rice physiology, yield-related parameters and yield of nine diverse rice varieties. Plants were subjected to free-air temperature enrichment within a greenhouse (Texas A&M AgriLife Research Center in Beaumont, Texas, U.S.A.) and were exposed to 25°C and 30°C NT from boot stage until harvest. The 1-MCP was applied at boot stage of the rice plant. Leaf photosynthetic rate, photochemistry, membrane stability, chlorophyll concentration, pollen viability, spikelet fertility and grain yield were determined.

Differential responses among the varieties to both HNT and 1-MCP were seen with respect to physiology, yield-related parameters and yield. These data should help unravel the physiological differences between varieties showing susceptible versus tolerant responses to high night temperature.

Effect of Sodium Chlorate as a Harvest Aid on Hybrid Rice

Frizzell, D.L., Hardke, J.T., Plummer, W.J., Casteneda-Gonzalez, E., and Lee, G.J.

Sodium chlorate is used as a harvest aid in rice on an increasing number of acres in Arkansas. Currently, the University of Arkansas System Division of Agriculture recommendation for application of a desiccant is to apply sodium chlorate when grain moisture is 180 to 250 g H_2O kg^{-1}. This is based on studies using conventional varieties during the late 1990s. However, little is known about the effect of sodium chlorate applications on hybrid rice in regard to impact on harvest moisture or milling yield. Therefore, a study was initiated in 2017 to evaluate the influence of sodium chlorate applications to hybrid rice within the currently recommended moisture range.

The study was seeded at the University of Arkansas System Division of Agriculture Rice Research and Extension Center using the RiceTec hybrid XP753. Sodium chlorate was applied at either 0 or 6.7 kg a.i./ha when grain moisture reached 240, 210, 180, or 150 g H_2O kg^{-1} and harvested at approximately 3 or 7 days (d) after application. The study was arranged as a randomized complete block with two replications. Means were separated using Dunnett's multiple comparison test within each harvest timing.

Sodium chlorate significantly reduced grain moisture compared to the untreated control only at 3 d after application at the 180 g H_2O kg^{-1} spray timing and 7 d after application at the 240 and 150 g H_2O kg^{-1} spray timings. However, sodium chlorate applications displayed a trend to reduce harvest moisture at both harvest timings across harvest moisture spray timings. Percent milled whole kernels (head rice) declined as much as 8% compared to the untreated control at 3 and 7 d after application. Percent head rice was significantly reduced by sodium chlorate application 3 d after application at 150, 180, 210, and 240 g H_2O kg^{-1}; and 7 d after application when sprayed at 180, 210, and 240 g H_2O kg^{-1}. Total milled rice was also reduced 3 d after application at 240 g H_2O kg^{-1}. Additional research is needed to adequately quantify the impact of sodium chlorate as a harvest aid to hybrid cultivars. However, results of this initial study suggest that caution should be used when making sodium chlorate applications to hybrid cultivars.

Arkansas Rice Grower Research and Demonstration Experiment Program

Lee, G.J., Hardke, J.T., Beckwith, A.G., Allen, C.S., and Chlapecka, J.L.

In 2017, the University of Arkansas System Division of Agriculture and the Arkansas Rice Research and Promotion Board initiated the grower research and demonstration experiment (GRADE) program. The focus of the GRADE program is to conduct large block replicated field trials on grower farms to bridge information between small plot research trials and grower field experiences. To accomplish this goal, the GRADE program utilizes large block plots of approximately ½ acre or larger within a grower's field. It is an interdisciplinary effort between growers, consultants, county Extension agents, Extension specialists, and researchers.

The program began on a limited basis with six trials for the 2017 growing season. All trials were arranged in a randomized complete block design with a minimum of three replications. Four of the locations were variety demonstrations utilizing the varieties Roy J, Diamond, Taggart and LaKast. Another demonstration evaluated row spacing and compared 10-inch drill spacing to 7.5-inch row spacing. There was also a seeding rate demonstration where Roy J was planted at 25, 40, 55, 70, and 85 lbs per acre. Finally, insecticide seed treatments were evaluated in furrow irrigated rice. Trial results will be presented.

A 5-Year Summary of the University of Arkansas Rice Research Verification Program

Mazzanti, R., Baker, R.P, Hardke, J.T., and Watkins, K.B.

Rice (*Oryza sativa, L.*) production is constantly changing as new cultivars are released and new production challenges arise. Producers continue to request the University of Arkansas System Division of Agriculture field-test existing technology to determine the profitability of rice production based on recommended practices. In 1983, the Arkansas Cooperative Extension Service and the Arkansas Rice Research and Promotion Board initiated the Rice Research Verification Program (RRVP). The RRVP is an interdisciplinary effort between growers, county Extension agents, Extension specialists, and researchers. The RRVP is an on-farm demonstration of all the research-based recommendations required to grow rice profitably in Arkansas. The trends in yields, management decisions, and impacts will be presented.

The specific objectives of the program are: (1.) to verify research-based recommendations for profitable rice production in all rice producing areas of Arkansas, (2.) to develop a database for economic analysis of all aspects of rice production, (3.) to demonstrate that consistently high yields of rice can be produced economically with the use of available technology and inputs, (4.) to identify specific problems and opportunities in Arkansas rice production for further investigation, (5.) to promote timely implementation of cultural and management practices among rice growers; and (6.) to provide training and assistance to county agents with limited expertise in rice production. Each RRVP field and cooperator was selected prior to planting. Cooperators agreed to pay production expenses, provide crop expense data for economic analysis, and implement Extension recommended production practices exclusively in a timely manner from seedbed preparation to harvest. Since the program's inception 35 years ago, RRVP yields have averaged 0.9 ton/ha (18 bu/acre) above the state average. The most recent 5-year RRVP average stands at 0.96 ton/ha (19 bu/acre) above the state average. The consistently higher yield averages of the program in comparison to the state average can mainly be attributed to intensive cultural management and integrated pest management.

Elevated Temperature Increases Arsenic Bioavailability in Rice Soil

Farhat, Y., Neumann, R., and Kim, S.

Rice uptake of arsenic threatens both crop yield and human health. Increasing temperatures may alter arsenic availability, uptake, and allocation. Rice, M206 variety, was grown under four different temperature treatments ranging from 25.4 - 33.0°C in unamended, rice-growing soil from Davis, California. We found that increasing temperature led to an increase in arsenic availability in the soil porewater. We are currently performing sequential extractions which target loosely adsorbed and redox sensitive arsenic species. Preliminary data suggests that the increase in porewater availability is paralleled by an increase in loosely adsorbed arsenic as well. Our findings indicate that climate change may exacerbate existing concerns about arsenic in rice.

Abstracts of Papers on Economics and Marketing
Panel Chair: Lanier Nalley

Economic Factors Driving USDA's 2017/18 U.S. Domestic Rice Market Baseline Projections

Childs, N.W. and Skorbiansky, S.R.

USDA's 2017/18 long-term annual supply and demand baseline results for the U.S. rice industry are presented for both long-grain and combined medium- and 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 2017/18 domestic baseline forecasts were developed in November 2017.

Economic and Environmental Impact of Weedy (Red) Rice Control in the U.S.A.

Durand-Morat, A., Nalley, L.L. and Thoma, G.

Weedy (red) rice (*Oryza sativa L.*) is one the most prevalent and damaging (both from a yield and economic standpoint) weed problems in direct seeding rice systems globally. The shift from transplanted to direct-seeded rice is one the primary reasons for the increased global weedy rice problem. Given the importance of increasing rice yields for global food security, primarily for the most vulnerable impoverished segments of the population in Asia, and how thinly traded the global rice market is, it is pivotal to be cognizant and prepared for potential supply shifters due to the increased presence in red rice associated with the transition to direct seed rice production globally. Expansion in direct-seeded rice may result in productivity and economic losses due to weedy rice infestations, reducing global rice supplies, creating potential increased price volatility, which can ultimately undermine the progress made by plant breeders, agronomists, and other rice scientists in their effort to combat food insecurity in Asia and globally.

Clearfield® (CL) is to date the only technology available to selectively eliminate red rice from commercial rice fields. In this study, we estimate the potential impact of weedy (red) rice on the global market by focusing on the U.S. as an empirical case study. We develop a counterfactual scenario in which we simulate the removal of the CL rice technology, that mitigates the impact of weedy (red) rice, and estimate the impact of weedy (red) rice by comparing the counterfactual against actual observed market outcomes. We estimate the 1) on farm yield impacts 2) consumer welfare impacts due to global price increase and 3) the environmental impact due to lower yields and alternative weed control.

The results suggest that red rice infestation leads to a significant reduction in rice yields, producer and consumer welfare, as well as an increase in the cost to ameliorate the environmental impact of rice production resulting from red rice infestation. The consequences of an increase in red rice infestation across rice production areas in Asia on the global rice market and food security can be severe.

Non-Convergence in Rice Futures Market

McKenzie, A.M. and Darby, J.L.

The economic functions of futures markets are price discovery, liquidity and risk management. However, these functions are compromised when futures and cash market prices fail to converge. For example, if futures and cash prices fail to converge to the same price at contract maturity the futures market cannot be said to fully reflect the value of a commodity. With regard to risk management, non-convergence is associated with unpredictable movements in basis, while hedging effectiveness is predicated on predictable movements in basis. Non-convergence also adds to market uncertainty and a reluctance on behalf of speculators and hedgers to actively trade futures, which ultimately damages the economic value of futures markets by reducing liquidity.

Prior research has shown that non-convergence in corn, soybeans and wheat markets occurred when the market price of physical storage exceeded the Chicago Mercantile Exchange storage rate at delivery locations. This has been attributable to an incentive for long futures traders to hold delivery instruments and earn the carry rather than load out and turn delivery instruments into cash rice. This incentive to hold delivery instruments results in a widening of the basis (more negative basis). It has been argued that this will occur when inventories are high at delivery locations and hence the price or value of storage is high and there are large carries in the futures. Prior research for corn, bean and wheat markets has demonstrated that the level of stored grain or inventories are negatively related to basis. In other words high levels of inventory are associated with wide negative basis levels.

In this paper we analyze whether large futures carries were the underlying cause of rice futures non-convergence. This issue of non-convergence was particularly acute for the rice market during the 2007 – 2008 and the 2010 – 2012 periods when historically wide or negative basis values were observed. Using Ordinary Least Squares regression we measure the degree to which rice futures basis values observed two months prior to contract maturity predict convergence at Chicago Mercantile delivery locations in Arkansas. A similar analysis is used to ascertain predictability of basis movements in related US and Mexican cash rice markets. In addition, we estimate the market price or value of storage at delivery time to determine when this exceeds the physical cost of storage at Chicago Mercantile delivery locations. We then regress delivery time basis values observed at delivery locations and other rice markets on our estimated value of storage, on futures carry spreads, and on inventory levels to determine if the price of storage results in wider basis values. Our results indicate that the incentive to store as captured by large futures spread carries does lead to wider basis values. We find that large future spreads that cover 80% or more of the cost-of-carry lead to poor convergence and basis predictability with respect to the various cash rice markets.

Economics of Row Rice Production in Arkansas

Mane, R.U., Watkins, K.B. and Henry, C.G.

Row rice (or furrow-irrigated rice) is an upland rice production system that involves irrigating rice with furrows. As of 2016, Arkansas had about 2.7 percent (16510 ha) of total rice production under row rice production. In 2017, the area under row rice is estimated to be 9 percent of total rice production.

The objective of the paper is to compare the economics of the row rice production system with alternative rice production systems. There is currently very little information available about the economics of the row rice system, and it is imperative for producers to know the economics of this system before they get involved with it. Actual field trials for this system were conducted in 2016, and data with respect to production costs and net revenues are summarized and reported in this paper.

The University of Arkansas 2016 Crop Enterprise Budgets are used to study profitability of rice under different production systems with emphasis on row rice. Economic data from six different row rice plots are compared with other production systems using data from four different producers. Producers provided production data sheets listing inputs, equipment used and timing of operations, and these data were used to develop crop budgets.

Based on the 2016 results, the average fertilizer and nutrient cost for row rice is $171.22/ha higher when compared with other production systems. Likewise, the chemicals or herbicides average cost for row rice is $209.77/ha, which is relatively low when compared to conventional and Alternate Wetting and Drying (AWD) fields. Cost of herbicides used in weed management of row rice is higher when compared to straight and counter levee systems. The net returns to row rice have a variation from a minimum of $93.95/ha to a maximum of $515.02/ha. The wide variation in net returns is attributed to variation in yields.

Non-Radial Technical Efficiency of Irrigation Water Use in Arkansas Rice Production

Watkins, K.B., Henry, C.G., Hardke, J.T., Mane, M.M., Mazzanti, R.S., and Baker, R.

Irrigation water is a significant component of agriculture in eastern Arkansas. Nearly 80% of all cropland acres in eastern Arkansas are irrigated, and rice is by far the most water intensive crop grown in the region. Irrigation water is becoming increasingly more limiting in many parts of the region due to extensive pumping of groundwater. Ninety-five percent of the groundwater used in eastern Arkansas agriculture comes from the Mississippi River Valley alluvial aquifer, which extends from Arkansas into Missouri, south into Louisiana, and under the Mississippi River into Tennessee and Mississippi. In many parts of the alluvial aquifer, groundwater withdrawals far exceed the rate of recharge, resulting in large cones of depression, particularly in the Arkansas Grand Prairie region in east central Arkansas and in areas west of Crowley's Ridge, a narrow geologic formation rising above the alluvial plain in northeastern Arkansas.

This study uses non-radial Data Envelopment Analysis (DEA) to measure the technical efficiency of irrigation water application for fields enrolled in the University of Arkansas (U of A) Rice Research Verification Program (RRVP). Non-radial DEA is a nonparametric, linear programming (LP) approach used for measuring relative efficiency among a set of decision-making units (rice fields in this case) with the most efficient decision making units lying on a production frontier. Unlike radial DEA, which moves an inefficient decision making unit to the production frontier by shrinking all production inputs equiproportionately, non-radial DEA shrinks each component of the observed input vector as much as possible until the production frontier is reached. Non-radial DEA thus allows for the measurement of technical efficiency for each production input as well as measurement of overuse for each production input used inefficiently. This study focuses on measurement of technical efficiency of irrigation water in rice production using data from 131 rice fields enrolled in the U of A RRVP for the period 2005 through 2016 for which water usage was measured using flow meters. The technical efficiency of irrigation water (TEwj) for field j can take on a value ≤ 1, with TEwj = 1 representing full technical efficiency of irrigation water application and TEwj < 1 representing technically inefficiency in irrigation water application, with overuse of irrigation water measuring 1 - TEwj.

Irrigation water TE averaged 0.670 across all 131 RRVP fields, indicating most RRVP fields on average were technical inefficient at applying irrigation water with average irrigation water overuse of 33%. Forty-seven RRVP fields (36% of the total fields evaluated) were fully efficient at applying irrigation water (TEwj = 1), while the remaining 84 RRVP fields had irrigation water TE scores ranging from 0.148 to 0.971. Irrigation water technical efficiency scores varied by field topography (contour levees, straight levees, zero-grade, and furrow/row rice fields), by water source (groundwater versus surface water) and by the presence or absence of multiple inlet (MI) irrigation. Irrigation water TE scores ranged in order from 0.558 for contour levee fields (44 fields), 0.696 for straight levee fields (64 fields), and 0.843 for zero grade fields (19 fields). Four of the 131 fields were furrow/row-rice fields and averaged 0.657 in irrigation water TE. Irrigation water TE scores by water source ranged from 0.649 for fields supplied by groundwater (103 fields) to 0.747 for fields supplied by surface water (28 fields). Contour and straight levee rice fields totaled 108, with 37 of these fields utilizing MI irrigation. Fields with MI averaged 0.703, while fields without MI averaged 0.607 in irrigation water TE. When comparing both field topography and the use of MI, contour levee fields without MI (33 fields) averaged 0.529 while contour levee fields with MI (11 fields) averaged 0.644 in irrigation water TE. Alternatively, straight levee fields without MI (38 fields) averaged 0.674 while straight levee fields with MI (26 fields) averaged 0.729 in irrigation water TE.

Economic Factors Driving USDA's 2017/18 International Rice Baseline Forecasts

Childs, N.W. and Skorbiansky, S.R.

USDA's 2017/18 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 33 countries (including the United States) and 9 multi-country regions. Aggregated, these 42 models account for total global rice production, supply, trade, and use. Economic factors driving long-term supply and use trends in key individual countries and regions are explained, as well as significant changes from the previous baseline. Markets are not segmented by class or type.

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 2017/18 baseline forecasts were developed in October 2017. USDA's annual baseline projections are used by market participants and policy makers for planning, budgeting, and decision making.

Institutional Agreements as Decisive Factors in the Development of Uruguayan Rice

Sanguinetti, M., Ferraro, B. and Lanfranco, B.

The Uruguayan rice sector is commonly seen as an integrated agro-industrial chain whose fundamental pillar is a unique pricing system originated by a private agreement between rice growers and millers. As a strategy based on this, the sector created of a whole network of institutional agreements that include things as management of the crop, agronomic and economics research, definition of the rice varieties released in the market, among other key issues that characterize rice production system in the country. The network not only involves farms and mills but also relies on important alliances with actors at both public and private levels. As a result, the Uruguayan rice sector has built an important reputation in the international market, being well-recognized due its productivity levels, safety, quality and uniformity of its products. For more than five decades, the price agreement was never questioned. It was strongly related to the consolidation of Uruguay as the most export-oriented rice producing country globally, occupying a relevant position in the top-ten list of net rice exporters in the last 20-30 years. Recently, increasingly high production costs at both farming and milling processes have raised some critical voices against the pricing system. Most critics claim the existence of asymmetry of information that allegedly gives some market power to millers and prevents from obtaining the efficient outcome postulated from economic theory in a free market.

The objective of this paper is discussing the strengths and weaknesses of this private pricing system from both a theoretical and empirical perspective. Under the perspective of the institutionalized economy and relevant concepts of the neoclassic economic theory, this research aims to discover if the institutional arrangements have been or continue to be key elements for further development of Uruguayan rice sector. In 1959, the national government ceased fixing the price of paddy price received by farmers. Every year, since then, representatives of the national rice growers association ACA (Asociación de Cultivadores de Arroz) and the four largest rice mills nucleated at GMA (Gremial de Molinos Arroceros) sit down in a negotiation table, without any government intervention to define the price to be paid by millers to farmers for their paddy rice. ACA is a business association that integrates 95% of the farmers from all over the country.

Uruguay harvests rice once a year, during its summer season. The pricing process starts right after harvest by monitoring the performance of rice exports during the whole trading year (March 1 to February 28). After deducting the value added by the milling process, including some profit level, what is left defines the price to be paid to farmers for their paddy. This is a weighted average price, which is the same for each farmer no matter which mill received the grain. The first important milestone in the process is the agreement of a provisional price, made effective by the end of June. At the end of the trading year, in theory, all the production was marketed. ACA and GMA representatives get together again to fix the final price for that season, with the consequent adjustments in the paychecks. When this occurs, the sector is going thru a new harvest.

A first analysis under the economic theory suggest some loss of efficiency on miller's side. Critics allege that millers usually hide the true nature of their cost structure while assuring some level of profit not based in market fundamentals. "What is left" after the deduction of the value added by the milling stage can or cannot be enough to reward the use production factors at the primary sector. Profit levels could be either positive or negative. Farmers face a level of uncertainty that millers do not face because the existence of asymmetric information. In principle, it would be possible for millers having no market incentives for seeking technical and economic efficiency, as farmers have. Nevertheless, any potential advantage millers could get can also be severely limited from the fact that they are completely price takers as suppliers in the international market.

In a more deep analysis, a potential price differential emerging between the actual pricing system and another one, closer to the ideal competitive supply-demand conditions can be seen as an insurance fee. Farmers are willing to pay to millers (usually also exporters) to ensure the placement of their production in the market. Millers are obliged to receive 100% of the production submitted by farmers. In that way, the latter transfer this marketing risk to the former, who will have to find the proper destinations of production. Farmer's engagement into this negotiated agreement is voluntary and they have been doing so for more than half a century, without any public intervention. The own agreement provides a private arbitrage process to be followed when direct negotiation does not comes out with a satisfactory outcome to both sides. This process, where each side appoint a referee, only happened twice in more than 50 years and this year could be the third such year. Other institutional and financial arrangements between farmers and millers have also allowed the development of different services (technical advice, purchase of inputs), also with the inclusion of other key players in this partnership, such as the national research institute, INIA (Instituto Nacional de Investigación Agropecua

Breaking Rice Yields through Sustainable Intensification Pathways

Saldías, R., Lanfranco, B. and Sanguinetti, M.N.

With the expiration of the Millennium Development Goals at the end of 2015, the international community has agreed on an ambitious and transformational 2030 development agenda. While the new set of Sustainable Development Goals (SDGs) and the concrete targets and indicators for achieving these goals are crucial frameworks to guide the global understanding of complex sustainable development challenges, to encourage action and foster accountability, each country still needs to choose its own sustainable development path, with specific, achievable actions and outcomes at the national and sub-national levels. In 2013, Uruguay was selected as a pilot country for a study case analysis of agricultural transformation pathways, under the United Nation's Sustainable Development Solutions Network initiative (SDSN). Although the main focus of the international project was the beef cattle production system, Uruguay authorities decided to broaden the scope of the study and extend the efforts of setting up SDGs to other key agricultural sectors: dairy cattle, rice, soybeans, and forestry.

This research outlines the fundamental elements of a pathway for transforming Uruguay's rice sector in a way that is consistent with post-2015 SDGs. It introduces the productivity and environmental targets for 2030 that constitute the basis of the pathway as well as the methodological approach used to develop them. Uruguay is probably the most export-oriented producing country of the word, selling around 95% of its total production in the international market. No other country actually devotes a proportion as high as Uruguay does. Each year, rice exports reach around one million metric tons of rice products, shipping weight, to more than 50 destinations. This is equivalent to more than 1.3 million metric tons of paddy, placing the country sixth to eighth in the top ten ranking of world net exporters of the cereal.

Sustainable intensification of Uruguay's rice sector is a multi-objective optimization problem. The challenge is to maximize profits by increasing productivity and reducing costs, keeping country's high standards of grain quality, while minimizing the impact over a suite of environmental variables (greenhouse gas emissions, biodiversity loss, water footprint, nutrient loss, etc.). Since the beginning, the definition of sustainable development targets was carried out along with all actors in the rice production chain, combining in-person consultations and workshop activities as much as possible. In order to analyze the feasibility of the necessary pathways for achieving the targets, a mixed-methods approach was adopted, blending intensive literature reviews with modeling efforts and expert judgment from scientists and academics, stakeholders, and decision makers from the public and private sector.

Uruguay rice production in Uruguay was modelled by using the ORYZA V3 model adapted to the local conditions. The productivity target was based on closing current exploitable yield gap between the average national yield and the potential yield adjusted for commercial capacity. According to the simulations, theoretical potential yield (TPY) achieved with the best technology is 14 metric tons per hectare (MT/ha). Assuming exploitable yield as 80% of TPY, that is 11.2 MT/ha, and that actual average yield of 8.1 MT/ha at the national level, there would be an exploitable yield gap of 3.1 MT/ha. After a thorough discussion with researchers, technicians, and farmers, the target for 2030 was set in 9.7 MT/ha. Using the final price of 2015/16 season as the price of paddy in 2030 (USD 245 PMT), and same costs per unit of inputs, profits are expected to rise from 50 to 210 USD/ha.

In the recent past, Uruguay´s rice sector has experienced significant increases in total national production because of agronomic improvements and high-yielding locally developed varieties. This growth did not bring any negative environmental consequences, mostly due to some characteristics of rice production in Uruguay such as the rotation with perennial pastures. The most common set of practices applied by rice producers currently obtaining the highest yields in Uruguay were defined as the technological alternatives that would turn possible the necessary transformation pathways for achieving 2030 production goals. Management practices applied today by leading farmers should be the common practices in 2030.

The environmental impacts were assessed through a set of 8 indicators, for which baseline and target measures were estimated and compared. According to the results, half of the environmental indicators will exhibit a positive evolution: net energy yield (GJ/ha), water use efficiency (kg rice/m^3), and nitrogen use efficiency (kg rice/kg applied N) should increase 15.2%, 22.6%, and 13.2%, respectively, while yield-scaled carbon footprint (kg CO_2 eq/Mg grain) should decrease 17.3%. On the other hand, net energy consumption (GJ/ha) is expected to rise 7%, nitrogen use (kg/ha) and nitrogen loss (kg/ha) are expected to increase 8.4%, whereas gas emissions (kg CO_2 eq/ha) are expected to increase 1.8%.

Uruguay Rice Production: Efficient in the International Market and Supportive of the National Economy

Fernández, E., Ferraro, B. and Lanfranco, B.

Uruguay is a very efficient export-oriented rice producer, exporting 95% of its national production. This large export market makes Uruguay the seventh largest rice exporter globally. Production has multiplied by 27 in the past 50 years, driven in the last two decades mainly by the increase in yields, reaching an average of 8571 kg.ha^{-1} for the 2016/2017 growing season on 165000 ha. Rice represented 5% of the country´s exports in 2016 accounting for more than US$ 434 million. Recently, external and internal factors are threatening historical competitiveness. Low international prices and higher production costs are particularly hampering competitiveness. This paper examines the evolution of the competitiveness of Uruguay rice sector and its contribution to national economy in the last decade.

Competitiveness of the rice sector was analyzed using a modified approach of the Policy Analysis Matrix. Private and social annual benefits were calculated for the last decade. Private benefits refer to economic returns received by private actors operating at various levels of the rice production chain (farm producers, transporters, millers and processing plants, etc.) given the current private prices with the existing taxes, interest rates and social security contributions. Social benefits are economic returns received by all the operators calculated under the assumption of social prices, with no taxes, interest rates or social security contributions considered. The difference between social and private benefits corresponds to the economic transferences from the rice sector to the Uruguayan economy.

After three singular years at the beginning of the decade affected by a drop in rice prices (US\$.t^{-1} 328, 241 and 250 respectively for 2008, 2009 and 2010), both social and private benefits have experienced a slow decreasing trend, being steeper in the last two seasons. Meanwhile transferences have kept almost the same level since 2010/11 with small variations among cropping seasons. Using current values, in 2016/17 social benefits were estimated in US$ 79 per processed metric ton of paddy rice, private benefits US$ 21 and transferences in US$ 58. Transferences from domestic factors cost (labor, capital costs, etc.) divergence between private and social prices calculation accounted for 68% of total transferences, while tradable factors cost (production and processing inputs, energy, etc.) divergence represented 2. % and gross income divergence was 29.5%.

When accounting for transferences the three main sources of divergence between social and private benefits are: taxes paid, country´s differential capital costs and social security contributions. Using deflated values, during the last decade taxes as a proportion of total transferences to the economy, decreased from 42.4% to 32%, capital costs maintained a value around 24% and social security contributions climbed from 34.3% to 43.8% in the last cropping season. The important drop of the tax transferences proportion is partially consequence of the diminished income tax collection from sector´s operators as result of the negative trend in private benefits registered. The relevance of social security contributions reflects the significant improvement in real value salaries paid in the sector and in the country in general, evolving above the inflation rate and the smooth upward trend in the US dollar exchange rate during the period.

Besides salaries, which changed from a value index of 67 to 126 in the last decade (based in constant value and referred to value index of 2011/12=100), other factors that affected the competitiveness of the rice sector were related to the decrease in domestic and export rice prices (186 to 76 and 166 to 93 respectively).

Proportion of private benefits as part of social total benefits (benefit ratio) generated from the entire rice production and processing chain decreased from 46% to 27% in the last seven years. Is expected that the situation shown by the figures will contribute to an endless and important political argue about country´s costs, labor productivity, equilibrium among sectors of the economy, within others. Nevertheless, from the stand point of an agricultural research organization like INIA (Instituto Nacional de Investigación Agropecuaria) the main question is to what extent technology development and extension can still contribute to the economic sustainability of the rice production business and it´s important role in supporting the country´s welfare, in a sector that already achieves high efficiency and productivity levels with no subsidies or external support.

The economic and environmental feasibility of engaging in a production intensification process towards 2030are addressed. The potential economic returns derived from a thorough application of the improved and adjusted technological package, seeking yield increases and higher export surplus are promising. Environmental impact indexes projections also show positive trends. Production intensification achieved through more efficient and environmental sustainable cropping systems, is believed to be the potential leading factor in keeping acceptable private economic benefits in the rice industry while continuing to contribute to the rest of the economy.

How Rice for Feed Consumption Affects Feed Markets

Skorbiansky, S.R., Childs, N.W and Hansen, J.

The U.N. Food and Agriculture Organization estimates that in 2011 over 33 million mt of rice were devoted to feed, 10 percent higher than in 2006 and 27 percent higher than in 2005. Historically, rice has been consumed as a food grain. The recent increasing trend of rice in feed markets, particularly in Asia, is tied to policies that distort incentives for growers to plant rice. These policies saturate stocks and have eventually led to government releases of rice for feed use at a small fractions of the procurement cost. There is little research on the effect of protectionist rice policies in Asia on other feed grains and oilseeds markets, partly due to the lack of data. The governments of Japan, South Korea, and Thailand have recently diverted rice into their feed markets; when rice becomes a substitute for other feeds, general economic principles suggest that it lowers demand for other grains. The USDA-ERS Baseline model shows that if China were to follow in these footsteps, an introduction of rice into its feed market would have an effect, albeit small, on the global and domestic corn markets.

Feasibility and Impact of Rice Self-Sufficiency Strategies in East Africa

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

The 2008 food crisis prompted many food importing nations to reconsider the need to be self-sufficient especially in their staple food needs. This awakening led to the launch of the Coalition for Africa Rice Development (CARD) initiative with a goal to double rice production in Africa. Under the CARD umbrella member countries drafted individual National Rice Development Strategies (NRDS). This study is a quantitative assessment of four East African countries' NRDS: Kenya, Rwanda, Tanzania and Uganda within dynamic global rice economy models. The NRDS targets and strategies are not realistic and included under estimation of rice consumption for Kenya, an incorrect rice production area for Tanzania and overly ambitious production targets for Rwanda and Uganda. Under a business-as-usual scenario, based on historical baseline projections none of the four countries will attain rice self-sufficiency by 2018. Furthermore, the area expansions and yield improvements required to attain self-sufficiency in these countries (with the exception of Tanzania) are unprecedented and highly unlikely to be achieved by the end of 2018. Imposing self-sufficiency through elimination of long grain rice imports would penalize the consumers extremely through high price increases and consequently rice consumption shrinkage in the four countries. In order to attain self-sufficiency without hurting consumers would require sizable improvements of production efficiency. Alternatively, the governments could use output price subsidies to boost production, but the cost would be very large and unrealistic particularly for Kenya. This study concludes that attaining rice self-sufficiency in these countries in the intermediate time horizon is unrealistic. Very large changes in resource allocation, productivity, and consumption trends will be required. It is however important to note that the results obtained in this study may be extremely valued as they are generated within a partial equilibrium framework and may be less dramatic if a general equilibrium framework was used.

Reducing Global Food Insecurity through Rice Breeding

Nalley, L.L., Shew, A.M. and Durand-Morat, A.

Researchers have extensively documented the economic benefits of agricultural research and development in both high and low-income countries. Specifically, plant breeding programs play a crucial role in improving yields and managing biotic and abiotic stresses in agricultural production. When evaluating breeding programs in high-income countries, economists typically estimate benefits in terms of increased yields and subsequent returns on investment in the form of increased producer revenues. However, far less attention is given to the impacts of plant breeding and public research on decreasing food insecurity, which is likely due to lower food security concerns amongst most high income countries. A few studies demonstrate how investments in plant breeding in low and middle income countries have affected food security, but most do not extend estimates of yield gain to analyze trade implications.

To our knowledge, no studies have investigated the global food security impacts of plant breeding programs in high-income countries. Public rice breeding in the United States (US) provides a unique medium to estimate the direct benefits of a high-income country's breeding program on food security because 40% of US rice is exported. Moreover, the majority of US rice exports are sent to low and middle income countries. Established rice research centers such as the International Rice Research Institute (IRRI) and Africa Rice breed specifically for lower income countries, directly affecting regional food security, but genetic gain enhancements derived from public breeding in high-income countries could also indirectly affect food security globally via trade and reduced global prices. Arkansas is the largest rice producing state in the US and exports approximately 40% of production at a value of nearly $1 billion. Furthermore, the University of Arkansas has one of the few public rice breeding programs in the United States, which makes Arkansas an insightful case study for estimating the international food security impacts. Therefore, the purpose of this study is to estimate both the increases to domestic producer revenues and the impacts on global food security via international trade resulting from the publically-funded rice breeding program at the University of Arkansas.

In this study, we estimate increases in total exports from the genetic gains of the rice breeding program at the University of Arkansas (UofA) Division of Agriculture from 1983 – 2016. Rice exports are based on both the quantity of rice (paddy yields) and the quality of rice (head-rice yields). Therefore, we implement location and year fixed-effects models, clustering standard errors on year, to identify the contributions of the UofA breeding program for both paddy yields and head-rice yields over time. Additionally, increased yield was imputed into the RiceFlow trade model to estimate shifts in price and exports.

Including spillover benefits from all UofA varieties, we find a total yield increase of 122.3 million tons per year resulting from the adoption of UofA varieties, driving the long grain rice price down by 1.6 percent and exports up by 56 million tons. Taking the per-capita rice consumption estimate for each U.S. trade partner, the expansion of U.S. long grain rice exports facilitated by the UofA breeding program is enough to feed over 3 million people annually: 1.2 million in Mexico, 385,000 in Venezuela, 100,000 in Iraq, and 80,000 thousand in Haiti, among others.

Intrinsic Rice Attributes and Consumer Preferences: Empirical Evidence from Peru

Durand-Morat, A., Bazzani, C., Nayga, R., West, G., and Price, H.

Previous studies have found that consumers' value food attributes differently. In particular for rice, the literature supports consumer preference variability by country, socioeconomic levels, and rice types. The variability of consumer preferences is not surprising to economists, but presents a challenge for agents in the rice supply chain.

The goal of this study is to analyze the rice quality attributes that drive consumer demand in Peru. The importance of this research is twofold. First, we assess consumer preferences for rice in an important regional market. The empirical trade information supports the idea that Peruvian consumers value rice quality so much that they are willing to pay a significant price premium on rice imports from Uruguay. Second, to our knowledge, no study has assessed consumer valuation for some of the attributes selected in this study such as presence of broken and chalk rice or rice color (associated for instance with the degree of milling). Yet these attributes are crucial for the commercialization of rice in most markets.

We assess consumer preferences for rice quality (percentage of broken rice, chalk rice, color, origin, and price) using a choice experiment approach. A total of 400 consumers from Lima, Peru, were surveyed in July 2017.

Our findings support our hypothesis that Peruvian consumers value rice quality highly. We estimate significant price premiums for rice with low percentage of broken rice and chalk rice. Furthermore, everything else equal, the results show that Peruvian consumers strongly prefer domestic versus imported rice. Our findings can have direct empirical application for domestic and international suppliers servicing the Peruvian market, for instance aiming in the definition of commercial strategies to improve their market opportunities.

Abstracts of Posters on Economics and Marketing
Panel Chair: Lanier Nalley

Economic Potential of Row Rice Production in Northeast Louisiana

Deliberto, M.A., and Hilbun, B.M.

Although a majority of the rice that is produced in Louisiana is cultivated under a continuous flood system, energy costs savings associated with pumping water, reduced labor costs, and sustainability efforts to conserve ground water reserves have contributed to an increased interest in rice produced under a furrow irrigated production system. This production practice is commonly referred to as "row rice" among producers throughout the mid-south region of the U.S. Focusing this discussion on rice production in Louisiana, approximately one-third of rice is produced in the northeastern region of the state with corn and soybeans being cultivated in rotation with rice. In addition to the potential for energy cost savings and aquifer conservation, rice producers in this region could potentially benefit from planting flexibility as furrow irrigated rice does not require in-field levees. This proves beneficial in situations when a producer chooses to delay enterprise selection resulting from market instability and/or adverse weather conditions present at planting.

Historically, fuel and labor have accounted for a one-fifth share of total variable operating costs of rice production in northeastern Louisiana. Therefore, a reduction to these input categories could have an impact on producer profitability. By utilizing a partial budget approach, the cost structure of a row rice system can be compared to traditional rice producing systems of the state. The use of partial budgeting is applicable to this situation as it can be used to evaluate input cost and/or usage that are either reduced or eliminated from the production process. However, rice variety selection will be an important consideration in the decision to adopt a row rice production system, as varieties should possess higher resistance to certain plant diseases. This will likely result in the producer incurring a greater seed cost (e.g. CLEARFIELD® hybrid) as compared to traditional CLEARFIELD® rice seed. Irrigation pumping and the use of poly-pipe tubing, similar to that used in corn and soybean production and that is present in the region are key components in evaluating the economic feasibility of rice production under such a system as the duration of pumping may be influenced by the amount of rainfall throughout the growing season. Production costs were obtained through project cooperators as no formal budget exists for this production system in Louisiana. The primary objectives of this research are to establish an operating budget with hopes to document any potential costs savings associated with row rice production.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Zhongli Pan

Effects of Resistance Starch in Rice Batter on Oil Uptake and Texture

Boue, S.M, Daigle, K., Chen, M.-H., and Bett-Garber, K.

There is growing interest in the creation of healthier foods with high fiber that still mintain high sensory properties. Fried foods are popular with consumers and typically are based on wheat and corn based batters. Rice ingredients are utilized in some foods, including fried batters, because they are known to be nutritious, gluten free, and hypoallergenic. They also have the unique functional property of low oil uptake during frying, which is essential for the development of low oil food products. Resistant starch (RS) is important since it is not easily digested and produces beneficial short chain fatty acids during fermentation in the colon. Also, higher RS in foods offers the possibility of moderated glucose delivery to the body, which can be beneficial to glucose balance. New strategies to incorporate RS into diets are thus needed, particularly in rice ingredients.

In this study we examined the effects of varying RS content in a batter on oil uptake and texture. Several different batter compositions of varying RS content were used. Low RS normal rice starch was converted into high RS starch with pullanase treatment and heating/cooling (RS Type 3, 18% RS content). Commercially available HiMaize (RS Type 2, 44% RS content) corn starch was also used for comparisons. The fried wheat batter absorbed the highest oil amount (51%) in our study and had the lowest hardness value. A commercially available long grain rice flour batter with 15% modified rice starch (18% RS content) produced slightly lower oil content (28.9%) after frying when compared to the rice flour batter (30.8%). Fried rice flour batter with 5% HiMaize starch had higher oil content (32.3%) than the rice flour batter. Hardness values (texture) of each the fried rice batters were higher than the wheat based batter.

Additionally, three rice flour batters from varieties with varying RS contents were examined for changes in oil uptake and texture, after frying. The 3 rice varieties chosen were a low amylose rice (low RS), a medium amylose rice (medium RS), and a new high amylose (high RS) variety. All three of the fried rice batters produced less oil content when compared with wheat flour, and the low amylose rice batter contained the least oil (30%). Texture analysis indicated a higher hardness value for the high amylose (high RS) fried rice batter.

For sensory evaluation, fried onion samples were prepared by using different batter formulations. Evaluations were conducted using the following attributes: harness, fracturability, crispness, and toothpacking. What flour had the lowest values for each of the four attributes. There were little differences in the four attributes between rice flour, rice flour with 15% rice RS, and rice flour enhanced with 5% HiMaize corn RS. When examining the three different rice varieties with varying RS contents, the low amylose (low RS) rice batter appeared to be harder, more fracturable and crisp, and had greater tooth packing when compared to the other two rice batters.

Effects of Growing Environment and Cooking Methods on Resistant Starch Content of High Amylose Rice Varieties

Chen, M-H., McClung, A.M. and Tabien, R.E.

Resistant starch (RS), a type of fermentable dietary fiber, has potential to improve colon health and decrease cardiovascular disease risk factors. It is defined as the fraction of the starch and the products of starch degradation that resist digestion in the small intestines of healthy humans and is partially or entirely fermented in the colon by the microbiota. For the purpose of enhancing RS (dietary fiber) in cooked rice, we evaluated how growing environment and cooking method affect the RS in high amylose rice varieties. Forty high apparent amylose rice varieties were grown in three environments (2 years in AR and 1 year in TX). Individually, the response of rice varieties to growing environment in RS content differed. However, on average, RS contents were higher for the two years grown in AR than in TX. In comparison a high amylose mutant, which contained higher RS than found in nature variants, had higher

RS content in TX than in AR. Around the globe, rice is typically cooked either at a fixed rice-to-water ratio or in excess water. We compared the effect of these two cooking methods on RS content using rice varieties varying in amylose content, gelatinization temperature, and minimum cooking time. Even though the rice cooked with excess water had higher percentage of fully cooked kernel and higher cooked rice moisture than the rice cooked at a fixed rice-to-water ratio, the RS were not significantly different between the two methods.

Development of Rice Mutants with Altered Starch Traits for the Enhancement of Grain Quality

Kim, H. and Tai, T.H.

High concentration of carbohydrates, predominantly starch, is stored in rice (*Oryza sativa* L.) endosperm and biosynthesis and accumulation of starch directly influences rice grain qualities such as kernel appearance, eating and cooking qualities, and milling yield. To improve rice grain quality, induced mutants with altered starch traits were isolated via forward and reverse genetic screens of rice mutant populations derived by chemical mutagenesis of the *temperate japonica* cultivars Nipponbare (n=4,096) and Kitaake (n=2,000).

Using Targeting of Induced Local Lesions in Genomes (TILLING), a reverse genetics approach, of Nipponbare M2 mutants, approximately 120 putative mutations were identified in exon regions of 15 starch-related genes including eight *Starch Synthase* (*SS*) genes, four *Starch Branching Enzyme* (*SBE*) genes, two *Isoamylase* (*ISA*) genes, and one *Rice Starch Regulator* (*RSR*) gene. In the M3 generation, 31 homozygous mutants were identified by Sanger sequencing and are being currently evaluated for grain morphology, and physicochemical properties. Of these lines, NM-5448, an *rsr1* mutant, showed larger grain size and NM-4936, an *sbe1* mutant, showed opaque, loosely packed round starch granules, higher amylose content, and altered amylose chain length distribution. These two mutations were backcrossed to Nipponbare to confirm the relationship between the mutations and the mutant grain phenotypes and to remove undesirable mutations in the genetic background.

A forward genetics approach was employed to screen Kitaake and Nipponbare populations (M4 generation), more than 20 putative mutants exhibited phenotypic variations in grain shape, starch granule shape/size, amylose content, and physicochemical properties. Of these, five mutants were selected based on potentially valuable grain quality characteristics; 1) KDS-1661 showed non-waxy opaque grain, larger grain size, lower grain hardness, loosely packed spherical starch granule, higher amylose content, and altered amylose chain length distribution, 2) KDS-1852 showed non-waxy opaque grains and loosely packed spherical starch granules, 3) KDS-2173 had non-waxy opaque, flat/shrunken and floury endosperm and loosely packed round starch granule, and 4) NE-334 had opaque and floury endosperm and spherical granules. High-amylose starch relates to high resistance to digestion which is good for human health. Spherical starch granules are also correlated to high-amylose starch and loosely packed compounds of granule is correlated to lower starch damage during milling for rice flour. To detect putative mutations, a targeted exon capture approach was employed. Probes for in-solution capture were designed for 16 starch-related genes including one *ADP glucose pyrophosphorylase* gene, two *Granule Bound Starch Synthases* (*GBSS*) genes, six *SS* genes, three *SBE* genes, two *ISA* genes, one *Starch Phosphorylase* (*Pho*) gene and one *Glucose 6-phosphate translocator* (*GPT*) gene. Initial analysis detected putative mutations in *ISA1* in KDS-1623B and in *SS3a* in KDS-1661. For further research through genetic mapping and segregation studies, F2 populations were developed between each of the five mutants and the *tropical japonica* cultivar L-202. Also, these mutants are being backcrossed to Kitaake or Nipponbare to remove background mutations.

Most of mutations identified by forward and reverse approaches are novel based on the natural variation present in the *O. sativa* germplasm of the 3,000 Rice Genomes Project. These novel starch-related mutations will be useful in furthering our understanding of starch biosynthesis and accumulation and may provide valuable germplasm for developing breeding materials for value-added or special use rice varieties.

Comparison of Rice Milling Quality Results from USDA Standard Laboratory Mill and Commercial Mills

Khir, R., Samsalee, N., Tsui, C., Lee, C., McHugh, T.H., and Pan, Z.

There is a need to assess the consistency in milling results obtained from the official FGIS laboratory mill operated under USDA standard procedures and those obtained from commercial mills. The objective of this study was to evaluate whether the official FGIS laboratory mill and procedures provide comparable results to commercial milling operations. To carry out this study, samples (rough and milled rice) were collected quarterly from four different commercial mills in California, Arkansas, and Louisiana. The samples included long- (pure and hybrid), medium- and short-grain. The samples were milled, inspected and graded according to the FGIS standard procedures in an official and licensed lab in Sacramento, CA. The milling results from commercial mills were also collected. The temperature and relative humidity of milling environment in the lab and commercial mills were recorded. Additionally, the moisture contents of rough and milled rice were measured. The results indicated that the temperature and relative humidity of milling environment of commercial mills were higher than those of the lab mill. However, the temperature of milled rice in lab mill was much higher than that of milled rice in commercial mills. The average of milled rice temperature was 33.9±6.3 ºC and 66.9±2.8 ºC for rice milled in commercial mills and lab mill, respectively. The moisture of rough and milled rice measured at lab mill was slightly lower than that measured at commercial mills. While, the moisture content measured using the standard oven method were significantly lower than those measured in Lab and commercial mills. There was inconsistency in the milling quality results obtained from lab and commercial mills. Additionally, the grades for commercial milled rice were higher than those of lab milled rice.

Influence of Infrared Radiation Heating on Physicochemical Characteristics of Rice

Ding, C., Khir, R., and Pan, Z.

Our previous research revealed that infrared (IR) heating has a promising potential to achieve high drying rate, energy saving, effective disinfestation, and disinfection of rough rice. It can also inactivate lipase and extend the storage lives of both rough and brown rice. In this study, the influence of IR heating on physicochemical characteristics of rice was investigated. The results from this study has further confirmed that IR drying has high heating and drying efficiencies compared to those of the conventional drying method. Additionally, IR heating could effectively maintain the stability of physicochemical characteristics of rice during storage. It has positive effects on the color, microstructure, cooking, texture gelatinization, and pasting characteristics of stored rice. The positive effects might be due to the annealing and denaturation effect of IR heating on starch and protein, and its inhibition effect on the activity of those enzymes related with the microstructure changes in brown rice during the storage time. Moreover, IR can effectively stabilize the rice bran and improve its utilization without affecting the quality of rice bran oil. It has been concluded IR heating followed by natural cooling should be an effective approach for rough rice drying.

Green Processing Technologies for Improving Germinated Brown Rice Milk Beverages

Beaulieu, J.C., Reed, S., Cole, M.R., Daigle, K.W. and Boue, S.M.

Rice feeds approximately half the world's population. Rice-derived beverages offer non-soy, lactose-free, hypoallergenic, cholesterol and gluten free value-added food sources. Rice milk beverages offer exceptional options for those with lactose intolerance, gluten sensitivities, obesity, heart disease, diabetes and consumers desiring to cut back on animal products. Worldwide sales of non-dairy milk alternatives more than doubled between 2009 and 2015 to $21 billion. Brown rice is nutritionally superior to white rice but, oils and rancidity can be problematic regarding storage and organoleptics. To avoid rancidity issues, stabilized rice or rice flour has been used for much past research and invention. Germinating brown rice is known to increase several health-promoting compounds. Herein, we are attempting to use green technologies, focusing on sprouted brown rice and processing with enzymatic treatments which, do not rely upon stabilization, to produce novel, value-added rice milk products. Through green technologies, focusing on sprouting organic brown rice and processing which does not rely upon stabilization, along with food-grade enzymatic treatments, we will deliver preliminary analysis of novel value-added health-beneficial rice milk beverages.

Organic 'Rondo' paddy rice was freshly de-hulled on a Satake in a pilot plant followed by sorting, grading and culling then 400-600g brown rice was pre-rinsed, placed into sprouting jars with screen lids for 30 min soaking treatments at 35°C in water ± 30 and 300 ppm peracetic acid, followed by a soak/sprouting cycle for 48 hr at 35°C. Samples were thermally softened and wet-milled using several rice to water ratios, ultimately passing a 140-mesh sieve before gelatinization and saccharification with food-grade enzymes. Initial rice and post-sprouted samples (proximate analysis) and several quality-related parameters at key processing steps were evaluated.

'Rondo' brown rice pH was ~7.14 which dropped after sprouting to 5.28±0.07, with germination rates of 97.0-99.0±1.0%. At 35 °C, rice absorbed 31.1±1.6% water. Peracetic acid rinses markedly reduced TPC and mold. Coleoptile lengths (2.30±0.89mm) decreased slightly in peracetic acid (~2.09±0.71mm). Phytic acid decreased 67% after sprouting, and total phenolics increased from 6.95±0.73 to 7.73±0.48 mg GAE/g. After an optimized softening and milling process, phenolics increased further to 8.65±0.80 mg GAE/g in crude beverages. 30 ppm peracetic acid only slightly decreased phenolics compared to germinated samples, and 300 ppm was apparently lethal (data not shown). Proximate analysis of the freshly de-hulled brown rice for crude protein (%), fat (%), fiber (%), ash (g/100g) and moisture content (%) was: 7.23±0.10, 4.16±0.13, 1.70±0.10, 1.40±0.03 and 9.88±0.09, respectively. Carbohydrates decreased from 75.6% to 53.0% after sprouting, and likewise, catabolic decreases in protein (27.2%) and fat (38.7%), occurred after sprouting. Initial processing regimes lost what appeared to be insoluble fiber and/or high molecular weight protein through sieves (e.g. 69.28, 0.73 and 13.60 for L*, a* and b*, respectively) yet, after refining the processing methods, no longer was tan colored residual lost after passing mesh sieves, and crude liquids appeared whiter in color (e.g. 78.45, -0.78 and 6.83 for L*, a* and b*, respectively). In germinated gelatinized samples, after 30 min, α-amylase liquefaction, 13.7 °Brix soluble solids were attained which, stabilized at 15.1 °Brix after 72h. Additional liquefaction enzyme treatments for starch/sugar conversions and analyses are in progress. Likewise sample analyses for starch/sugar, particle size, viscosity and gamma-aminobutyric acid are proceeding.

Dissection of Genetic Architecture of Grain Chalk Using NIR Spectroscopy

Barnaby, J.Y., Huggins, T., Lee, H.S., Oh, M.R., McClung, A.M., Pinson, S.R.M.,
Tarpley, L., Kim, M.S., and Edwards, J.

Chalk is a major quality characteristic that causes grain breakage during milling and loss of crop value. In this study, we sought to elucidate the quantitatively inherited grain chalk trait in rice and to conduct genome-wide association mapping to identify SNPs and candidate genes associated with grain chalk. Whole grain rice (dehulled rough rice) of the USDA mini-core collection rice germplasm grown in AR (2009 and 2010) and TX (2008) was evaluated using a high throughput phenotyping tool, hyperspectral imaging system. This diversity panel has approximately 220 varieties originating from around the world, includes representatives of the five subpopulations of *O. sativa*, and has an associated genomic dataset of 3.3 million SNP markers. Our results showed that a wavelength range of 600-700 nm of visible NIR (VisNIR) spectroscopy was significantly associated with the grain chalk phenotype, and further identified several chalk related genes, i.e. phosphatase protein, serine/threonine kinase, phospholipase, glycosyl hydrolase family proteins, that were identified previously, as well as other novel genes. Furthermore, quantification of the chalk trait using this imaging system was validated using a bi-parental mapping population segregating for grain chalk. These results indicate the value of using hyperspectral imaging as a means of non-destructive high throughput phenotyping for rice grain chalk and suggest the possibility of using this method for other physicochemical grain properties.

Improving Milled Rice Nutrition via Manipulation of Starch Crystalline Structure and Micronutrient Penetration Treatments

Peng, V., Mujahid, H., and Peng, Z.

Milled rice is deficient in many important nutrients including protein, fat, vitamins, minerals, and fibers except carbohydrates. The zinc, iron, vitamin A and vitamin C contents are remarkably low compared with other cereal crops. The poor nutrition of milled rice has caused severe malnutrition problems, particularly among children and older populations, in developing countries where the access to other food is limited. . The supplemented micronutrients in fortified/enriched rice produced using current rice nutrition fortification/enrichment methods can't sustain the washing step prior to cooking, which is a traditional practice used by most families in regions where rice is used as the staple. More importantly, recent studies have shown that washing rice before cooking is critical because it can substantially remove arsenic by removing the powders derived from rice husk and rice bran, both of them contain very high content of arsenic compared with milled rice. To overcome the problem, we have developed a new rice nutrition enrich/fortification method in which the enriched/fortified rice can sustain the washing step before cooking. Palatability tests and nutrient content analysis have demonstrated that consumers can't tell the difference between regular rice and our fortified/enriched rice in both appearance and taste while the nutrition level of the fortified/enriched rice has been substantially improved.

Effect of Water Management and Silica Slag Application on the Arsenic Content of Rice

Harrell, D.L., Kongchum, M., and Adotey, N.

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 Codex Alimentarius Commission recommends that the concentration of inorganic As (As_i) in polished (milled white) rice should not exceed 0.2 mg kg^{-1} while As_i in brown rice should not exceed 0.35 mg kg^{-1}. Previous research has indicated that growing rice using alternative water management practices such as alternate wetting and drying (AWD), semi-aerobic methods (furrow irrigated, flush only irrigated) and those that utilize at least one drain event (straighthead management) can significantly reduce As_i. Some previous research has also shown that silica containing soil additives can also reduce total As in rice. No research has evaluated the combined effects of water management and a Si soil amendment on rice As content. The objective of this study was to evaluate the combined effects of different water management practices and a silicate slag (Si-slag) soil amendment on rice grain yield, As concentration in rice straw, and the As concentration in milled, brown and paddy rice.

A field trial was established in 2017 at the H. Rouse Caffey Rice Research Station on a Crowley silt loam soil. The trial contained three water management practices and 3 soil amendments. Water management practices included: 1) delayed flood water management (DF), where rice is managed in upland conditions until the 5^{th}-leaf or first tiller stage of rice development when the permanent flood was established; 2) AWD water management, where rice was managed like DF for the first 3 weeks after flooding and then the water was allowed to subside naturally until the soil was exposed in the middle of the paddy which was followed by re-flooding; and 3) semi-aerobic (SA) water management, where rice was only flushed weekly. Soil amendment treatments included: 1) Si-slag applied at 6.7 Mg ha^{-1} (3 tons A^{-1}; 60% ECCE); 2) ag lime at 4.8 Mg ha^{-1} (2.15 tons A^{-1}; 85% ECCE); and 3) no amendment. Plant samples were taken at harvest, dried, threshed, and milled. Straw, milled rice, brown rice, and paddy rice were digested and total arsenic (As_t) was determined by ICP-OES.

Rice yield was not significantly altered due to the soil amendment by water management interaction or the soil amendment main effect. Rice grain yield was significantly higher for DF (11,987 kg ha^{-1}) and AWD (10,331 kg ha^{-1}) as compared with SA (5,632 kg ha^{-1}) water management. The As_t concentration in the straw, paddy, brown, and milled rice was not changed due to the water management by soil amendment interaction or by the main effect of soil amendment. However, a significant response was observed for the straw, paddy, brown and white rice As_t concentration due to water management ($P < 0.001$; LSD = 0.1). The As_t concentration in the straw at harvest was highest with DF (0.61 mg kg^{-1}), significantly lower with AWD (0.35 mg kg^{-1}), and was reduced further with SA (0.17 mg kg^{-1}) water management. The Ast concentration in rough ($P < 0.001$; LSD = 0.06), brown ($P < 0.001$; LSD = 0.06) and milled ($P < 0.001$; LSD = 0.6) rice were all significantly altered by water management. Rough rice As_t concentration was 0.68, 0.58 and 0.43 mg kg^{-1} under DF, AWD and SA, respectively. Brown rice As_t concentration was 0.63, 0.53 and 0.38 mg kg^{-1} under DF, AWD and SA, respectively. Milled rice As_t concentration was 0.53, 0.45 and 0.34 mg kg^{-1} under DF, AWD and SA, respectively.

Silicon Amendments for Managing Arsenic Accumulation in Rice

Limmer, M.A., Mann, J., Amaral, D.C., Vargas, R., and Seyfferth, A.L.

Arsenic is a problematic contaminant in paddy rice due to the carcinogenicity of its inorganic forms. The addition of silicon to is a promising technique to limit rice accumulation of arsenic as arsenite enters rice roots through silicon transporters. In this work, we applied three silicon-rich amendments to rice paddy microcosms. The three amendments included calcium silicate, rice husk, and rice husk char, all of which are available to farmers. An unamended control was also included. The goal of this work was to examine the ability of these amendments to provide a long-term source of silicon and minimize rice uptake of arsenic. Throughout the experiment, porewater and greenhouse gas fluxes were measured weekly. At harvest, plants were dissected into various parts and analyzed for nutrient and arsenic concentration. Arsenic speciation was measured for ripe polished grain and ripe bran. Iron plaque mineral composition was analyzed by EXAFS.

All three amendments performed similarly compared to the control. In most aboveground plant parts, Si-rich amendments significantly increased Si concentrations. Similarly, the Si-rich amendments, particularly the rice husk char, decreased plant accumulation of As and slightly decreased grain accumulation of inorganic arsenic. Si-rich amendments also increased the percentage of ferrihydrite in the root iron plaques, which may affect arsenic sorption in the root iron plaques. Porewater concentrations of nutrients, DOC, and arsenic were not significantly affected by any of the treatments. Methane emissions only significantly increased for the Husk amendment, likely due to the lability of the carbon provided by this amendment. Collectively, the results suggest that these amendments all provide similar levels of silicon to rice resulting in decreased accumulation of arsenic.

Stable Mercury Isotopes in Polished Rice and Hair from Rice Consumers

Rothenberg, S.E., Yin, R., Hurley, J.P., Krabbenhoft, D.P., Ismawati, Y., and Donahue, A.

Rationale: Fish consumption is considered the primary dietary source for methylmercury; rice ingestion is also an important dietary exposure pathway for methylmercury. Mercury (Hg) stable isotopes are useful tracers for understanding sources and biogeochemical fate of mercury in the environment. In a population, where rice is the primary but not exclusive dietary source of methylmercury, we hypothesize that mercury stable isotope signatures will differentiate between rice and fish consumption.

Methods: Hg isotopic signatures were investigated in 46 rice (*Oryza sativa* L.) samples from four sites, including Daxin, China (n=21), Wanshan, China (n=8), Indonesia (n=14), and Arkansas, USA (n=3). In addition, for rice samples from Daxin, China, we also characterized mercury isotope ratios in corresponding human hair samples (n=21). For each of the 21 participants, we previously quantified the proportion of methylmercury intake through rice (range: 31-100%), and the daily servings of fish (range: 0-0.8 servings/day) (Hong et al., Environmental Research, 2016).

Results: Both mass-dependent (MDF, reported as δ^{202}Hg) and mass-independent fractionation (MIF, reported as Δ^{199}Hg and Δ^{201}Hg) fractionation of Hg isotopes were observed. For rice, we observed negative MDF (δ^{202}Hg range: -3.5‰, 0‰) and minor MIF (Δ^{199}Hg range: -0.24‰, 0.16‰) (n=46). Compared to rice, for participants from Daxin, China, hair δ^{202}Hg was higher (δ^{202}Hg range: -0.86‰, 1.3‰), while Δ^{199}Hg was slightly higher (Δ^{199}Hg range: -0.09‰, 0.41‰) (n=21). Hair δ^{202}Hg values were enriched on average (± 1 SD) by 1.9 ± 0.61‰ relative to corresponding rice samples, suggesting substantial MDF occurred during methylmercury metabolism. Using simple linear regression, the Δ^{199}:Δ^{201} slope (± standard error (SE)) was identical for paired rice and hair samples (rice: 1.16 ± 0.11; hair: 1.16 ± 0.10, n=21 for both). More importantly, hair Δ^{199}Hg was significantly inversely associated with the proportion of methylmercury intake from rice (Spearman's rho = -0.91, p<0.01, n=21), and significantly positively correlated with daily servings of fish (Spearman's rho = 0.54, p=0.01, n=21); i.e., as the proportion of methylmercury intake from rice increased, MIF decreased.

Conclusions: Overall, results suggest that Hg isotopes (especially MIF) in human hair can be used to distinguish methylmercury intake from rice versus fish.

Genetic and Physiological Relationships between Grain Arsenic and Resistance to Straighthead

Pinson, S.R.M., Edwards, J.E., Heuschele, D.J., Tarpley, L., Isbell, C., Green, C.E., and Smith, A.P.

There is global concern regarding the amounts of arsenic (As) contained in rice grains and foods. The World Health Organization (WHO) recently set a CODEX limit of 0.2 ppm inorganic As in milled white rice, and a lower limit of 0.1 ppm was advised for baby food products. Arsenic is also toxic to plants, with rice straighthead disease being associated with As-toxicity. Plants have evolved mechanisms that reduce As toxicity, and increased resistance to rice straighthead disease may be due to regulation of As uptake, transport, sequestration/tolerance or a combination of all three to mitigate toxic effects from As. Each of these mechanisms could also be contributing to the wide (200-fold) differences in grain-As reported among rice accessions. Arsenic toxicity and grain-accumulation are of greater concern in rice than other grain crops because the redox conditions in flooded rice paddies makes soil-As more available for plant uptake. One method proposed that can reduce grain-As concentrations by about 10-fold is to produce rice without a flood for all or part of the production season, but this can increase pest damage and decrease yields. Because roots uptake As through phosphorus (P) and silica (Si) transporters, application of P and Si fertilizers have also been evaluated means of decreasing grain-As and straighthead severity.

Our research has focused on identifying rice genes and physiological factors that can be exploited to reduce grain-As. A previous study of 1763 international accessions (the USDA Rice Core), identified some rice accessions with higher than average As concentrations in their grain (a.k.a. "grain-As Accumulators") and others with low grain-As concentrations (a.k.a. "Excluders"). It appears that US rice breeding efforts have inadvertently decreased grain-As in that US cultivars released more than 30 years ago accumulated more grain-As than more recent US cultivars. Compared to global varieties with a similar intermediate maturity, modern USA cultivars have lower grain-As. A set of 16 rice accessions (8 Accumulators and 8 Excluders, including 'Lemont' and 'Jefferson') were selected for further study. When the Accumulators and Excluders were compared for As concentration and metabolism in leaves and roots under field and hydroponic conditions, data indicated that reduced grain-As concentrations were not due to reduced root uptake or root-to-shoot transfer rates, but were associated with more efficient sequestration of As in leaf vacuoles, a process that involves several sulfur (s) containing compounds. This raised the question of whether application of S-containing fertilizer to increase S in rice plants could be used to decrease grain-As by increasing As-sequestration.

The effects of foliar application of $MgSO_4$ fertilizer on grain-As and straighthead response were investigated. Initial evaluation of foliar fertilization applied at the booting stage to one-half of three production fields planted with the same hybrid appeared promising. However, a second year of study involving replicated field plots of multiple pure-line and hybrid cultivars, as well as a repeat conducted in the commercial fields showed that neither grain-As nor straighthead were reduced even in the plots treated twice (seedling and booting stage) with a higher rate of $MgSO_4$ than that applied the previous year. Both inorganic and total As were evaluated in the grain, with neither showing a reduction due to foliar treatment with $MgSO_4$. In contrast, grain-S concentrations did increase with treatment, indicating that the foliarly applied S did enter and transport through the treated plants.

Relationships between grain-As, grain-P, grain-S, hull-Si, and straighthead resistance in rice were further investigated by identifying QTLs for each of these traits in a single association mapping population – the USDA Rice Minicore. This population of 194 diverse accessions was recently resequenced in China, providing publically available high density genome-wide SNP marker loci with which to map grain-elements and hull-Si using previously collected phenotypic data. Response to MSMA-induced straighthead disease was evaluated in the Minicore in 2015 and 2016, two replications per year. Genome wide association study (GWAS) identified multiple putative QTLs (from 3 to 21) for each of these traits, but there was little co-location of QTLs among the five traits. None of the QTLs we identified for grain-As under flooded field conditions (where As stress occurs) overlapped with QTLs for straighthead, grain-P, grain-S, or hull-Si; two straighthead QTLs overlapped with grain-P QTLs.

Because reduced As uptake or enhanced As detoxification and sequestration would be expected to reduce both grain-As and straighthead, we anticipated finding some grain-As QTLs to be co-located with straighthead QTLs. Overlap with grain-P, grain-S, or hull-Si QTLs was sought as additional knowledge on the mechanisms underlying grain-As and straighthead QTLs. We found no overlap between the grain-As and straighthead QTLs identified in the Minicore population. It appears that the wide variations for grain-As and straighthead observed within the Minicore are regulated by different genes.

Effect of Harvest Moisture Content and Seeding Rate on Organic Arborio Rice Milling Yield

Emery, A., Bergmann, J.P., Gehrig, A., Deitz, C., Kluge, A., Soderstrom, D., Lundberg, E., Benson, L., Lundberg, J., and Jiang, J.

Maximizing head rice yield in Arborio-type varieties continues to be a challenge for organic rice producers and processors, with average head rice yield being low at 2,094 kg/ha and head rice percent at 40.8 over last three years at Lundberg Family Farms. The objective of this study was to evaluate the effect of seeding rate and harvest moisture content on grain yield, milling quality (head rice %), and head rice yield (grain yield x head rice %) for organic Arborio rice.

We compared three seeding rates (168, 224, and 280 kg/ha) in three replicated strips. Each strip was divided into six plots (29.2 square meters per plot) for data collection. Throughout the growing season, agronomic traits including seedling vigor, plant density, heading date and lodging resistance were observed. For grain yield and milling quality data analysis, a 9.3 square meter sample was harvested within each plot at three different dates (Oct 24, Oct 31, and Nov 14). We found that both harvest moisture content and seeding rate had a significant effect on head rice yield, however, the head rice yield increase was correlated with grain yield increase and not milling quality for both factors. In response to three harvest moisture contents (29.7, 25.6, and 22.7%), grain yield was significantly different at 3,919, 4,389 and 4,157 kg/ha, respectively; the head rice percent was not significantly different at 50.2, 51.0, and 51.9%, respectively. As a result, head rice yield averaged significantly different at 1,963, 2,239, and 2,162 kg/ha, respectively. Likewise, in response to three seeding rates (168, 224, and 280 kg/ha), grain yield was significantly different at 3,751, 4,363, and 4,352 kg/ha, respectively; the head rice percent was not significantly different at 51.2, 50.0, and 51.9%, respectively. As a result, head rice yield was significantly different across treatments, averaging 1,919, 2,181, and 2,264 kg/ha, respectively. As expected, an increase in seeding rate resulted in an increase in plant density and lodging percentage, but did not have an effect on heading date.

The results from this experiment indicated that harvesting organic Arborio rice at a moisture content of 25% can significantly increase both grain yield and head rice yield. In this study, the optimal seeding rate for organic Arborio rice production was 224 kg/ha; further increase in seeding rate did not significantly increase grain yield or head rice yield.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2020 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 2020 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 38th 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 required and should be submitted to the respective panel chairs 2 ½ months prior to the 38th RTWG meeting in 2020, or earlier as stated in the Call for Papers issued by the 38th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2020 RTWG meeting and their email and mailing addresses are presented following this section. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Michael Salassi
   Dept. of Agricultural Economics and Agribusiness
   LSU AgCenter
   101 Martin D. Wooden Hall
   Baton Rouge, LA 70803
   Phone: (225) 578-2713
   Fax: (225) 578-2716
   Email: msalassi@agcenter.lsu.edu

2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author’s affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
    a. Include a statement of rationale for the study.
    b. Briefly outline methods used.
    c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 38th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 38th 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 38th 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 2020 PANEL CHAIRS

Breeding, Genetics, and Cytogenetics:

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Stoneville, MS 38776

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Yuba City, CA 95991

IN MEMORY OF

Larry Godfrey

Larry Godfrey died April 18, 2017, in Davis, CA, after a six year battle with cancer. Larry grew up in Indiana and received his Bachelor's and master's degrees in entomology from Purdue University and his doctorate in entomology from the University of Kentucky. Since 1991, Larry was an Extension Specialist for the University of California Department of Entomology working on vegetable and field crops. Larry's work on rice focused on the development of management practices for arthropod problems. He conducted research on growers' fields and at the Rice Experiment Station in Biggs, and participated in extension activities, such as grower and industry meetings. Larry's research and extension efforts were highly respected and recognized by his colleagues. He received the Excellence in IPM Award in 2005 and the Distinguished Achievement Award in Extension in 2010 from the Pacific Branch of the Entomological Society of America, and in 2014 he received the Distinguished Rice Research and Education Team Award form the RTWG for his contributions to the field of rice arthropod management. Larry trained many graduate students and mentor farm advisors working with him on vegetable and field crops. Larry loved to be out in the field, and continued working on his projects through his health struggles. California and the US rice industry lost a great researcher, educator and friend.

IN MEMORY OF

Joseph A. Musick, Jr.
(March 9, 1936 – February 27, 2017)

Dr. Joseph "Joe" Musick was the Resident Director of Rice Research Station, Crowley, LA, from 1985 to 2003. He is a strong supporter of RTWG and the rice industry for many years. He obtained his BS degree from University of Arkansas, Agricultural Economics in 1969, MS degree from the same university in 1971, and Ph.D. from University of Missouri in 1980. His vision was to help maintain and develop high quality multi-disciplinary research and educational programs with emphasis on agricultural production, economic development, natural resource conservation, and human development to address the needs of citizens in the southwest region and other rice growing areas of the state.

He served in various professional and industry support activities, including the Louisiana Rice Research Board as Advisor and Coordinator of research projects; U.S.A. Rice Federation as Advisor and Ex-officio member; Rice Foundation as Advisor and Ex-officio member; U.S.A. Rice Federation Environmental Committee as Committee member; and U.S. Rice Producers' Legislative Group as Advisor, Farm Policy and Programs.

His position required budgeting and fiscal responsibility for an annual budget of approximately 3.6-4.5 million dollars, supervised 28 professional-scientific personnel involving 12 agricultural scientific disciplines, and also supervised 27 classified and 15 to 35 transient personnel. His responsibility included coordinating agreements among the state agricultural experiment stations of Arkansas, Louisiana, Mississippi-Dale Bumpers National Rice Research Center, Texas, and Puerto Rico for a rice winter nursery. The winter nursery provided for multiple plantings of rice breeding lines and has contributed to accelerated rice variety development.

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 (highest number of votes) 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. Electronic submissions of the nominations are preferred; these should be submitted as a single pdf file, with the exception of a one-page summary of accomplishments that should be provided at the same time, but as a MS Word file. Hard copies can be submitted, in which case fifteen (15) complete copies of each nomination must be submitted, and a one-page summary of accomplishments 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 S.-T. Tseng	B. Wells	S.D. Linscombe	
			Advances in Rice Nutrition Team	
2000 Biloxi, MS	D.M. Brandon J.W. Stansel	R.K. Webster	P.K. Bollich R.J. Norman	C.E. Wilson
			Bacterial Panicle Blight Discovery Team	
2002 Little Rock, AR	F.L. Baldwin R.H. Dilday	M.A. Marchetti J.F. Robinson	M.C. Rush	D.E. Groth A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
2004 New Orleans, LA	P.K. Bollich A.D. Klosterboer F.N. Lee W.H. Brown	J.A. Musick J.E. Street J.F. Williams S.L. Wright	F.N. Lee A.K. Moldenhauer	M.A. Marchetti
			Individual	
			R.D. Cartwright	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			LSU Rice Variety Development Team	
			S. Linscombe	X. Sha
2006	T.P. Croughan	J.N. Rutger	P. Bollich	R. Dunand
The Woodlands, TX	R. Talbert	F. Turner	L. White	D. Groth
			Individual	
			R. Norman	
			Bakanae Team	
			J. Oster	R. Webster
2008	M.C. Rush	R. Dunand	C. Greer	
San Diego, CA	C. Johnson			
			Individual	
			D. Groth	
2010	T. Miller	J. Thompson	Individual	
Biloxi, MS	J. Kendall		E. Webster	
			Advances in Nitrogen Use Efficiency Team	
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, LA			L. Espino	M. Way
			L. Godfrey	
			Individual	
			J. Saichuk	
			Clearfield Rice Technology Research Team	
2016	Rolfe J. Bryant	Lawrence M. White, III	D. Groth	
Galveston, TX	Farman Jodari		D. Harrell	
			S. Linscombe	
			E. Webster	
			Individual	
			Terry Siebenmorgen	
			Rice Irrigation Management Team	
2018	Merle Anders	Johnny Saichuk	Merle Anders	Jarrod Hardke
Long Beach, CA	Randall "Cass" Mutters	Terry Siebenmorgen	Michelle Reba	Arlene Adviento-Borbe
	Steven D. Linscombe	Lloyd T. "Ted" Wilson	Benjamin Runkle	Bruce Linquist
			Chris Henry	Steve Linscombe
			Joe Massey	Dustin Harrell
			Individual	
			Michael Orrin "Mo" Way	

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
36th	2016	Galveston, Texas	E.P. Webster	L. Tarpley	M.E. Salassi
37th	2018	Long Beach, California	L. Tarpley	B. Linquist	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

2018

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)

Old Business

i) The Chair opens the meeting
ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

New Business

The Necrology Report read by Chair.

The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.

The Chair leads a discussion of any New Business that has developed since the last RTWG meeting. Several months prior to the RTWG meeting the Chair should solicit any New Business items from the Executive Committee.

b. Closing Executive Committee Meeting (held on last day of meeting)

Old Business

i) The Chair opens meeting
ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. Opening General Session and Business Meetings

The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

a. Opening General Session and Opening Business Meeting (begins the RWTG meeting)
   i) The Chair opens the meeting and thanks the host state delegation for preparing the program.
   ii) The Secretary welcomes the RTWG membership to their state.
   iii) The Chair opens the Business Meeting by asking the Secretary to read the minutes of the Closing Business meeting from the previous RTWG meeting and the Chair then entertains a motion for acceptance of the minutes.
   iv) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.
   v) The Chair reads the Necrology Report and asks for a few moments of silence.
   vi) The Nominations Committee Chair reads the nominations for the Executive Committee and Nominations Committee to the RTWG membership. The RTWG Chair then entertains a motion to accept the nominations.
   vii) The Chair calls on the Chair of the Location and Time Committee of the next biennial meeting to report when and where the next RTWG meeting will be held.
   viii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.
   ix) The Chair asks for a motion to adjourn the Opening Business Meeting.
   x) The General Session usually ends with invited speaker(s).

b. Closing Business Meeting (ends the RTWG meeting)
   i) The Chair opens the meeting and calls for Committee reports from Rice Crop Germplasm, Rice Variety Acreage, Rice Industry, and the Publication Coordinator.
   ii) The Chair thanks the Publication Coordinator(s) for their efforts in coordinating, editing, and publishing the RTWG Proceedings.
   iii) The Chair thanks the host state delegation for hosting the RTWG Meeting.
   iv) The Chair then passes the Chair position to the Secretary/Program Chair. The incoming Chair thanks the Past Chair for service to the RTWG and presents the Past Chair with a plaque acknowledging their dedicated and valuable service to the RTWG as the Chair.
   v) The incoming Secretary/Program Chair informs the membership of the time and place for the next RTWG meeting.
   vi) The incoming Chair invites everyone to attend the next RTWG meeting and asks for a motion to adjourn the RTWG meeting.

3. Publication Coordinator(s)

The Publication Coordinator(s) are responsible for providing instructions for manuscript preparation, collecting abstracts from the Panel Chairs, assembling all pertinent information for inclusion in the Proceedings, final review, and publication of the Proceedings upon the conclusion of each RTWG meeting. The Publication Coordinator(s) solicit input from the Executive Committee, Panel Chairs, and the general membership for changes and/or adjustments to the RTWG Proceedings content, style, format, and timetable. It is, however, the Publication Coordinator(s) responsibility to make the final decision on changes appropriate to insure the Proceedings is a quality product and reflective of the goals and objectives of the organization. This flexibility is needed to insure that publication of this information through their respective institution is done in accordance with university or other agency requirements. The Publication Coordinator(s) are responsible for updating the guidelines for submitting abstracts as needed and including this information in the published Proceedings and also on the RTWG host website once the call for abstracts is made. The Publication Coordinator(s) are responsible for mailing proceedings in electronic 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 Chair 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, 2018	Secure Hotel
May 1, 2019	Pre-RTWG planning meeting
June 15, 2019	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 2019	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 2019	First call for papers and a call for award nominations
Sept. 15, 2019	Second call for papers (Reminder; e-mail only)
Oct. 15, 2019	Titles and interpretive summaries due
Dec. 1, 2019	Abstracts due
Dec. 1, 2019	Award nominations due to Chair
Dec. 1, 2019	Registration and housing packet sent
Jan. 3, 2020	Reminder for registration and hotel (e-mail only)
Jan. 29, 2020	Last day for hotel reservations
Jan. 30, 2020	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 2020	Registration due without late fee
Mar. 2, 2020	38^{th} 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.

Sunday: 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.

Monday: 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.

Tuesday: 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.

Wednesday: The biennial meeting usually ends on Wednesday with the Closing Executive meeting and then the Closing Business meeting.

10. Symposia

Symposia are welcomed in conjunction with the RTWG biennial meetings. Symposia must not interfere with the RTWG biennial meetings and are to be held prior to the committee meetings on the first day (i.e., Sunday) of registration 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:

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b. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

c. Type: Do not use any word processing format codes to indicate boldface, etc. Use 10 point Times New Roman font.

d. Heading:
   i) Title: Center and type in caps and lower case.

ii) Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
iii) Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

e. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

f. Content is limited to one page.
i) Include a statement of rationale for the study.
ii) Briefly outline methods used.
iii) Summarize results.

g. Tables and figures are not allowed

h. Literature citations are not allowed.

i. Use the metric system of units. English units may be shown in parentheses.

j. When scientific names are used, *italicize* them -- do not underline.

C. Guidelines for RTWG Awards

1. The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

a. <u>The Distinguished Rice Research and/or Education Award</u>

i) <u>Individual category</u> – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research and (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress, and promise technical advances in the rice industry.

ii) <u>Team category</u> – Same as the individual category, one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

b. <u>The Distinguished Service Award</u> - Awards to be made to designate individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, or industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2. The Awards Committee shall consist of the Executive Committee.

3. Responsibilities and duties of the Awards Committee are as follows:

a. To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee members cannot nominate or write letters of support for an individual or team for the RTWG awards. If a member of the Awards Committee is nominated for an award in a given category, it is common courtesy to abstain from voting in that category.

b. In the event that a real or perceived conflict of interest regarding award nomination packets exist, the Chair 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 (highest number of votes) 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. Electronic submissions of the nominations are preferred; these should be submitted as a single pdf file, with exception of a one-page summary of accomplishments that should be provided at the same time, but as a MS Word file. Hard copies can be submitted, in which case fifteen (15) complete copies of each nomination must be submitted, and a one-page summary of accomplishments 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.

37^{TH} RTWG ATTENDANCE LIST

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