Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Sixth Rice Technical Working Group

Galveston, Texas: March 1 – March 4, 2016

Edited by: Michael E. Salassi, Lee Tarpley and Eric P. Webster

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

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station

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RICE TECHNICAL WORKING GROUP

Organization and Purpose

The Rice Technical Working Group (RTWG) functions according to an informal memorandum of agreement among the State Agricultural Experiment Stations and the Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, and the Agricultural Research Service, the Economic Research Service, the National Institute of Food and Agriculture, and other agencies of the United States Department of Agriculture. Membership is composed of personnel in these and other cooperating public agencies and participating industry groups who are actively engaged in rice research and extension. Since 1950, research scientists and administrators from the U.S. rice industry and from international agencies have participated in the biennial meetings.

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

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

Several 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 2016 Meeting

The 36th RTWG meeting was hosted by Texas and held at the Moody Gardens Hotel Spa and Convention Center in Galveston, Texas, from March 1 to March 4, 2016. The Executive Committee, which coordinated the plans for the meeting, included Eric P. Webster, Chair; Lee Tarpley, Secretary; and Charles E. Wilson, Jr., Immediate Past Chair. Geographic Representatives were Trent Roberts (Arkansas), Bruce Linquist (California), Matthew VanWeelden (Florida), Mike Stout (Louisiana), Jeff Gore (Mississippi), Donn Beighley (Missouri), Ted Wilson (Texas), and Frank Carey (Industry). Administrative Advisors were John Russin (Experiment Station - Louisiana), Rogers Leonard (Extension Service - Louisiana), and Anna McClung (USDA-ARS). Publication Coordinator was Michael Salassi (Louisiana). The Industry Representative was Frank Carey (Tennessee). Website coordinator was Eric Webster. The Local Arrangements Coordinators for Texax were M. O. Way (Chair), Fugen Dou, Rodante Tabien, Yubin Yang, Xin-Gen Zhou, and Lee Tarpley.

Location and Time of the 2018 Meeting

The 2018 RTWG Meeting Location Committee recommended that the 37th RTWG meeting be held by the host state California. The meeting will be held from February 18 to February 21, 2018, at the Westin Long Beach in Long Beach, California.

2016 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. Terry Siebenmorgen. The team award was presented to the LSU AgCenter Clearfield Rice Technology Research Team, whose members included Drs. Don Groth, Dustin Harrell, Steve Linscombe, and Eric Webster.

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. Rolfe Bryant, Dr. Farman Jodari and Mr. Larry White.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 36th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2016 proceedings. The 2016 proceedings was edited by Michael E. Salassi, Lee Tarpley (Secretary), and Eric P. Webster (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 37th RTWG (2018 meeting) proceedings are included in these proceedings.

Committees for 2018

Executive:

Chair:	Lee Tarpley	Texas
Secretary:	Bruce Linquist	California

Geographical Representatives:

Xueyan Sha	Arkansas
Luis Espino	California
Matthew VanWeelden	Florida
Henry S. Utomo	Louisiana
Bobby Golden	Mississippi
Michael Aide	Missouri
Ted Wilson	Texas
Pat Clay	Industry

Immediate Past Chair:

Eric P. Webster	Louisiana

Administrative Advisors:

John Russin	Experiment Station
Rogers Leonard	Extension Service
Anna McClung	USDA-ARS

Publication Coordinator:

Mike Salassi	Louisiana

Web Page Coordinator:

Eric Webster	Louisiana

Industry Representative:

Frank Carey	Tennessee

2018 Local Arrangements:

Bruce Linquist (Chair)	California
Luis Espino	California
Whitney Brim-Deforest	California
Randal Mutters	California
Michelle Leinfelder-Miles	California
Kent McKenzie	California
Kassim Al-Khatib	California
Lauren McNees	California

Nominations:

Jason Bond (Chair)	Mississippi
Charles E. Wilson, Jr.	Arkansas
Randall (Cass) Mutters	California
Matthew VanWeelden	Florida
Adam Famoso	Louisiana
Sam Atwell	Missouri
Fugen Dou	Texas
Pat Clay	Industry

Rice Crop Germplasm:

Georgia Eizenga, Chair	USDA-ARS
James Correll	Arkansas
Adam Famoso	Louisiana
Farman Jodari	California
Karen Moldenhauer	Arkansas
Ediliberto Redoña	Mississippi
Paul Sanchex	California
Xueyan Sha	Arkansas
Qiming Shao	Crop Protection Service
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
Chuck Wilson	Arkansas
Kent McKenzie	California
Bobby Golden	Mississippi
Donn Beighley	Missouri
Ted Wilson	Texas

2018 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:	
Thomas Tai	California
Economics and Marketing:	
Lanier Nalley	Arkansas
Plant Protection:	
Luis Espino	California
Processing and Storage:	
Zhongli Pan	California
Rice Culture:	
Randal (Cass) Mutters	California
Rice Weed Control and Growth Regulation:	
Kassim Al-Katib	California

RESOLUTIONS
36th RTWG – 2016

The 36th meeting of the RTWG, held in Galveston, Texas, March 1 to March 4, 2016, 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 36th meeting.

1. Eric P. Webster, RTWG Chair, and all other members of the Executive Committee who organized and conducted this very successful meeting. We recognize Lee Tarpley 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 Moody Gardens Hotel, Freeman A/V, and the Galveston Island Convention & Visitors Bureau, Galveston, Texas, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements Committee chaired by M. O. Way, Texas, for the site selection and overseeing arrangements. To the faculty and staff of the Texas A&M AgriLife Research Center at Beaumont, Texas, 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 Texas A&M AgriLife Research staff who contributed time and effort for numerous vital tasks that made sure this meeting was a success.

5. The Panel Chairs, Rodante Tabien, Michael Salassi, Shane Zhou, Ming-Hsuan Chen, Fugen Dou, and Muthu Bagavathiannan, and moderators for planning, arranging, and supervising the technical sessions. The Symposia Chairs and Co-chairs, Fugen Dou, Yubin Yang, L. Ted Wilson, Rodante Tabien, Lee Tarpley, Ming-Hsuan Chen, M.O. Way, Shane Zhou, Yulin Jia, and Yeshi Wamishe for planning, arranging and supervising these special sessions. Special recognition is due for the efforts of the chairs, Jenny Wang and Michael Salassi, to collect, organize, and edit abstracts for the Website posting and final publication.

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

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

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

9. We gratefully recognize our many sponsors that made the 36th Rice Technical Working Group meeting possible.

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Distinguished Rice Research and/or Education Award

Terry Siebenmorgen

The most all-encompassing example of Terry Siebenmorgen's accomplishments is the creation, and sustained growth, of the University of Arkansas Rice Processing Program. Dr. Siebenmorgen initiated this program in 1994 as an industry-interactive, multidisciplinary effort focusing on rice processing operations. The Rice Processing Program is recognized internationally as a focal point for information and research on rice processing. The Program has been supported in large part by annual contributions from over 25 companies located across the United States, Europe, South America and Asia for now over 20 years. Siebenmorgen organizes the annual Industry Alliance Meeting to share research results, demonstrate new equipment and procedures, and solicit Program feedback and direction. This meeting has steadily grown in attendance and stature and is regarded as a hallmark of the Rice Processing Program.

The scope of Dr. Siebenmorgen's research program ranges from pre-harvest property characterization, through drying, storage, milling, and end-use quality evaluation. A unique aspect of his research has been to improve engineering aspects of rice post-harvest technology through better understanding of the development, physicochemical properties, and processing behavior of individual kernels. His major technical research areas are presented as follows:

<u>Glass Transition Hypothesis</u>: A series of studies have been conducted to apply polymer chemistry principles to the rice drying process. Equipment and uniquely-designed procedures were developed to measure the "glass transition temperature" of kernels, how this temperature is affected by kernel moisture content, and the dramatic changes in kernel properties surrounding this temperature. This fundamental work has led to the formulation of a hypothesis describing why milling yields can be deleteriously impacted during the drying process.

<u>Environmental Impacts on Rice Quality</u>: A multidisciplinary effort has quantified the effects of nighttime air temperatures (NTATs) occurring during kernel development on rice milling and end-use quality. This work has statistically quantified the deleterious impacts of NTATs on milling and functional properties and has also indicated the reproductive stages during which high-temperature exposure damage is incurred. This research has spanned over 10 years, ranging in scope from environmental chamber and phytotron experiments to multi-state field plots. The work offers strong evidence for explaining the previously-inexplicable processing variability that has plagued the rice industry for many years.

<u>Factors Impacting Rice Milling Yields</u>: Pioneering efforts have been made to quantify kernel-to-kernel property distributions through the introduction of modern technology that rapidly measures individual kernel properties. This work has explained trends in milling and functional quality of rice and has changed the thinking to view a rice lot as a collective compilation of individual kernels rather than simply as a bulk average commodity.

<u>Milled Rice Breakage</u>: A sporadically-occurring, yet tremendously costly problem that existed in the rice industry was one in which freshly-milled rice fissured and subsequently broke apart during handling or processing. A large collaborative project involving several companies was conducted to develop specialized equipment and test protocols to determine that the underlying cause, and kinetics, of this problem was related to rapid moisture transfer to/from kernels. Based on the results, several companies have altered their milling equipment and operation logistics.

Distinguished Rice Research and/or Education Team Award

Don Groth, Dustin Harrell, Steve Linscombe, and Eric Webster

One of the most important developments to come from the H. Rouse Caffey Rice Research Station in recent years has been the introduction of Clearfield rice. This technology has probably had a greater impact on Louisiana rice production than any other new technology developed from the Station's research efforts. Clearfield technology allowed for the chemical control of red (weedy) rice in a rice production field for the first time ever. Red rice is a noxious weed in rice production and is a close genetic relative of commercial rice, actually belonging to the same taxonomic species (*Oryza sativa*) as cultivated rice. Because they are so closely related, it is extremely difficult to develop a herbicide that will kill red rice without injuring commercial rice if used in the same field.

In the 1990s, induced mutants were developed at the Rice Station that were resistant to imidazolinone herbicides. Red rice, as well as conventional rice, is susceptible to these herbicides. As a result, it was now possible to develop a technology for the control of red rice through the use of these induced mutants and the imidazolinone herbicides. Eventually, imazethapyr in 2002 followed by imazamox in 2007 were labelled by American Cyanamid (later BASF) for use with this technology. For the first time, rice fields infested with red rice could be seeded with a variety developed through the use of these mutants. The field could then be sprayed with imazethapyr or imazamox, which would control the red rice plants without harming the plants of the resistant variety.

Rice breeders at the HRC Rice Research Station led by Steve Linscombe took these mutated plants and through conventional breeding techniques developed agronomically-adapted rice varieties that could be grown successfully in Louisiana and other southern rice producing states. The first commercial production of Clearfield rice in Louisiana was in 2002. The use of this technology grew after the initial introduction, and by 2012, more than 65 percent of the rice acreage in the southern United States was seeded with Clearfield varieties and hybrids. Since 2002, the HRC Rice Research Station has released 11 Clearfield rice varieties, both long- and medium-grain, for use by Louisiana rice producers. These varieties have also been the predominant pureline varieties used by rice producers with Clearfield technology in the other southern rice producing states.

One of the difficulties with the introduction of the Clearfield system was that the most successful mutants were induced in the very sheath blight-susceptible variety Cypress. Sheath blight, caused by the fungus *Rhizoctonia solani*, is the most important rice disease in the southern United States and worldwide, second only to blast. Louisiana's high humidity and temperatures favor the development of the disease, so improved disease management practices were needed to control sheath blight. How a farmer manages sheath blight can mean the difference between a profit and a loss. Targets for improving sheath blight control included disease resistance and cultural and chemical management practices. Most of the older Clearfield rice varieties are very susceptible to sheath blight. In inoculated versus uninoculated or fungicide-treated plots, these earlier varieties, including CL161, lost 20 to 25% of their yield potential to sheath blight under heavy disease pressure. Through crossing and disease screening programs, most currently grown Clearfield varieties are now rated moderately susceptible to susceptible and only lose 5 to 17% of their yield potential under heavy disease pressure.

By developing improved IPM methods, such as avoiding excessive plant populations and nitrogen (N) applications, and using scouting to predict fungicide need, the percentage of Clearfield fields receiving a fungicide application for sheath blight has been reduced over the years. Also, fungicide application technology has been greatly improved by precisely determining timing, rate, and disease spectrum of each fungicide. Don Groth has been the leader for the research that has led to improvements in disease control in the Clearfield system.

Reduced seeding rates was another beneficial change that occurred when the shift from water to drill seeding occurred in Louisiana with the introduction of Clearfield rice. In water-seeded rice, recommended seeding rates were from 90 to 120 pounds of seed per acre. Today, as a result of agronomic research and updated seeding rate guidelines, drill-seeded Clearfield rice is commonly sown at seeding rates from 50 to 80 pounds per acre. This represents a reduction in seeding rates of approximately 45%. In addition to using less seed, drill seeding Clearfield rice allows seed and the resulting stand of rice to be evenly distributed throughout a field reducing much of the yield variation often seen throughout water-seeded fields. Plant populations were also reduced using drill-seeding methods, which in turn reduced the occurrence of rice diseases like sheath blight. If sustainable agriculture is defined as using less to produce more, then Clearfield rice has truly made Louisiana rice production more sustainable than ever before.

Drill- or dry-broadcast seeding of Clearfield rice has also had an impact on the way rice is fertilized with N. In water-seeded rice, N was often applied by utilizing multiple applications of N fertilizer into standing water or on top of muddy soil. The efficiency of these early season N fertilization practices is very low, often resulting in less than 30% of the applied N actually making it into the rice plants. Today, dry-seeded Clearfield rice is fertilized when the rice is at the 4-leaf stage of development using granular urea applied on dry ground followed by establishing the permanent flood. This method incorporates the N fertilizer and stabilizes the N. Fertilizing rice using this strategy more than doubled the efficiency of N in rice production. However, one problem did exist with this method of fertilization. If irrigation of a rice field took several days to establish a flood, urea exposed on the soil surface could result in large losses of N as a gas. Research with enhanced efficiency fertilizers resulted in the recommendation of treating urea with a urease inhibitor containing the active ingredient NBPT or NPPT if it took more than three to five days to flood a field. The result was a substantial reduction of gaseous N losses to the environment. Today, when recommended N fertilization guidelines are followed, N fertilization in rice can often reach efficiencies of 80% or higher, making rice production one of the most N efficient crops grown in the United States. Dustin Harrell was responsible for much of the agronomic research that has led to these major improvements through the use of Clearfield technology.

Eric Webster has been responsible for much of the weed control research that has led to the successful use of Clearfield technology in Louisiana rice production. Imazethapyr has both preemergence and postemergence activity on many grasses, including red rice and broadleaf weeds. With the ability to control red rice with a single herbicide having residual and postemergence activity, producers have more flexibility to apply Newpath in a manner that suits their immediate needs. The Clearfield system also allows the use of more residual herbicides, such as Prowl, Facet, and Command, to aid the rice in the early part of the growing season by reducing early season weed competition. This also allows producers to move to the use of ground application equipment and reduces the number of aerial herbicide applications needed to manage weeds.

The weed management project, with research conducted in Louisiana on Clearfield rice, directly impacted wording of the Newpath label and how the herbicide would be used to maximize weed control with this new herbicide-resistant rice. The Clearfield system has had a major impact on rice weed management in Louisiana and other rice producing states in the mid-south. This technology has had a positive impact on the environment with the reduction in the amount of water, pesticide, and fertilizer use, while at the same time having a positive impact on weed management, increased yields, and profitability of Louisiana rice production. In reality, the Clearfield technology took a struggling rice industry in Louisiana and made it profitable again. In 2001, the average yield in Louisiana was 5,500 lb/A. In the 14 years since the release of Clearfield rice and its widespread adoption in the state, average yields have increased by up to 2,000 lb/A. This increase can mostly be attributed to Clearfield rice through improved varieties, increased N efficiency, better disease management, and vastly improved weed control.

This technology changed the way many Louisiana producers grow rice. Prior to Clearfield rice, most farmers water-seeded rice as a means of culturally controlling red rice. With this system, a field would be flooded and then worked in the water with an implement to destroy any existing vegetation, including any germinated red rice. Sometime later, the field would be broadcast-seeded with an airplane. After a few days to allow for germination and growth, the field would be drained for a short time to allow the roots of the small seedlings to penetrate the soil. The field would then be reflooded before the soil was allowed to crack. The small rice plants would then be allowed to grow through the shallow flood. This system helped minimize red rice by depriving the red rice seed in the soil of oxygen, which is needed for germination. However, this system only suppressed red rice at best and sometimes was not very successful in doing so.

With Clearfield technology, famers can dry-seed (drill or dry-broadcast) fields. Not only does this system do a much better job of controlling red rice, it also allows for a reduction of the red rice seed in the soil. Remember that the water-seeding system depends on preventing buried seed from germinating, where dry-seeding allows for red rice seed germination after which the imazethapyr herbicide kills the red rice plants, thus reducing the red rice seed in the soil.

There are other advantages of the dry-seeded system. In the water-seeded system, when the fields are drained to allow the seedlings to anchor into the soil, there is often a high level of suspended soil particles in the water that moves into the receiving stream. Not only does this increase sediment levels in the stream but it could also significantly decrease dissolved oxygen levels. This is typically much less of an issue with dry-seeding, which makes this system more environmentally sound. Under some conditions, the dry-seeded system also reduces the total amount of irrigation water necessary to grow the rice crop. Some seedling diseases are more common in water-seeded rice as well.

This technology has had a positive impact on the environment with the reduction in the amount of water, pesticide, and fertilizer use, while at the same time having a positive impact on weed management and increasing yields and profitability of Louisiana rice production. These four team members have been instrumental in the successful adoption of Clearfield rice technology in Louisiana as well as in all the southern U.S. rice producing states.

Distinguished Service Award

Rolfe J. Bryant

Dr. Rolfe J. Bryant, with the USDA, Agricultural Research Service, has served the rice industry for 19 years as a Research Chemist focusing on rice grain quality. During this time Dr. Bryant provided perspective, creativity, new and unique methodologies, and major improvements in techniques for identifying and creating rice with superior grain quality for present and future markets. His service to the rice industry has been multifaceted, from the evaluation of breeding lines for end-use quality traits to understanding the genes and environmental factors that influence grain quality, starch structure and starch-synthesis enzyme activities. As part of a team he developed analytical methods to evaluate valueadded and health-beneficial traits which led to the identification of novel germplasm containing previously unidentified genes and subsequently contributed to the development of new rice cultivars containing these value-added traits.

Professionally, Dr. Bryant is an active participant at Rice Technical Working Group (RTWG) meetings. He has served as Panel Chair for the RTWG "Postharvest Quality, Utilization and Nutrition" panel. He also regularly participates in the American Association of Cereal Chemists and has been elected to national technical advisory committees.

As a service to all U.S. public rice breeding programs, Dr. Bryant provided quality analysis (amylose content, alkali spreading value, protein content, lipid content, etc.) for thousands of early generation experimental breeding lines each year. He always went the "extra mile" by accepting additional breeding lines to assist the breeders. Additionally, he annually analyzed the 200 Uniform Rice Regional Nursery entries to ensure that breeders had the necessary information for identifying and releasing new cultivars with acceptable or superior grain cooking, processing and sensory quality for both domestic and export markets. To expand the usefulness of the U.S. rice germplasm collection to rice breeders and researchers he routinely analyzed accessions in the National Small Grains Collection and these data are part of Germplasm Resource Information Network that is publicly available. In addition, Dr. Bryant systematically characterized approximately 1,800 diverse world accessions composing the Rice Core Collection for grain quality traits. In addition he documented the negative impact of red rice contamination on white rice cooking and processing quality and the negative impact on quality of grain yellowing during storage.

As rice researchers and growers experimented with different cultural practices to increase yield and reduce expenses, Dr. Bryant conducted research that confirmed that many of these new cultural management practices had no negative impact on cooking and processing quality, and thus could be adopted by growers.

Utilizing his analytical knowledge to develop appropriate methods, Dr. Bryant contributed to the development of 35 commercial and specialty cultivars and germplasm releases. This included the development of two low-phytic acid germplasms, Kaybonnet *lpa*1-1 and goldhull low phytic acid, both noted for having about 50% less phytic acid and a 7-fold increase in digestible inorganic phosphorus content without suffering negative impact on availability of other minerals. He developed a rapid method to analyze volatile chemical compounds that impact rice flavor and demonstrated this method can even be used on single kernels. Additionally, this method can distinguish the chemical compounds unique to aromatic rice cultivars, which is necessary for breeding aromatic rice. Silica from rice hulls is potentially useful for high-valued industrial compounds. Dr. Bryant modified methods to determine the silica concentration in rice hulls from a diverse collection of rice cultivars, then used them to identify and make available to breeders genes controlling silica content. Dr. Rolfe Bryant's contribution to developing and modifying methods used to evaluate potential new cultivar releases has contributed significantly to U.S. rice breeding programs. Throughout his career he has collaborated with researchers from diverse disciplines and organizations. His research and service to the rice research community has helped to sustain and enhance grain quality for the USA rice industry.

Distinguished Service Award

Farman Jodari

Farman Jodari received a B.S. in Agronomy from Tabriz University, Tabriz, Iran; a M.S. in Agronomy Crop Science major, with a minor in Agricultural Engineering in 1979, and a Ph.D. in Agronomy, Crop Physiology major with a minor in Statistics from Mississippi State University in 1981. From 1981 to 1983 he was a Post-Doctoral Research Associate at the LSU Southeast Louisiana Research Station. Franklinton, LA. In 1983, he join the LSU Rice Breeding Program at Crowley, LA, as an instructor and advanced to a tenured associate professor before moving to the Rice Experiment Station Biggs, CA, in 1999 to lead the long-grain breeding project there to the present day.

While in the LSU Rice Breeding Program, he participated in its expansion and transition to national prominence. He has participated as a breeder in the development and release of numerous rice varieties for conventional and specialty markets in the southern region and California.

Dr. Jodari has always been a "high quality breeder" and that has been a continuing theme in his career. This is reflected in his participation in the release of 'Cypress' by LSU, still identified as the gold standard for U.S. long-grain milling. In addition, his devotion to aromatic rice breeding produced the improved aromatic `Dellmati' and 'Delrose' varieties and laid a foundation for the release of later aromatics by LSU. His high quality focus has also produced high quality long grains adapted to the cool California climate including 'L-206' and the basmati and aromatic varieties, `Calmati-202,' and 'A-202,' respectively. Yield potential has not been forgotten as his long grains are often the top performers in the University of California Statewide Yield Test.

Farman conducts related research studies that provide information to facilitate variety development efforts, as well as provide useful information to U.S. rice producers. He has published his work as both senior and co-author in many publications. Two of his articles on grain fissuring effects on milling yield of rice cultivars as influenced by environmental conditions were key in improving rice milling and grain quality in the United States and around the world. He has developed a significant national and international reputation because of his research activities. He is an active member and has played a leadership role in the USDA Rice Crop Germplasm Committee as Chairman, U.S. Public Rice Breeding Group, and as a member of Rice Technical Working Group.

Distinguished Service Award

Lawrence M. White, III

Mr. Larry "Smokey" White has been in charge of the H. Rouse Caffey Rice Research Station's Foundation Seed Program for most of his 35 plus year tenure there. One of the very important functions of the Rice Research Station is the production of foundation rice seed. Foundation seed is the first step in the commercialization of a rice variety, insuring that the seed a grower purchases to plant his crop is the variety he chooses and is of high germination, purity and free from noxious weeds such as red rice. The objective of this program is to provide Louisiana farmers with foundation seed rice of new varieties developed through the Louisiana Agricultural Experiment Station's breeding program and of established commercial varieties originating either at the Rice Station or at research centers in neighboring states. Mr. White's main objective was to purify, increase and distribute foundation seed rice. Larry has long prided himself in making sure superior foundation seed was produced. In fact, the Rice Station's Foundation Seed Program is widely regarded as one the finest in the United States, thanks primarily to Mr. White's efforts.

During his time at the Rice Station, Mr. White was a very loyal, dedicated, helpful and cooperative individual. He was a very positive model for all of the other employees that he worked with. He arrived at work each morning prior to 6 a.m. and often stayed late to make sure a job was accomplished. Larry was also on the station most Saturdays and Sundays during the growing season to monitor his seed fields (check flood water levels, evaluate growth stages, etc.). Mr. White was responsible for coordinating the multitude of activities that are necessary for the successful production of pure seed to facilitate the first (and most important) step in providing the industry with the highest quality of registered and certified classes of pedigreed rice. The seed Mr. White produced was the farmer's link with the work of the plant breeder. It is the product of successive generations of selection and testing to establish its value as crop seed and eventually as a commercial commodity. A very important step in seed production is roguing seed production fields. This involves walking the entire field to locate and remove noxious weeds and off-type rice plants. Most seed producers rogue fields once and sometimes twice. Mr. White's fields were all rogued at least four times and sometimes even more. Roguing is not a pleasant task. His insistence that fields be rogued multiple times was evidence of his dedication and commitment. Mr. White is familiar with and followed all of the rules and regulations pertaining to the certification of agricultural seed set forth by the Louisiana Seed Law.

Mr. White understood that in order for his program to be successful, the rice variety efforts must be successful as well. To facilitate this, he worked very closely with rice breeders and support personnel in the breeding project. This also allowed him to have first-hand experience with and knowledge of potential new rice varieties that might be entering his program in the future. Mr. White understood that the primary function of the foundation rice seed project is in support of the Louisiana rice industry. He totally understood that in order for this project to be successful, there needs to be a very close cooperative working relationship between all Rice Station projects, seed dealers, farmers, Louisiana Cooperative Extension personnel, chemical company representatives, farm equipment dealers, etc. Mr. White maintained this type of relationship with everyone that he dealt with. Larry was an excellent spokesman for the Rice Station as well as his project.

Mr. White continuously evolved his production and postharvest practices to benefit his program. He was one of the first in southwest Louisiana rice production to utilize laser leveling on his seed production fields. He also was a pioneer in the adoption of conservation tillage seeding programs for rice production, which is currently utilized on 100% of Rice Station seed production area. Mr. White exceled in his relationships with coworkers at the Rice Station, as well as others. He was widely regarded as one of the most helpful and cooperative individuals at the Rice Station. He was always helping other projects when time allowed. This included the most laborious tasks performed on the station such as butting levees and cutting hand harvested samples. This spirit of cooperation has set a very positive example that has encouraged other station employees to help coworkers whenever possible.

Mr. White has furthered his education and knowledge by attending all rice field days and grower meetings and interacting with researchers and farmers. He attended classes on pesticide application and stayed up-to-date on all of the regulations. He attended educational conferences such as the Rice Technical Working Group and the Conservation Tillage Rice/Cotton Conference. He was invited to travel to China recently to observe and consult in rice seed production there. Mr. White retired in October of 2015. For his long-time valuable service to the Louisiana and U.S. rice industry, he is very deserving of the significant recognition associated with the RTWG Distinguished Service Award.

Minutes of the 36th RTWG Meeting

Opening Executive Committee Meeting

In attendance: Eric Webster (Chair), Lee Tarpley (Secretary), Chuck Wilson (Immediate Past Chair), Trent Roberts (Arkansas Rep.), Bruce Linquist (California Rep.), Matthew VanWeelden (Florida Rep.), Mike Stout (Louisiana Rep.), Jeff Gore (Mississippi Rep.), Donn Beighley (Missouri Rep); Ted Wilson (Texas Rep.), Frank Carey (Industry Rep.), John Russin (Experiment Station Administrative Advisor), Rogers Leonard (Extension Service Administrative Advisor), Mike Salassi (Publication Coordinator), and Steve Linscombe (requested).

Chair Eric Webster called the meeting to order at 8:00 a.m. on March 1, 2016, at the Moody Gardens Hotel Spa & Convention Center in Galveston, Texas.

Old Business

Eric Webster presented that the previous meeting was held at the Sheraton New Orleans in New Orleans, Louisiana.

Eric Webster presented the minutes from the 35th RTWG in 2014. Lee Tarpley moved that the minutes be approved as printed and dispense with reading and Chuck Wilson seconded.

New Business

Award recipients for the 2016 meeting include: Terry Siebenmorgen, Research and Education Award; and Rolfe Bryant, Farman Jodari, and Larry "Smokey" White, Distinguished Service Awards. The Team Award was presented to the Clearfield Technology Team. Members of that team included Steve Linscombe, Don Groth, Dustin Harrell and Eric Webster.

Eric Webster asked for individuals that should be included in the necrology report.

Eric Webster (for Anna McClung) presented Robert "Bob" Cogburn and Robert Fjellstrom. Lee Tarpley presented Julian Craigmiles and Glenn Whitney.

Eric Webster initiated discussion concerning means to more effectively use the RTWG's permanent website (rtwg.net). Steve Linscombe indicated that previous Proceedings of the RTWG meetings really ought to be placed on the website.

Chuck Wilson moved and Ted Wilson seconded that LSU or a designee be charged with uploading the previous Proceedings to rtwg.net, and that links be provided on the permanent site to the host website for the upcoming meeting and to the site for the most recent meeting. The measure was approved.

Lee Tarpley discussed the program and layout of the Conference Hotel.

Lee Tarpley, on behalf of "Mo" Way (Chair of Poster Arrangements), presented the setup for the Poster contest, which is new for RTWG.

John Russin indicated the need to rewrite the SERA018 project, and that the opportunity should be used to change the title to the "Rice Technical Working Group" because this is the title in common use. The rewrite will need to be submitted in late winter '17/early spring '18. The suggested writing committee was Steve Linscombe (chair), Chuck Wilson, Lee Tarpley and Bruce Linquist. Ted Wilson moved that the committee of these members be accepted; Chuck Wilson seconded. The SERA018 Project writing committee consisting of these members was approved.

John Russin indicated that, although the RTWG meetings have good participation, very few of the attendees are SERA018 project members, thus the RTWG activity is not truly reflected in the federal databases. Discussion ensued about how to improve membership levels. Chuck Wilson suggested that we could send an email to the RTWG listserv; that Executive Committee members could be required to be a member; and that the RTWG Chair could write a letter to Center Directors of key rice research centers to approach their faculty. The question arose if Project members must be affiliated with a university; answer: No, but interested non-University-affiliated folks would need to work with their state agricultural experiment station director to become a member.

After some discussion of the process for receiving nominations for and voting on awards, Donn Beighley moved that the procedure be changed to allow submission of nominations and distribution of nomination packets by either hard copy or electronic means. The motion was seconded by Lee Tarpley. The measure was approved.

Bruce Linquist announced the 2018 meeting will be held in Long Beach, CA, on February 18 to 21, 2018, at the Westin Long Beach.

Lee Tarpley agreed that Texas A&M AgriLife Research would pay for the RTWG website for two years, and indicated that costs have increased some.

Lee Tarpley moved that the meeting be adjourned and was seconded by Chuck Wilson. Meeting was adjourned at 8:45 a.m.

Opening Business Meeting

Chairman Eric Webster called the meeting to order at 9:10 a.m. on March 2, 2016, at the Moody Gardens Hotel Spa & Convention Center in Galveston, Texas.

Lee Tarpley was asked to read the minutes from the last RTWG meeting. Steve Linscombe moved to dispense with the reading of the minutes and Chuck Wilson seconded the motion. The motion was approved.

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

Chairman Eric Webster stated the importance of and encouraged RTWG attendees to become members of the SERA18 Project.

Bruce Linquist announced that the 37th RTWG meeting will be held in Long Beach, CA, on February 18 to 21, 2018, at the Westin Long Beach.

Larry Godfrey, chair of the Nominations Committee, recommended the following individuals for leadership for the 37th RTWG:

Lee Tarpley – Chair
Bruce Linquist – Secretary
Eric Webster – Immediate Past Chair

Geographical Representatives:
Xueyan Sha – Arkansas
Luis Espino – California
Matthew VanWeelden – Florida
Henry S. Utomo – Louisiana
Bobby Golden – Mississippi
Michael Aide – Missouri
Ted Wilson – Texas
Pat Clay – Industry

Nominations Committee:
Jason Bond – Mississippi (Chair)
Charles Wilson, Jr. – Arkansas
Randall (Cass) Mutters – California
Matthew VanWeelden – Florida
Adam Famoso – Louisiana
Sam Atwell – Missouri
Fugen Dou - Texas
Pat Clay – Industry

Steve Linscombe moved to accept the nominations and seconded by Tim Walker, motion passed.

Lee Tarpley announced the sponsors for each level: Tejas, Gulf Coast, Rio Grande, High Plains, and Big Thicket. Appreciation was also given to all those aiding in organizing the meeting.

Lee Tarpley announced the general schedule, including changes to the program, of the 36th RTWG meeting.

Steve Linscombe moved that the business meeting be adjourned and seconded by Jason Bond.

Meeting was adjourned

Closing Executive Committee Meeting

In attendance: Eric Webster (Chair), Lee Tarpley (Secretary), Chuck Wilson (Immediate Past Chair), Anna McClung (USDA-ARS Administrative Representative), Trent Roberts (Arkansas Rep.), Bruce Linquist (California Rep.), Matthew VanWeelden (Florida Rep.), Mike Stout (Louisiana Rep.), Jason Bond (acting Mississippi Rep.), Donn Beighley (Missouri Rep.), Pat Bollich (Louisiana), and Mike Salassi (Publication Coordinator).

Chairman Eric Webster called the meeting to order at 7:00 a.m. on March 4, 2016, at the Moody Gardens Hotel Spa & Convention Center in Galveston, Texas.

Old Business

Lee Tarpley stated we had about 430 attendees. Student participation appears to have increased from previous meetings.

New Business

The question was asked if the RTWG should consider changing to a society rather than operating as a project. A concern was that such a change would mean losing the ability to use university resources to run the meetings, so that an executive VP might need to be hired, and a business plan and constitution would need to be developed.

There was general discussion concerning if and how RTWG should seek to attract additional attendees: international attendees, sessions on prominent/"hot" topics; grower participation. There were concerns that industry participation might be down.

There was general discussion concerning the student poster competition. Suggestions for improvement included that posters could be clumped together, rather than organized, for example, by panel, separating out PhD and MS contestants, ensuring consistency in judging among panels, improving pre-meeting notice of criteria to be used in judging and format requirements, aggressively advertising the competition. Eric Webster or Jason Bond will send out a score sheet used by a society, which has an active student poster competition, to request comments for possible adaptation to RTWG. A suggestion was to add a paragraph to the MOP on poster competition procedures. It was agreed that Bruce Linquist (Secretary/Program Chair for 2018) would assign someone to work with Jason Bond (Chair of poster competition) to develop the procedures for 2018.

Lee Tarpley provided an update on the panel business meetings held during the 2016 RTWG meeting. All panel recommendations were received but not yet compiled. Two items arose from the panel meetings that deserved attention by the Executive Committee. One concerned a recommended to encourage the use of bullets/numbered items in the Recommendations; it was agreed that such use should be encouraged.

The other item concerned a proposed name change of the "Breeding, Genetics & Cytogenetics Panel" to the "Breeding, Genetics & Genomics Panel." If approved, this name change could be reflected in the new project, which will be rewritten to route for approval in early 2018. Lee Tarpley moved to change the name as presented; seconded by Mike Stout. The name change was approved.

Donn Beighley motioned that the executive committee meeting be adjourned and seconded by Lee Tarpley.

After no further business, the meeting was adjourned at 8:20 a.m.

Closing Business Meeting

Chairman Eric Webster called the meeting to order at 8:30 a.m. on March 4, 2016, at the Moody Gardens Hotel Spa & Convention Center in Galveston, Texas. He extended his gratitude to Texas for hosting the 36th RTWG, and to Michael Salassi for his efforts at publishing the proceedings.

Mike Salassi, publication coordinator, gave a report on the proceedings for 2016 meetings. He indicated he would be in communication with the panel chairs to finalize the abstracts.

The Rice Variety Acreage Committee (Dustin Harrell, Chair) met on March 1, 2016, as part of the RTWG meeting. Kent McKenzie moved and Chuck Wilson seconded that the reading of these minutes be dismissed; the reading was dismissed. The full minutes of the committee meeting held on March 1, 2016, will be provided in the Proceedings.

Georgia Eizenga presented the Rice Germplasm Committee report on behalf of Farman Jodari. The Rice Germplasm Committee met on March 1, 2016, as part of the RTWG meeting. The Rice CGC met on March 1 from 4-6 pm. To begin with the minutes of the 2015 meeting in Stoneville, MS were approved. Three ex-officio members, Peter Bretting, Gary Kinard and Harold Bockelman, participated in the meeting via conference call. Peter Bretting from the USDA/ARS office of National Programs presented a report on the status of the National Plant Germplasm collections including number of accessions, distributions and budget. Gary Kinard, USDA/ARS National Germplasm Resources Lab, reported on the transition from GRIN to GRIN-Global which was completed in February. Harold Bockelman, curator of the small grains collection reported on the status of the rice germplasm collection including new accessions and distribution. Jack Okamura, ARS/USDA National Program Leader for rice was in attendance. Marth Malapi-Wright, from APHIS newly hired for Poaceae Quarantine, was in attendance. She introduced herself and reported on the accessions coming through quarantine in her office. Committee members discussed the needs for additional rice germplasm introduction. Continued revisions to the rice crop vulnerability report were discussed. Paul Sanchez and Adam Fomosa were elected to serve on the committee and Karen Moldenhauer was re-elected to serve another term. Georgia Eizenga was elected as the committee chair.
A motion was made to accept the report by Kent McKenzie and seconded by Larry Godfree. The report was accepted.

Eric Webster reported on behalf of Industry Representative, Dr. Frank Carey. The Rice Technical Working Group Industry Committee again held a successful luncheon at the 36th RTWG meetings in Galveston, Texas, on Wednesday, March 2, 2016. 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 2016 Industry luncheon met all of these goals. The luncheon was attended by approximately 320 guests who heard Mr. Ron Gertson of Gertson Farms Partnership. He spoke of the challenges of water conservation and management in a difficult political environment in the state of Texas. There was a high level of interest as indicated by the attendance and amount of discussion following the presentation.

The Industry Committee would like to thank Dr. Mo Way and Dr. Lee Tarpley for their invaluable assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 37th RTWG meetings in California in 2018. Submitted by Frank Carey.

A motion was made by Chuck Wilson to accept the report and seconded by Jarrod Hardke. The report was accepted.

Eric Webster presented an executive committee report: there was much discussion concerning the student poster competition. There is a need to get the procedures standardized and to provide potential competitors with much advance notice of requirements and judging criteria. California will appoint a chair, and Mississippi (host in 2020) will appoint a co-chair, to the 2018 poster competition committee. There was also discussion on the possibility of RTWG changing to be a society rather than a Project. Eric Webster explained to the attendees that this would mean losing the ability to use university resources to run the meeting and also a possible change in nonprofit status.

Trent Roberts moved that, once the rules are in place for the student poster contest, that the secretary select a person from the host state and one from the successive state to serve on the student competition committee; seconded by Lee tarpley. The motion was accepted.

Anna McClung complimented the officers on the considerate reading of the necrology letters and the summaries of the award nominations at the Opening Business meeting. Anna McClung moved that a curriculum vitae be required to be included in the packet for award nominees. Chuck Wilson seconded. The motion was approved.

Chairman Eric Webster extended his gratitude to Texas for hosting the 36th RTWG and to Michael Salassi for his efforts at publishing the proceedings.

Chairman Eric Webster again thanked the RTWG for the opportunity to serve as Secretary and Chair. He thanked Lee Tarpley and "Mo" Way for the successful 36th meeting. He then passed the gavel to Lee Tarpley, incoming Chair. He presented a plaque that illustrates the history of the RTWG leadership since 1950 to Lee Tarpley.

Lee Tarpley presented a plaque to Eric Webster in recognition of his service to the RTWG. Lee Tarpley thanked the faculty and staff of the Texas A&M AgriLife Research Center at Beaumont/Eagle Lake, who were instrumental for making the 36th RTWG a success.

A motion was made to adjourn the 36th RTWG meeting by Chuck Wilson and seconded by Ted Wilson.

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 2018 RTWG Executive Committee and Nominations Committee:

<u>Executive Committee:</u>

Lee Tarpley	Chair
Bruce Linquist	Secretary
Eric Webster	Immediate Past Chair

<u>Geographical Representatives:</u>

Arkansas	Xueyan Sha
California	Luis Espino
Florida	Matthew VanWeelden
Louisiana	Henry S. Utomo
Mississippi	Bobby Golden
Missouri	Michael Aide
Texas	Ted Wilson
Industry	Pat Clay

<u>Nominations Committee:</u>

Mississippi	Jason Bond, Chair
Arkansas	Charles Wilson, Jr.
California	Randall (Cass) Mutters
Florida	Matthew VanWeelden
Louisiana	Adam Famoso
Missouri	Sam Atwell
Texas	Fugen Dou
Industry	Pat Clay

Submitted by
Larry Godfrey

Rice Crop Germplasm Committee

The 36th meeting of the Rice Crop Germplasm Committee was held on Tuesday, March 1, 2016, in Galveston, TX, in conjunction with the 36th Rice Technical Working Group. Members in attendance were Farman Jodari (Chair), Georgia Eizenga, Martha Malapi-Wright, Anna McClung, Karen Moldenhauer, Jack Okamuro, Qiming Shao, Rodante (Dante) Tabien, and M.O. Way. Members participating via conference call were Peter Bretting, Harold Bockelman and Gary Kinard. Members not present were Jim Correll, Jim Oard, Xueyan Sha and Tim Walker. Guests in attendance were Donn Beighley, Adam Famoso, Joe Kepiro, Kent McKenzie, and Ed Redoña. The meeting was called to order at 4:00 pm.

The minutes of the 35th Rice Crop Germplasm Committee held on January 27, 2015, in Stoneville, MS, were approved by a motion from Karen Moldenhauer, seconded by Georgia Eizenga, and supported by the other committee members.

Gary Kinard, USDA/ARS National Germplasm Resources Lab, reported on the transition from GRIN (Germplasm Resources Information Network) to GRIN-Global which was lauched in February. Gary mentioned the overview presentation being given via a webinar as part of RTWG by Marty Reisinger on Thursday, March 3, and encouraged people to attend. The previous GRIN had to be changed to meet the current security requirements. It is hoped that GRIN-Global will be used by many genebanks throughout the world, thus enabling better networking between countries to share information regarding accessions, if not the accessions themselves. It is hoped that GRIN-Global will be a major feeder into GENESYS, the portal to other national collections. Gary informed the group that proposals for the Plant Exploration and Exchange Program for FY2017 are due July 22, 2016.

Harold Bockelman, Curator of the Small Grains Collection, reported on the status of the rice germplasm collection including six new accessions which have a PVP being added and approximately 1,095 seed packets being distributed in response to 111 requests. Harold updated the number of accessions with descriptor information. Currently, there are 19,040 accessions in the collection. Kent McKenzie mentioned the new quarantine procedures California has invoked.

Jack Okamuro, ARS/USDA National Program Leader for rice, reported Kay Simmons had retired and Maureen Whalen has been hired as the new Deputy Administrator for Crop Production and Protection. She has a strong plant science background. The Natural Resources and Sustainable Agriculture positon is also open. Jack discussed that the next important step to improve breeding is to make phenotyping more efficient to better utilize the genotyping resources currently available.

Martha Malapi-Wright, USDA/APHIS PPQ, newly hired for *Poaceae* quarantine, was in attendance. She introduced herself and reported that 75 accessions were imported from IRRI (International Rice Research Institute) of which 73 produced seed that was shipped to the importer. Currently, 110 accessions from IRRI were being grown and 100-130 entries could be grown in the current year. She would need seed by Sept.-October. Ed Redoña suggested bringing the MAGIC (Multi-parent Advanced Generation Inter-cross) populations being developed by IRRI through quarantine.

Anna McClung, USDA/ARS Dale Bumpers National Rice Research Center (DBNRRC), informed the group of the "*Tropical Japonica* Core Collection" being established at the DBNRRC. It includes many of the lines imported from Brazil 2-3 years ago. Also, she mentioned that there may other accessions which would be good to import. The importation of the accessions which are included in the 3,000 Genomes Project (3K Genomes) headed by IRRI was discussed. An accession name match identified those 3K accessions already in the USA. This collection has a large number of *indica* accessions.

Joe Kepiro, rice breeder, Rice Research Inc., challenged the committee with the problem a small company now has importing rice seed into California with the restructuring of the state importation guidelines. Suggestions were given as to how to deal with this issue.

Peter Bretting from the USDA/ARS office of National Programs, made a powerpoint presentation on the status of the National Plant Germplasm System (NPGS) which highlighted the increased number of accessions, distributions, budget and priorities for the NPGS. The highest priorities are acquisition, maintenance, regeneration, documentation & data management, and distribution, with lower priority given to characterization, evaluation and enhancement. Peter highlighted how the collection is much more "visible" with the introduction of GRIN-Global and the challenge of flat budgets despite the increased use, doing more with less. There is increased emphasis on crop wild relatives. Peter stressed the importance of the crop vulnerability statements, as well as updating and reviewing the statement.

The need to revise and update the rice crop vulnerability statement was discussed. Jeff Oster and Don Groth have provided a list of rice diseases for the statement. M.O.

Way agreed to provide the list of the rice insect pests. Other points discussed were the Mexican Rice Borer which is also found in sugarcane, which is a pest in Texas and southern Louisiana. Anna mentioned the need for abiotic stress information in the statement.

With the new GRIN-Global, all the CGC minutes can be made available via the website. Most likely the historic record of the CGC minutes are at the DBNRRC as paper copies. Anna suggested these be scanned as pdf files and uploaded onto the website.

Farman made recommendations for committee changes after contacting members whose terms were completed in 2016. His recommendations were Paul Sanchez and Adam Famoso for 6-year terms on the committee in the positions held by M.O. Way and Jim Oard; Karen Moldenhauer for another 6-year term and Georgia Eizenga as committee chair for Farman Jodari whose term was completed. Ed Redoña was recommended to complete the term for Tim Walker. These actions were approved by a unanimous vote from all committee members present.

Karen Moldenhauer made the motion to adjourn, Georgia Eizenga seconded the motion, and the motion was supported by all members.

Rice Crop Germplasm Committee members as of March 1, 2016, with year term ends in parentheses:

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

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

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

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

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

Dr. Ediliberto Redoña (2018)
Mississippi ed.redona@msstate.edu

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

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

Dr. Qiming Shao (2018)
Crop Protection Service qiming.shao@cpsagu.com

Dr. Rodante Tabien (2018)
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 2016 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 2018 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 3:30 p.m.

In attendance were committee members: Chuck Wilson, University of Arkansas; Kent McKenzie of California Rice Commission; Johnny Saichuk of Louisiana State University; Bobby Golden of Mississippi State University; and Donn Beighley of University of Missouri. Ted Wilson of Texas A&M AgriLife Research was absent. Guests in attendance were: Kirk Johnson and Rick Geddes.

Harrell distributed and presented the minutes of the 2014 Acreage Committee meeting and asked for a motion to accept them as presented. Kent McKenzie moved and Donn Beighley seconded the motion to accept the minutes as presented. The motion carried.

Chuck Wilson presented the Arkansas report. He said 1.48 million acres were grown in 2014 and were reduced in 2015 to 1.385 million acres. The reduction in acres in 2015 was due largely to weather issues with 250,000 – 300,000 acres of prevented planting acres. The average yield for 2014 was 168 bushels per acre. The 2015 average yield was 163 bushels per acre. Clearfield varieties and hybrids made up approximately 45% of the acres planted. Hybrids made up approximately 45% of the overall acres with XL729, CLXL745, and XL753 making up the majority of the acres. The acres of rice in 2016 was estimated to increase to around 1.7 million acres due to the favorable economics of rice as compared to the other row crops. New rice releases Diamond (long grain) and Titan (medium grain), as well as the re-release of CL172 (Clearfield long grain) were discussed.

Dustin Harrell gave the report for Louisiana. He said acreage had increased from 405,220 acres in 2013 to 455,411 acres in 2014. Acres were made up of approximately 85% long grain, 14% medium grain, and 1% special purpose in 2014. Top planted varieties included CL111 (31.5%), Jupiter (13%), CLXL745 (11%), Cheniere (9.5%), CLXL729 (6.2%), and CL151 (5.6%). Clearfield acres were approximately 59% of the total acres planted with Clearfield varieties and Clearfield hybrids making up 70 and 30% of the Clearfield acres, respectively. Hybrid acres made up approximately 25.6% of the total acres in Louisiana. Acres in 2015 declined to 412,303. Long grain made up 83%, medium grain made up 15% and special purpose rice made up 2% of the total acres planted. Top planted varieties included CL111 (34.5%), Jupiter (13.2%), CLXL745 (11.9%), Cheniere (9.2%), CL151 (6%), and CLXL729 (5.5%). Hybrids made up approximately 25% of the total acres. Clearfield acres made up 60% of the total acres with Clearfield varieties representing 71% of the Clearfield acres and Clearfield hybrids making up the remaining 29% of the Clearfield acres in the state. Rice acres were expected to remain the same to slightly higher in Louisiana in 2016.

The California report was presented by Kent McKenzie. He reported a decrease in rice acres from 2013 to 2014. Acres in 2014 were 445,000. Rice acres decreased further in 2015 to 423,000. The decline in acres was due to the limited water for irrigation. However, the snowpack is good and water should be more available in 2016 and the acres are predicted to increase to around 500,000. There is a possibility that some of the water allocated to rice farmers could be sold and that could have a negative effect on rice acres. Three new varieties were released - Calmochi-203 (sweet rice), M209 (medium grain), and L207 (long grain).

The Mississippi report was given by Bobby Golden. He mentioned that the Mississippi estimates were provided by rice crop consultants. Consultants are used on 80% of rice acres in Mississippi. Rice acres increased in 2014 to approximately 188,200 acres with an average yield of 164 bu/A. The top planted varieties and hybrids in 2014 were CL151, XL753, Rex, CL111, and CL152. Rice acres in 2015 were reduced to 145,712 acres with an average yield of 158 bu/A. Many more acres in 2015 were not planted due to weather conditions (wet weather). The top planted varieties and hybrids in 2015 were XL753, CLXL745, Rex, and CL151. He predicted that acres may increase considerably in 2016 due to favorable economics of rice compared to other row crops.

Donn Beighley presented the Missouri report. He said planted acreage in 2014 was 216,000. Planted acres in 2015 declined to 182,000 acres. The leading varieties and hybrids were CLXL745 (45%), CL111, and CL151 (25% together), LaKast and RoyJ (20% together), and Caffey (2%). The new variety MM11 was released.

The Florida report was given by Harrell using data that was submitted by Matthew VanWeelden of the University of Flordia, extension agent Palm Beach County. Total acres in 2014 was 20,440. Acres were planted to the following varieties: Cheniere, Cocodrie, Cypress, Mermentau, Roy J, Taggart, and Wells. Acres in 2015 increased to 22,817. Acres were made up of the following varieties: Cheniere, Jupiter, Mermentau, Roy J, Taggart, Wells, and Rex.

There being no further business 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 36th RTWG meetings in Galveston, Texas, on Wednesday, March 2, 2016. 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 2016 Industry luncheon met all of these goals. The luncheon was attended by approximately 320 guests who heard Mr. Ron Gertson of Gertson Farms Partnership. He spoke of the challenges of water conservation and management in a difficult political environment in the state of Texas. There was a high level of interest as indicated by the attendance and amount of discussion following the presentation.

The Industry Committee would like to thank Dr. Mo Way and Dr. Lee Tarpley for their invaluable assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 37th RTWG meetings in California in 2018.

Submitted by
Frank Carey

2014 Arkansas Harvested[1] Rice Acreage Summary.

COUNTY/ PARISH	2013 Acreage	2014 Acreage	MEDIUM GRAIN		LONG GRAIN									
			Jupiter	Others[2]	CL111	CL151	CL152	Mermentau	CLXL729	CLXL745	XL753	Roy J	Wells	Others[2]
Arkansas	71,885	91,155	6,444	3,253	1,345	2,422	2,691	2,440	946	28,255	22,470	9,685	891	10,313
Ashley	4,533	11,182	855	0	549	549	549	0	2,197	2,746	2,636	549	0	549
Chicot	25,107	34,839	536	0	2,615	2,092	2,092	1,098	3,660	12,550	6,449	2,440	0	1,307
Clay	64,740	81,506	8,124	549	3,818	33,405	2,863	2,386	0	17,857	10,499	1,145	145	716
Craighead	57,987	71,509	12,652	466	4,758	11,894	4,418	4,214	0	5,478	5,383	8,156	8,156	5,933
Crittenden	21,568	51,036	8,395	923	0	197	492	962	2,403	13,800	11,308	6,637	0	5,919
Cross	65,315	88,036	15,776	1,425	10,070	11,682	3,222	3,222	290	11,682	11,279	17,418	223	1,748
Desha	9,605	25,266	6,034	0	0	5,851	1,984	1,945	0	6,849	2,097	506	0	0
Drew	7,116	11,312	314	0	0	3,704	2,580	0	0	3,158	1,556	0	0	0
Faulkner	1,815	2,582	0	0	0	0	0	594	0	671	645	361	0	310
Greene	62,804	78,405	6,714	0	0	29,268	1,802	1,771	0	28,028	5,391	770	0	4,660
Independence	7,764	12,747	2,148	0	3,099	3,595	0	0	0	3,409	0	0	496	0
Jackson	68,299	104,194	30,730	1,883	3,000	18,500	3,390	6,035	5,940	11,839	8,030	10,000	0	4,848
Jefferson	55,438	72,463	1,892	0	0	0	0	1,086	0	55,589	2,533	10,133	0	1,230
Lafayette	3,164	4,434	0	0	443	554	554	0	0	1,330	443	665	0	443
Lawrence	83,775	99,922	10,216	5,309	4,466	15,185	5,359	8,486	357	10,719	4,707	24,563	0	10,555
Lee	16,540	29,920	2,006	0	900	0	0	840	3,752	3,002	4,502	13,897	0	1,021
Lincoln	12,104	21,516	393	0	0	0	0	3,391	0	4,675	10,922	2,135	0	0
Lonoke	68,474	89,732	4,539	0	2,642	2,202	2,642	3,402	10,675	42,276	9,688	3,814	7,046	806
Mississippi	27,261	53,540	1,362	0	9,196	2,627	0	5,255	0	8,828	5,255	2,627	15,764	2,627
Monroe	37,199	59,492	4,934	2,460	1,212	727	0	5,206	3,636	8,787	3,030	17,271	1,480	10,751
Phillips	18,177	32,643	806	0	0	0	3,265	6,531	0	3,102	9,796	6,531	1,306	1,306
Poinsett	86,445	121,569	38,865	1,625	6,474	26,933	3,885	4,273	3,885	6,474	5,827	11,434	5,179	6,716
Pope	1,531	2,205	0	0	0	902	110	0	0	1,193	0	0	0	0
Prairie	54,202	63,640	6,817	1,702	4,558	1,042	3,907	3,516	4,083	20,186	7,163	3,907	0	6,759
Pulaski	3,371	4,168	128	0	0	209	209	0	626	2,371	417	209	0	0
Randolph	29,145	35,657	8,952	0	2,523	3,604	360	0	5,587	1,405	6,018	0	0	7,208
St. Francis	26,454	38,443	5,688	396	184	2,472	184	2,472	0	1,129	5,902	16,600	885	2,531
White	9,885	13,192	1,890	0	0	638	64	926	1,686	2,105	5,448	0	0	435
Woodruff	47,389	61,925	4,707	0	11,236	4,994	1,873	1,873	12,485	4,994	4,994	13,146	0	1,623
Others[3]	6,100	6,989	0	0	323	1,272	152	503	238	1,530	236	1,421	586	729
Unaccounted[4]	14,808	4,781												4,781
2014 Total		1,480,000	191,915	19,990	73,412	186,518	48,648	72,426	62,445	326,016	174,626	186,022	42,156	95,825
2014 Percent		100.00%	12.97%	1.35%	4.96%	12.60%	3.29%	4.89%	4.22%	22.03%	11.80%	12.57%	2.85%	6.47%
2013 Total	1,070,000		106,396	8,207	63,749	103,897	82,903	10,500	79,479	238,356	66,474	147,961	33,601	128,476
2013 Percent	100.00%		9.94%	0.77%	5.96%	9.71%	7.75%	0.98%	7.43%	22.28%	6.21%	13.83%	3.14%	12.01%

[1] - Harvested acreage. Source: USDA-NASS, 2015. [2] - Other cultivars: AB647, Antonio, CL142-AR, CL261, Caffey, Cheniere, Cocodrie, Colorado, Della-2, Francis, Jazzman, Jazzman-2, LaKast, RiceTec CL XP4534, RiceTec XL723, RiceTec XP4523, Rosemont, and Taggart. [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.

2015 Arkansas Harvested[1] Rice Acreage Summary.

COUNTY/ PARISH	2014 Acreage	2015 Acreage	MEDIUM GRAIN Jupiter	MEDIUM GRAIN Others[2]	LONG GRAIN CL111	CL151	LaKast	Mermentau	CLXL729	CLXL745	XL753	Roy J	Wells	Others[2]
Arkansas	91,155	86,669	6,212	3,451	2,172	8,315	1,747	640	2,344	29,216	17,064	7,422	0	8,086
Ashley	11,182	9,105	981	0	0	0	0	0	0	8,124	0	0	0	0
Chicot	34,839	27,057	0	617	630	4,093	0	1,350	2,528	7,914	6,775	1,786	0	1,364
Clay	81,506	69,905	9,086	1,249	529	26,138	2,929	467	206	23,299	4,001	1,451	550	0
Conway	1,703	1,149	0	0	0	763	0	0	0	0	0	386	0	0
Craighead	71,509	66,874	10,239	7,591	14,620	3,457	1,898	16,079	0	6,842	963	5,185	0	0
Crittenden	51,036	43,842	3,422	3,092	0	1,572	389	0	3,276	11,763	11,182	6,161	0	2,984
Cross	88,036	84,001	17,214	480	3,073	13,097	6,568	1,249	711	6,495	12,437	21,012	0	1,724
Desha	25,266	17,226	3,539	2,196	0	608	893	1,662	0	1,153	5,096	2,078	0	0
Drew	11,312	9,550	1,895	474	0	0	0	0	0	7,181	0	0	0	0
Greene	78,405	66,208	5,958	0	0	14,655	0	1,256	0	21,691	20,377	657	0	1,519
Independence	12,747	9,974	1,596	84	2,045	2,045	0	0	0	2,045	818	818	409	0
Jackson	104,194	82,216	18,707	13,979	1,515	13,107	4,894	519	228	7,228	8,539	8,864	0	4,558
Jefferson	72,463	64,767	3,607	709	0	8,968	6,675	0	0	34,851	1,241	8,717	0	0
Lafayette	4,434	3,546	0	0	355	355	0	0	0	1,418	709	355	0	355
Lawrence	99,922	91,554	19,290	0	6,699	25,054	3,228	8,942	0	11,751	3,083	11,880	0	1,628
Lee	29,920	21,744	1,431	0	0	1,341	2,041	121	2,220	1,662	5,166	7,316	0	445
Lincoln	21,516	21,016	1,782	0	0	0	0	0	0	989	15,078	3,279	0	0
Lonoke	89,732	80,916	4,799	662	1,564	7,536	1,033	1,564	11,262	20,831	18,211	9,340	0	4,151
Mississippi	53,540	47,953	1,431	0	0	4,215	3,901	1,246	0	2,098	21,244	2,749	11,226	0
Monroe	59,492	48,728	5,711	697	233	838	7,017	1,071	652	7,036	3,176	20,399	0	1,900
Phillips	32,643	16,094	0	543	0	0	2,239	11,321	0	1,990	0	0	0	0
Poinsett	121,569	110,824	34,132	11,351	3,503	16,634	6,398	103	0	6,867	4,027	20,646	5,504	1,692
Pope	2,205	2,186	0	0	0	0	0	0	109	2,077	0	0	0	0
Prairie	63,640	61,743	8,631	1,974	5,932	1,454	2,067	2,429	4,113	12,169	12,199	4,938	0	6,180
Pulaski	4,168	3,799	962	0	0	294	0	0	0	1,472	589	294	294	0
Randolph	35,657	30,009	10,907	0	4,503	0	0	0	3,659	0	6,530	0	0	4,409
St. Francis	38,443	37,462	7,046	24	275	1,922	1,446	2,237	0	9,337	258	11,751	1,131	2,068
White	13,192	10,073	2,029	0	0	676	0	0	1,528	2,919	1,685	0	0	1,236
Woodruff	61,925	50,874	4,302	1,902	1,104	2,294	9,045	758	7,967	5,260	5,666	11,080	0	1,496
Others[3]	7,868	2,746	0	0	0	406	51	0	0	815	560	113	775	26
Unaccounted[4]	4,781	5,596												5,596
2015 Total		1,286,000	184,910	51,076	48,751	159,837	64,460	53,015	40,804	256,492	186,673	168,677	19,889	51,415
2015 Percent		100.00%	14.38%	3.97%	3.79%	12.43%	5.01%	4.12%	3.17%	19.94%	14.52%	13.12%	1.55%	4.00%
2014 Total	1,480,000		191,915	19,990	73,412	186,518	3,143	72,426	62,445	326,016	174,626	186,022	42,156	141,330
2014 Percent	100.00%		12.97%	1.35%	4.96%	12.60%	0.21%	4.89%	4.22%	22.03%	11.80%	12.57%	2.85%	9.55%

[1] - Harvested acreage. Source: USDA-NASS, 2016. [2] - Other cultivars: AB647, Antonio, Caffey, Cheniere, Cocodrie, Della-2, Francis, Jazzman, Jazzman-2, RiceTec XL XL746, RiceTec CL XP4534, RiceTec XL723, RiceTec XP4523, and Taggart. [3] - Other counties: Clark, Franklin, Faulkner, Hot Spring, Little River, 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.

RICE PRODUCTION OF CCRRF VARIETIES

	2014			2015		
Variety	Seed Acres[1]	Percentage	Estimated Acres[2]	Seed Acres[1]	Percentage	Estimated Acres[2]
M-104	272	1.5	5802	195	1.1	3944
M-105	2047	11.3	43663	2573	14.4	52039
M-202	1752	9.7	37371	1095	6.1	22147
M-205	2791	15.5	59533	2806	15.7	56752
M-206	9513	52.7	202917	8958	50.2	181178
M-208	500	2.8	10665	323	1.8	6533
M-209	6	0.0	6	491	2.8	491
M-401	1037	5.7	22120	1260	7.1	25484
M-402	120	0.7	2560	148	0.8	2993
Medium Grain	18038	100.0	384750	17849	100.0	361000
S-102	371	39.6	12108	359	30.2	9231
Calhikari-201	15	1.6	480	103	8.7	2694
Calhikari-202	88	9.4	2875	60	5.0%	1543
Calmochi-101	460	49.1	15013	540	45.4	13886
Calmochi-203	4	3.1	33	128	10.8	128
Calamylow-201	0	0.0	75	0	0.3	160
Short Grain	938	98.5	30600	1190	100.3	30600
L-206	123	28.2	1072	101	26.3	1747
A-201	92	21.1	802	93	24.1	1606
A-301	45	10.3	392	0	0.0	0
Calmati-202	49	11.2	427	4	1.0	69
A-202	127	29.1	1107	187	48.5	3228
Long Grain	436	100.0	3800	385	100.0	6650
FSA CA Acres						
Medium		91.0	405000		89.8	380000
Short		8.1	36000		8.5	36000
Long		0.9	4000		1.7	7000
Total		100.0	445000		100.0	423000

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

[2] Acreage estimated based on seed production of these varieties assuming they account for 95% of the medium and long grains and 85% of the short grain California planted acres reported by NASS.

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

2014 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2014	MEDIUM GRAIN			Long Grain													Special Purpose	
	Acreage	Caffey	CL271	Jupiter	Cheniere	CL111	CL151	CL152	CL 161	CLXL729	CLXL745	Cocodrie	Cypress	Mermentau	XL753	XP754	Other[1]	Jazzman 2	Other SP[2]
Acadia	85,445	866	110	6,246	9,536	29,816	8,057	3,642	300	4,987	8,800	2,021	1,247	5,415	1,906		1,642	689	165
Allen	15,436	495	0	3,981	528	2,638	505	0	0	1,200	3,783	200	211	739	573		275	203	105
Avoyelles	11,988	0	0	775	2,800	2,900	0	0	0	0	2,900	0	0	0	0	0	2,613	0	0
Beauregard	1,249	0	0	0	0	0	0	0	0	371	156	0	0	0	207		515	0	0
Calcasieu	15,213	135	0	2,229	707	3,983	2,274	0	0	899	3,765	167	0	604	450		0	0	0
Caldwell	1,141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,141	0	0
Cameron	11,833	470	0	1,608	978	3,818	3,652	0	0	385	922	0	0	0	0	0	0	0	0
Catahoula	1,300	0	0	500	0	0	0	230	0	0	570	0	0	0	0	0	0	0	0
Concordia	9,791	0	0	0	475	950	900	50	0	1,900	2,970	0	0	0	901	0	1,645	0	0
East Carroll	1,588	0	0	200	510	55	0	0	0	0	583	0	0	0	0	0	0	0	240
Evangeline	45,905	294	350	4,285	726	10,500	4,400	0	0	8,800	4,800	2,100	0	1,000	4,950	0	2,100	0	1,600
Franklin	3,004	0	0	521	0	0	0	0	0	0	2,483	0	0	0	0	0	0	0	0
Iberia	1,128	0	0	0	850	75	0	0	0	0	0	0	0	0	203	0	0	0	0
Jeff Davis	83,484	1,271	50	16,530	3,010	23,900	1,021	1,745	0	5,340	0	610	605	4,535	13,267	8,810	1,956	734	100
Lafayette	533	20	0	308	0	113	0	0	0	0	57	0	0	35	0	0	0	0	0
La Salle	554	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	534	0	0
Madison	7,320	0	0	875	3,996	709	0	0	0	0	0	1,160	0	580	0	0	0	0	0
Morehouse	37,618	0	0	10,717	3,500	15,000	0	0	0	0	8,401	0	0	0	0	0	0	0	0
Natchitoches	3,813	0	0	991	0	2,000	0	0	0	0	822	0	0	0	0	0	0	0	0
Ouachita	9,176	0	140	2,762	0	4,266	0	2,008	0	0	0	0	0	0	0	0	0	0	0
Pointe Coupee	1,859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,859	0	0
Rapides	11,000	0	0	4,175	4,200	2,475	0	0	0	0	0	150	0	0	0	0	0	0	0
Red River	407	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	407		
Richland	5,613	0	0	341	0	300	0	1,300	0	0	2,730	0	0	0	0	0	0	0	942
St. Landry	26,062	0	0	2,891	3,354	8,825	1,910	5,268	0	201	2,570	0	0	543	0	0	0	0	500
St. Martin	3,437	0	0	0	404	354	0	376	0	487	36	0	0	0	1,620	0	160	0	0
St Mary	221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	221	0	0
Tensas	3,140	0	0	0	330	0	0	0	0	0	225	0	0	0	708	350	1,527	0	0
Vermilion	53,427	722	0	391	7,533	30,928	2,720	2,040	262	3,714	1,203	575	286	2,740	0	313	0	0	0
West Baton Rouge	575	0	0	0	0	0	0	0	0	0	575	0	0	0	0	0	0	0	0
West Carroll	2,154	0	0	0	0	0	0	0	0	0	1,610	0	0	0	0	0	544	0	0
2014 Total	455,414	4,273	650	60,346	43,437	143,605	25,439	16,659	562	28,284	49,961	6,983	2,349	16,191	24,785	9,473	17,139	1,626	3,652
2014 Percent	100	0.94	0.14	13.25	9.54	31.53	5.59	3.66	0.12	6.21	10.97	1.53	0.52	3.56	5.44	2.08	3.76	0.36	0.80

[1] Other varieties include:CL261, hybrid blend, hybrid seed rice, Neptune, XP760, undetermined

[2] Other special purpose include: Hidalgo, Milagro, Sabine

2015 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Long Grain

Parish	2015 Total Acreage	Total long grain	Variety											Hybrid							
			Catahoula	Cheniere	Cocodrie	Cypress	Mermentau	Wells	CL111	CL151	CL152	CL161	CL162	CLXL729	CLXL745	CLXP756	XL723	XL753	XP754	XP760	HybridSP[1]
Acadia	81,847	73,744	400	7,000	500	0	10,500	0	32,037	9,130	1,500	0	0	4,000	6,000	0	0	2,677	0	0	0
Allen	13,628	9,219	0	600	0	0	1,459	0	2,230	700	220	0	0	1,100	1,810	0	0	1,100	0	0	0
Avoyelles	12,096	11,931	130	2,950	175	0	0	0	3,010	0	0	0	0	0	2,780	0	2,636	250	0	0	0
Beauregard	1,039	1,039	0	0	0	0	25	0	0	280	0	0	0	65	0	209	0	210	250	0	0
Calcasieu	12,673	9,516	0	480	71	0	950	0	5,295	2,210	0	0	0	100	410	0	0	0	0	0	0
Caldwell	567	567	0	0	0	0	0	0	567	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	11,314	8,758	0	0	0	0	450	0	4,290	3,197	0	0	0	370	451	0	0	0	0	0	0
Catahoula	1,319	1,319	0	0	0	0	0	0	0	0	0	0	0	0	600	0	0	0	0	61	659
Concordia	7,244	7,244	0	150	0	0	0	0	808	100	0	0	0	1,285	2,772	0	250	0	0	880	999
East Carroll	2,035	1,317	0	295	0	0	0	0	450	52	0	0	0	0	520	0	0	0	0	0	0
Evangeline	40,701	36,832	0	2,250	500	0	1,000	0	11,306	2,276	0	0	0	8,500	4,500	0	0	5,500	0	1,000	0
Franklin	2,949	2,949	0	35	0	0	0	0	0	0	0	0	0	0	2,514	0	0	0	0	400	0
Iberia	1,033	1,033	0	341	0	0	0	0	96	0	175	0	0	0	208	0	0	213	0	0	0
Jeff Davis	75,669	55,991	200	2,000	500	0	4,600	0	22,394	0	0	0	0	5,719	10,878	200	0	9,500	0	0	0
Lafayette	762	516	0	0	0	0	100	0	256	82	0	0	0	0	78	0	0	0	0	0	0
Madison	6,338	4,624	0	855	975	0	0	0	594	0	0	0	0	0	1,100	0	0	0	0	1,100	0
Morehouse	31,532	20,923	0	0	0	0	0	0	18,563	890	0	0	0	0	1,470	0	0	0	0	0	0
Natchitoches	3,481	2,321	0	1,765	0	0	0	0	556	0	0	0	0	0	0	0	0	0	0	0	0
Ouachita	7,569	2,374	0	1,155	0	0	0	152	840	0	227	0	0	0	0	0	0	0	0	0	0
Pointe Coupee	1,397	1,397	97	102	225	623	78	0	56	0	69	45	75	0	0	0	0	0	27	0	0
Rapides	8,560	8,010	0	6,020	100	0	0	0	1,850	40	0	0	0	0	0	0	0	0	0	0	0
Red River	416	416	0	0	0	0	0	0	0	0	0	0	0	0	416	0	0	0	0	0	0
Richland	5,308	4,151	0	0	0	0	0	0	161	0	887	0	0	0	3,103	0	0	0	0	0	0
St. Landry	23,968	21,596	0	4,849	0	0	447	0	8,396	3,380	2,828	0	0	0	1,484	0	0	212	0	0	0
St. Martin	3,502	3,286	0	295	0	0	0	0	625	0	375	0	0	485	150	0	0	956	0	400	0
Tensas	3,427	3,427	0	0	0	0	0	0	0	0	0	0	0	0	1,923	0	0	1,424	0	80	0
Vermilion	49,901	47,456	0	6,739	0	0	4,746	0	27,192	2,468	617	0	0	1,092	4,176	0	0	427	0	0	0
West Baton Rouge	508	508	0	0	0	0	0	0	508	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	1,521	1,521	0	0	0	0	0	0	0	0	0	0	0	0	1,521	0	0	0	0	0	0
Total	412,303	343,984	827	37,881	3,046	623	24,355	152	142,079	24,805	6,898	45	75	22,716	48,863	409	2,886	22,469	277	3,921	1,658
Percent (of long grain)		100	0.24	11.01	0.89	0.18	7.08	0.04	41.30	7.21	2.01	0.01	0.02	6.60	14.21	0.12	0.84	6.53	0.08	1.14	0.48
Percent (of all acres)		83.43	0.20	9.19	0.74	0.15	5.91	0.04	34.46	6.02	1.67	0.01	0.02	5.51	11.85	0.10	0.70	5.45	0.07	0.95	0.40
Total								240,786										103,198			
Percent (of long grain)								70.0										30.0			
Percent (of all acres)								58.4										25.0			

[1] HybridSP is hybrid seed rice production, unspecified.

2015 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Parish	2015 Total Acreage	Medium Grain: Total medium Acreage	Variety: Caffey	Jupiter	Neptune	CL271
Acadia	81,847	7,653	500	6,506	147	500
Allen	13,628	4,309	258	4,051	0	0
Avoyelles	12,096	165	0	165	0	0
Beauregard	1,039	0	0	0	0	0
Calcasieu	12,673	3,157	0	3,062	95	0
Caldwell	567	0	0	0	0	0
Cameron	11,314	2,554	0	300	2,254	0
Catahoula	1,319	0	0	0	0	0
Concordia	7,244	0	0	0	0	0
East Carroll	2,035	302	0	302	0	0
Evangeline	40,701	3,869	300	3,569	0	0
Franklin	2,949	0	0	0	0	0
Iberia	1,033	0	0	0	0	0
Jeff Davis	75,669	18,148	250	17,698	200	0
Lafayette	762	246	0	246	0	0
Madison	6,338	1,715	0	1,715	0	0
Morehouse	31,532	10,609	0	10,609	0	0
Natchitoches	3,481	1,160	0	1,160	0	0
Ouachita	7,569	1,948	0	1,828	0	120
Pointe Coupee	1,397	0	0	0	0	0
Rapides	8,560	550	0	550	0	0
Red River	416	0	0	0	0	0
Richland	5,308	191	0	191	0	0
St. Landry	23,968	2,145	0	1,405	0	740
St. Martin	3,502	0	0	0	0	0
Tensas	3,427	0	0	0	0	0
Vermilion	49,901	2,445	611	1,100	0	734
West Baton Rouge	508	0	0	0	0	0
West Carroll	1,521	0	0	0	0	0
Total	412,303	61,166	1,919	54,457	2,696	2,094
Percent (of medium grain)		100	3.14	89.03	4.41	3.42
Percent (of all acres)		14.84	0.47	13.21	0.65	0.51

Parish	Special Purpose: Total Special Purpose	Variety: Della 2	Hidalgo	Jazzman 2	Sabine
Acadia	450	0	0	450	0
Allen	100	50	0	50	0
Avoyelles	0	0	0	0	0
Beauregard	0	0	0	0	0
Calcasieu	0	0	0	0	0
Caldwell	0	0	0	0	0
Cameron	0	0	0	0	0
Catahoula	0	0	0	0	0
Concordia	0	0	0	0	0
East Carroll	416	0	0	0	416
Evangeline	0	0	0	0	0
Franklin	0	0	0	0	0
Iberia	0	0	0	0	0
Jeff Davis	1,530	30	0	1500	0
Lafayette	0	0	0	0	0
Madison	0	0	0	0	0
Morehouse	0	0	0	0	0
Natchitoches	0	0	0	0	0
Ouachita	3,247	0	0	0	3247
Pointe Coupee	0	0	0	0	0
Rapides	0	0	0	0	0
Red River	0	0	0	0	0
Richland	966	0	259	0	707
St. Landry	227	0	0	227	0
St. Martin	216	0	0	216	0
Tensas	0	0	0	0	0
Vermilion	0	0	0	0	0
West Baton Rouge	0	0	0	0	0
West Carroll	0	0	0	0	0
Total	7,152	80	259	2,443	4,370
Percent (of Special Purpose)	100	1.12	3.62	34.16	61.10
Percent (of all acres)	1.73	0.02	0.06	0.59	1.06

2014 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

COUNTY	2013	2014	Acreage	% MC	LONG GRAIN													MEDIUM	OTHER
	ACREAGE	ACREAGE	Change	Ratooned	XL753	CLXL745	PRESIDIO	CL152	ANTONIO	XP754	CHENIERE	XL723	CL151	DIXIEBELLE	CLXL729	XL760	CATAHOULA	JUPITER	
East Zone																			
Brazoria	17763	3825	-78.50%																
Chambers	18869	22295	18.20%	29	7432			7298			804							4865	1897
Galveston	2255	603	-73.30%	0															
Hardin	263	579	120.20%																
Jefferson	18820	25566	35.80%	70		10227												15339	
Liberty	5312	6046	13.80%	70	2684	598		1197										1566	
Orange																			
East Total	63282	58914	-6.90%	53	11051	11835		9280			878							23797	2072
Northwest Zone																			
Austin	2159	2152	-0.30%	0	2152														
Colorado	22554	27291	21.00%	85	18577	2076		409		1229		218	136	164	355				4125
Fort Bend	5061	5011	-1.00%	60	496	371	1687	791			301	655		605		105			
Harris																			
Lavaca	1856	2139	15.20%	15		163	1106	325		545									
Robertson																			
Waller	3950	4113	4.10%	5	2576	464	128					723				222			
Wharton	27372	31220	14.10%	15	12251	2969	4469	3719	2407	343	1000		1657	281	312	156	187		1469
Lamar	130	204	56.90%																
NorthWest Total	63082	72130	14.30%	44	36149	6059	7415	5260	2412	2124	1305	1604	1797	1055	669	485	188		5608
Southwest Zone																			
Calhoun	2306	1532	-33.60%																
Jackson	10601	9872	-6.90%	15	405	326	4767	346	1017		652	336		227				1165	632
Matagorda	1566	2817	79.90%																
Victoria	2041	2105	3.10%				1404			701									
Cameron																			
SouthWest Total	16514	16325	-1.10%	15	552	444	8411	472	1386	955	889	458		309				1588	861
Northeast Zone																			
Bowie																			
Hopkins	217	99	-54.40%																
Red River																			
Northeast Total	217	99	-54.40%																
State Total	143095	147468	3.10%	45	47784	18350	15837	15022	3801	3081	3074	2063	1798	1365	669	485	188	25402	8547

2015 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

COUNTY	2014 ACREAGE	2015 ACREAGE	Acreage Change	%MC Ratooned	LONG GRAIN XL723	PRESIDIO	CLXL745	CL152	CL151	CHENIERE	XL753	CL111	TEXMATI	CATAHOULA	XL760	MERMENTAU	ANTONIO	DIXIEBELLE	SIERRA	RISOTTO	MEDIUM JUPITER	OTHER
East Zone																						
Brazoria	3825	7121	86.20%	0		5697							1424									
Chambers	22295	14274	-36.00%	0																		14274
Galveston	603	673	11.60%																			
Hardin	579	460	-20.60%																			
Jefferson	25566	19677	-23.00%	40	2442		2876	1911				2699									9749	
Liberty	6046	6046	0.00%	83	4421		351	1021														254
Orange																						
East Total	58914	48251	-18.10%	27	7033	5836	3302	3001				2762	1459								9977	14881
Northwest Zone																						
Austin	2152	2307	7.20%	88	2307																	
Colorado	27291	25936	-5.00%	73	19193	1686	1245	596	519	1193	104				259	389		52	700			
Fort Bend	5011	5141	2.60%	81	972	2606				730	180							653				
Harris																						
Lavaca	2139	2379	11.20%	76	1308	1071																
Robertson																						
Waller	4113	4289	4.30%	99	2452	82	408				1205				142							
Wharton	31220	28850	-7.60%	72	8358	3430	2882	2133	5217	1297	1470			202	836	547	260	173	115			1931
Lamar	204																					
NorthWest Total	72130	68902	-4.50%	76	34585	8874	4535	2730	5738	3220	2959			202	1237	937	260	878	816			1932
Southwest Zone																						
Calhoun	1532																					
Jackson	9872	9306	-5.70%	39	4918	827	195	233		883				251			576				1339	84
Matagorda	2817	2113	-25.00%	58	300								264	1267		194	53			36		
Victoria	2105	1985	-5.70%	100		992				992												
Cameron																						
SouthWest Total	16325	13404	-17.90%	51	5218	1819	195	233		1875			264	1518		194	629			36	1339	84
Northeast Zone																						
Bowie																						
Hopkins	99																					
Red River																						
Northeast Total	99																					
State Total	147468	130557	-11.50%	56	46836	16529	8032	5964	5738	5095	2959	2762	1723	1720	1237	1131	889	878	816	36	11316	16897

Mississippi rice variety acreage survey.

	Certified Acreage (All Rice)			Variety	Acreage		
County	**2014**	**2015**			**2014**	**2015**	**2016 Projection**
Bolivar	47680	42139		CL111		11961	4500
Coahoma	14486	9933		CL151		16110	19000
Desoto	2318	99		CL152		10848	2500
Grenada	282	893		CL163		386	17500
Holmes	203	195		CLXl745		28245	28750
Humphreys	3427	2576		CLXL729		11452	13000
Issaquena	443	345		CLXL4534		3421	7400
Leflore	6001	5059					
Panola	10368	5966		XL753		21743	32000
Quitman	15716	12220		XL723		2586	7500
Sharkey	857	789		Cheineire		3022	2500
Sunflower	25242	15612		Rex		21653	31000
Tallahatchie	12859	7142		Mermentau		8054	7400
Tate	1083	955		Lakast		1421	4200
Tunica	28609	25833		Other		4810	6000
Washington	15744	13027		**Total CL**		82423	92650
Yazoo	868	914		**Total Hybrid**		63289	88650
Grand Total	**188200**	**145712**		**Grand Total**		145712	183250

Missouri Rice Acreage
2014 @ 213,000 harvested 216,000 planted.
2015 @ 174,000 harvested 182,000 planted

South Florida Rice Varieties and Acreage (2014)

Cheniere	5,402
Cocodrie	1,056
Cypress	108
Mermentau	4,511
Roy J	4,017
Taggart	2,116
Wells	3,230
Total	20,440

South Florida Rice Varieties and Acreage (2015)

Cheniere	1,706	7%
Cocodrie		0%
Cypress		0%
Jupiter	661	3%
Mermentau	5,857	26%
Roy J	8,270	36%
Taggart	4,312	19%
Wells	1,168	5%
Rex	843	4%
Total	22,817	100%

RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

RODANTE TABIEN, Chair; THOMAS TAI, Chair - Elect (2018); J. EDWARDS, G. EIZENGA, K. JOHNSON, J. KEPIRO, A.C. MCCLUNG, X. SHA, E. SEPTININGSIH, and M.THOMSON, Participants.

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.

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

Genetics

Additional information is needed on the mode of inheritance of economically important characters including chalk, head rice recovery, and physio-chemical characteristics required by multiple industry users. Phenotypic and genetic associations among such characters should be determined. Basic research is needed to determine the factors influencing pollination and fertilization over a wide range of plant environments. Efforts should be made to incorporate the cytoplasmic and nuclear genetic elements necessary for hybrid rice production into germplasm that is well adapted to the respective rice growing areas. Also, information on the economics of hybrid rice seed production is needed. Genetic control of efficiency of solar energy conversion, including photosynthetic efficiency, respiration losses, translocation rates, source-sink relationships, plant morphology, chlorophyll characteristics, etc., must be explored to determine if such factors can benefit the development of superior yielding cultivars. Understanding the genetic, epigenetic, physiological, morphological, and environmental factors that influence ratoon crop yield is important for cultivar improvement. Genetic stocks and new rice accessions that have current or as-yet-unanticipated value should be preserved by entering them into the Genetic Stocks - Oryza (GSOR) collection or the USDA Germplasm Resources Information Network (GRIN). Materials in the GSOR will be accessible through GRIN and will be distributed to interested researchers.

Molecular Genetics and Genetic Engineering

Molecular genetic studies have accelerated rapidly in rice due to the favorable qualities of this species, including its small genome size, ease of transformation, and availability of genome sequence information. Molecular markers, such as RFLPs, RAPDs, AFLPs, STS, microsatellites, and SNPs, have been used to map loci controlling economically important traits. A national effort to maintain and update databases, and germplasm 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 developing markers relevant to U.S. breeding efforts. Genetic engineering is considered an emerging tool that will complement traditional methods for germplasm and cultivar development. Genes for herbicide, insect, and disease resistance and nutritional quality are being isolated and transferred to elite lines for field evaluation. Rice breeders should cooperate with molecular geneticists for proper evaluation and selection of lines that would benefit the rice producers. When available, genes for increased yield, grain quality, disease resistance, and stress tolerance should be transferred into elite lines or directly into commercial cultivars.

Response to Environment and Changing Climate

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

Hybrid Rice Research

Hybrid rice has proved its advantages on yield, disease resistances, and adaptation in the U.S. and received wide interest from growers, processers, and researchers. Current research is focused on development of 2- and 3-line male sterile germplasm adapted to the southern U.S. and elucidating genetic control of male sterility/fertility, outcrossing characteristics, general combining ability (GCA), and specific combining ability (SCA) using the most updated genomic technology. The USDA rice germplasm world collection contains about 20,000 accessions introduced from 116 countries, which provides the wide range of genetic diversity for distant crosses that is essential for yield heterosis. Hybrid rice breeding consortia also provide members with access to improved germplasm and cooperative research focusing specifically on hybrid rice breeding and development. The achievements from genomic research should improve (1) breeding efficiency for hybrid rice cultivars using molecular markers to assist selections of improved male sterile and restoring lines, (2) elite outcrossing characteristics for effective production of male sterile lines and hybrid seeds, (3) GCA as well as SCA for maximum heterosis (4) determining purity of sterile and restorer lines and (5) tagging of genes associated with heterosis. Similarly with conventional cultivars, development of new hybrids that have high yield potential, improved resistance to diseases and insect pests, and have grain milling and cooking properties necessary to meet the needs of domestic and export markets is critical. Separate testing methods for hybrids and inbreds need to be developed to understand the yield potential under nitrogen practices which maximize production and reduce input costs.

Resistance to Diseases and Insects

Intensive studies are required to develop cultivars resistant to economically important diseases and insects. Breeding for increased resistance to all known fungus races responsible for rice diseases blast (*Magnaporthe oryzae*), sheath blight (*Rhizoctonia solani*), aggregate sheath spot (*Rhizoctonia oryzae sativae*), and stem rot (*Sclerotium oryzae*) should be emphasized with the objective of obtaining highly resistant cultivars within all maturity groups and grain types. Efforts should be made to develop cultivars with greater field resistance to brown spot (*Bipolaris oryzae*), kernel smut (*Neovossia horrida*), false smut (*Ustilaginoidea virens*), the water mold complex (*Achlya and Pythium* spp.), sheath rot (*Sarocladium oryzae*), narrow brown leaf spot (*Cercospora janseana*), bacterial panicle blight (*Burkholderia glumae*), bakanae (*Gibberella fujikuroi*), leaf scald, leaf smut, "pecky rice", and the physiological disease straighthead should be continued. A continuing emphasis on germplasm resources for resistance to these diseases in various cultural systems is needed. Breeding for insect resistance to rice water weevil (*Lissorhoptrus oryzophilus* (Kuschel)), rice stink bug (*Oebalus pugnax* (Fabricius)), grape colaspis, sugarcane borer (*Didatrea saccharalis* (F.), Mexican rice borer (*Eoreima loftini* (Dyar), 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 should be pursued. As germplasm lines are recovered from interspecific crosses, their cooperative evaluation for disease resistance, insect resistance, and other traits important in commercial production would be essential for their application to the U.S. rice industry. Data from these evaluations should be entered in GRIN/GRAMENE or other appropriate databases.

Fertilizer Response

Factors that determine fertilizer response and lodging resistance and affect yield components are closely associated in determining total production and quality of grain. These factors must be studied collectively in order to understand the effects of quality, quantity, and timing of fertilizer applications on plant growth and yield components. Efforts should be made to develop cultivars with enhanced fertilizer use efficiency. N-Star utilization should be encouraged so growers can maximize yields with appropriate inputs and help ensure loss of inputs that will not cause run-off issues.

Milling, Processing, Cooking, and Nutritional Characteristics

Basic studies are needed to learn more about the role of each constituent of the rice kernel in processing, cooking behavior, nutritional value, and health benefits. As these properties are more clearly delineated, new techniques, including bioassays, should be developed to evaluate breeding lines for these factors. These studies should be coordinated with attempts to genetically improve grain quality factors, including translucency, head rice yields, protein content, mineral composition, cooking properties, and resistant starch. Effort should be made to obtain industry feedback on our breeding effectiveness for grain quality improvement. Standardization of chalk methods should be worked on with researchers from around the globe to ensure selection and validation is consistent with industry standards and measurements that utilize similar methodologies. There is increased interest in developing rice cultivars to target specialty markets, such as soft cooking rice, aromatics, waxy types, Jasmine and Basmati types, and Japanese premium quality rice. Research efforts need to be directed toward determining quality traits associated with various specialty rice varieties, analytical methods for evaluation, genetic variability, influence of environmental variables on character expression, and factors associated with consumer acceptance.

Development and Distribution of Superior Breeding Materials

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

Germplasm Evaluation and Enhancement

Efforts should be made to develop relatively adapted, broad-based gene pools having a diversity of phenotypic and genotypic traits based on genetic understanding of the World Collection. Characteristics include components required for increasing yields of cultivars and/or hybrids, such as straw strength, seed size, panicle size, seed set, and panicle number per plant. Molecular data base information associated with these traits should be made available to public and private rice researchers. Other useful characteristics such as bioenergy production from rice by-products may be incorporated into existing or new gene pools as appropriate when such germplasm is identified during evaluation efforts. Genetic male sterility and/or gametocides that are essential for hybrid rice may facilitate these efforts. Development of indica germplasm with high yield and grain quality standards similar to U.S. cultivars should be pursued. The core strategy is an effective way to evaluate large germplasm collections phenotypically and genotypically. 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. Efforts need to be made to develop high throughput phenotyping methods, and statistical and bioinformatics methods of analysis to utilize the data.

Training of New Rice Breeders

There is concern about the decreasing number of students interested in pursuing degrees in plant breeding. Who will replace the current and retiring U.S. rice researchers in the future? New efforts to develop and train our next generation of scientists at all levels needs to be undertaken. In addition to developing rice germplasm and knowledge, all rice researchers, but especially breeders and geneticists, are encouraged to interact with the public at many levels, educating students from kindergarten through Ph.D. levels about these fields of research and encouraging students to enter them. Interest in molecular genetics is currently high. With that, combined with the fact that rice has served as a genetic model for other crops, the geneticist pool is presently larger than the pool for breeders. Interaction with K-12 students, teachers, science curriculum coordinators, and advisors is strongly urged as a means to encourage students to select plant breeding-related fields of study for their college degrees. Interaction with undergraduate students will be required to encourage them to continue their studies with higher degrees to become knowledgeable breeders and geneticists. In addition, breeders must know both the theoretical issues of field design and the practical issues of field set-up and must have an understanding of environmental interactions and genotype response. Students from the B.S. through the Ph.D. levels should be encouraged to gain both laboratory and field training. Changes in college degree requirements may be required to adequately prepare the next generation of plant breeders and geneticists. Effort should be made to create opportunity for rice breeders to interact with breeders of other crops for information exchange.

ECONOMICS AND MARKETING

M. SALASSI, Chair; L. NALLEY, Chair-Elect (2018); R. ALI, E. CHAVEZ, N. CHILDS, A. DURAND-MORAT, L. FALCONER, R. MANE, A. McKENZIE, F. MUTHEE, A. NAHAR, J. RAULSTON, S. RAZAFINJOELINA, F. TSIBOE, and B. WATKINS, Participants.

Supply/Production Research

Investigate water use practices in various rice production regions and estimate the costs to producers of compliance with EPA water use and quality regulations.

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

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

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

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

Evaluate the economic costs and returns of alternative rice production technologies.

Policy, Demand, and Marketing Research

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

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

Evaluate the performance of the rough rice futures market.

Evaluate supply and demand factors in the domestic and international rice markets.

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

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

PLANT PROTECTION

X.-G. ZHOU, Chair; L. ESPINO, Chair-Elect (2018); S. BELMAR, S. BROOKS, T. GEBREMARIAM, A. GIBBONS, D. GROTH, S. HENSLEY, Y. JIA, R. MILLERS,T. MULAW, M. STOUT, S. UPPALA, Y. WAMISHE, and X. WANG, Participants.

Diseases

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

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

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

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

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

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

1. Systematic and coordinated field monitoring and diagnostics should be established and continued long term in the various rice states to detect new pathogens or changes in existing ones. Yearly surveys on the genetic makeup of blast, including the composition of blast avirulence genes in blast nurseries in each state, should be conducted to support existing and future research and extension programs, including breeding for improved resistance using major resistance genes.

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

3. Research should be conducted to backcross effective blast-resistant genes (Pi-ta, Pi- 9, Pi-42, and/or Pi-43) into elite breeding materials. Results of pathogen surveys demonstrate that Pi-ta, and Pi-9 are useful R genes.

4. 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.

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

6. 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.

7. 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.

8. 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.

9. Given the failure of the current system of importation and quarantine of rice germplasm to allow rapid and orderly dissemination and usage of exotic rice

germplasm for U.S. breeding programs, additional funding should be sought to research and implement a more workable but safe system. While existing federal quarantine procedures are effective and warranted, the United States needs to fund enough personnel and facilities to make them practical – a situation that does not currently exist.

10. 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.

11. 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.

12. 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.

13. 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.

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

15. 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.

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

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

Insects and Other Animal Pests

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

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

The major insect pests that damage the seed or rice plants between planting and harvesting are the rice water weevil, *Lissorhoptrus oryzophilus* Kuschel; rice stink bug, *Oebalus pugnax* (Fabricius); grape colaspis, *Colaspis brunnea* (Fabricius), *Colaspis louisianae*; stem borers, *Diatraea saccharalis* (Fabricius), *Eoreuma loftini* (Dyar), and *Chilo plejadellus* Zincken; rice leaf miner, *Hydrellia griseola* (Fallen); South American rice miner, *Hydrellia wirthi* Korytkowski; armyworm, *Pseudaletia unipuncta* (Haworth); fall armyworm, *Spodoptera frugiperda* (JE Smith); chinch bug, *Blissus leucopterus* (Say); various species of leaf and plant hoppers; numerous grasshopper species (Locustidae and Tettigoniidae); midge larvae (Chironomidae); greenbug, *Schizaphis graminum* (Rondani); bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus.); rice root aphid, *Rhopalosiphum rufiabdominalis* Sasaki; western yellowstriped armyworm, *Spodoptera praefica* (Grote); yellow sugarcane aphid, *Sipha flava* (Forbes); an exotic stink bug, *Oebalus ypsilongriseus* (DeGeer), found in Florida; sugarcane beetles, *Eutheola rugiceps* (LeConte); and billbugs, *Sphenopherous* spp.; thrips (various species); and rice delphacid, *Tagosodes oryzicolus*. Pests other than insects can damage rice directly or indirectly. *Triops longicaudatus* (LeConte), the tadpole shrimp, causes seedling drift by dislodging loosely rooted seedlings while feeding on the leaves and roots. Crayfish, *Procambarus clarkii* (Girard), damage irrigation systems by burrowing and also reduce stand establishment by feeding on germinating seeds and small seedlings. Birds trample and feed on seeds and sprouting and ripening rice. Rodents, through their burrowing activity, damage levees and directly feed on rice plants.

The panicle rice mite, *Steneotarsonemus spinki* Smiley, is primarily a greenhouse pest of rice but has been found in very low numbers in commercial rice fields in the South. This mite has been associated with panicle blight. The channeled apple snail, *Pomacea canaliculata* (Lamark), has been found in commercial rice fields in Texas, but, to date, has not been problematic. Recently (2015), the rice delphacid, *Tagosodes orizicolus* (Muir), was found attacking ratoon rice in Texas. U. S. entomologists must continue to monitor commercial rice fields for new and/or invasive pests and develop effective pest management programs if these pests cause economic or environmental loss (see item 9 below).

Specific recommendations include the following:

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

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

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

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

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

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

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

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

9. Investigate the effects of new irrigation methods and organic production on insect pests.

10. Monitor rice for possible introduction of exotic pests.

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

12. Integrate efforts of stored product entomologists into plant protection panel, perhaps, by having joint plant protection, process, storage, and quality presentations.

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

POSTHARVEST QUALITY, UTILIZATION, AND NUTRITION

M.-H. CHEN, Chair; Z. PAN, Chair-Elect (2018); F. ARTHUR, B. ADAM, Y. YANG, J. CAMPBELL, T. MCKAY, and S. PINSON, Participants.

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

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

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 carbon dioxide monitoring system for early detection of insect decay in rice.

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

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

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

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

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

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

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

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

Improve inspection methods for measuring chemical constituents and quality factors.

Develop identity preservation, traceability and detection technologies for all rice.

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

F. DOU, Chair; R. MUTTERS, Chair-Elect (2018); L. TARPLEY, K.R. REDDY, D. HARRELL, M. KONGCHUM, A. ADVIENTO-BORDE, T. RICHMOND, D. COX, G. BATHY, C. WILSON, R. DELONG, B. RUNKLE, M. REBA, D. FRIZZELL, J. HARDKE, N. SLATON, B. GOLDEN, M. FRYER, M. MARCOS, D. CARRIJO, M. ESPE, and B. LINQUIST; Participants.

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

Cultural Practices
Evaluate rotation systems that involve rice.

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

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

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

Expand research on crop residue management, including soil incorporation, collection, and economic uses. Study management systems that enhance ratoon production.

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

Explore crop establishment, including planting methods and geometry, plant density, seeding date, and other factors necessary to characterize BMPs for various cultivars of interest.

Evaluate the use of harvest aid chemicals in rice production.

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

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

M. BAGAVATHIANNAN, Chair, K. AL-KATIB, Chair-Elect (2018), E. WEBSTER, J. NORSWORTHY, C. MEYER, R. MILLER, S. MCCOY, N. STEPPIG, B. MCKNIGHT, E. BERGERON, M. PALHANO, S. MARTIN, M. YOUNG, J. NOLDIN, D. GEALY, J. BOND, R. LIU, R. SCOTT, C. SANDOSKI, S. LUDWIK, B. GUICE, and D. ELLIS, Participants.

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

Chemical Weed Control
Evaluate weed control systems for prevention and management of herbicide-resistant weeds.

Mechanisms of resistance.

Evaluate new chemicals for the control of weeds in rice.

Facilitate label clearance and continued registration for rice herbicides.

Evaluate varietal tolerance to herbicides in cooperation with plant breeders.

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

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

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

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

Cooperate in the development of herbicide-resistant rice weed control systems.

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

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

Intensify studies on weed biology and physiology, gene flow, molecular biology, and population genetics.

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

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

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

Evaluate the influence of cultural practices on red rice control.

Study methods for the biological control of important rice weeds.

Evaluate rice cultivars for weed suppressive traits.

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

Study basic biological and physiological processes regulated by applied chemicals.

Facilitate label clearance for growth regulators.

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

Understand interactions between plant growth regulators and environmental factors.

Abstracts of Papers from the Overview of Sustainable Organic Rice Production Symposium
Symposium Moderator: F. Dou

An Overview of Organic Rice Production

Dou, F., Guo, J., Valdez Velarca, M., McClung, A., Zhou, X., and Hons, F.

Organic rice research has been conducted at Beaumont, TX, for 3 years where we evaluated the effects of winter cover crop, rice variety, soil amendment product, nitrogen rate, and seeding rate on rice productivity. Although there was a trend for the white clover treatment to produce higher rice grain yields than ryegrass, it was not statistically significant. Variety had significant effects on all aspects of rice production – yield, height, maturity, disease resistance, and milling quality. Nature Safe and Rhizogen had the same effect on rice production, indicating they have equal nutritional value. Increasing N rate of the soil amendments increased rice yield but only the 210 kg N/ha had a significant effect. Cover crop, soil amendments, and variety affected rice diseases.

Increasing seeding rate linearly increased rice grain yield primarily through increased panicle numbers. Also, weed density was negatively impacted by increased seeding rate. Variety selection was important to handle weed pressure in organic rice production. Our study indicated that appropriate variety selection plus optimal seeding rate are critical for high yields in organic rice production and are more important than cover crop or nutrient amendments.

Organic Rice Diseases and Their Management

Zhou, X.G., Dou, F., and McClung, A.

Management of diseases is a challenge to organic rice producers. No synthetic chemicals, including fungicides and fertilizers, are allowed for use on organic rice. Instead, organic rice production relies on cultivars, animal and green manures, tillage, water, and other biological measures to maintain soil and plant health and to supply plant nutrients. However, these practices may result in changes in the severity of diseases and their management as compared to conventional practices. This presentation summarizes the results of field studies conducted on organically managed land at Beaumont, Texas, during 2009 through 2014 to manage rice diseases using cultivar resistance, cover crop, fertility, tillage and biocontrol management tools. Organic rice diseases: Disease comparisons were made on more than 20 rice cultivars and elite lines grown under organic and conventional management in 2009-2011. Organically produced rice was more vulnerable to seed rot and seedling diseases, narrow brown leaf spot (NBLS), brown spot, and straighthead than conventional rice. Because of the limited options for disease control, other diseases that might cause significant damage to organic rice included sheath blight, sheath rot, blast, bacterial panicle blight, false smut, black kernel, and pecky rice caused by various fungi and bacteria and insect injury.

Cultivar resistance: 20 cultivars and elite lines were evaluated for resistance to NBLS and brown spot during 2010-2014. Most cultivars showed a degree of resistance to NBLS. GP2, Jasmine 85, Rondo, Tesanai 2, XL 723 and XL 753 were among the most resistant to NBLS. Cocodrie, Colorado, Cybonnet, Jazzman, Presidio and Sierra were susceptible or highly susceptible to NBLS. None of the cultivars were immune to brown spot; Charleston Gold, Cybonnet, Jazzman, and Jupiter were the most susceptible. Brown spot was lowest on GP2, Tesanai 2 and Wells. Tesanai 2, GP2, and Rondo, all originating from China, had yields that ranked among the highest.

Cover crop and fertility: A trial was conducted in 2012, 2013 and 2014 to evaluate the impact of cover crop and organic fertilizer alone or in combination on NBLS and brown spot. Production following the incorporation of clover winter cover crop resulted in a consistent reduction in NBLS and brown spot than following winter fallow. Production following ryegrass cover crop incorporation reduced NBLS in 1 of 3 years and brown spot in 2 of 3 years. Regardless of cover crop, an application of the soil amendment NatureSafe or Rhizogen at 90, 150 or 210 kg N/ha significantly reduced NBLS and brown spot compared to the nonamended control.

Tillage practice: Two separate trials were established in 2010 and 2011 to evaluate the impact of tillage on straighthead. White clover was planted in the fall and terminated the following spring. In preparation for planting, one trial was conventionally tilled while the other used no-till prior to direct seeding of the rice crop. In the no-tilled plots, straighthead occurred in all 20 cultivars evaluated, with Cocodrie and its derived lines, Antonio and Colorado, having the most severe symptoms while other cultivars, including Presidio, GP2, Rondo and Tesanai 2, showed considerable resistance. In contrast, no symptoms of straighthead were observed in any of the cultivars using the conventional tillage.

Biocontrol: Efficacies of seven biocontrol agents for suppression of sheath blight and NBLS were evaluated in sheath blight-inoculated plots in 2010 and 2011. Serenade Max (*Bacillus subtilis* strain QST713, 14.6% a.i.) and Serenade ASO (*B. subtilis* strain QST713, 1.34% a.i.) were effective in reducing sheath blight in 2011. Serenade Max also significantly reduced NBLS in both years. Serenade Max increased yield up to 20% over the untreated control.

In conclusion, organic rice is more vulnerable to the diseases such as NBLS and brown spot than conventional rice. Cultivar, cover crop, fertility, tillage, biocontrol and their combinations can be effective tools to manage diseases in organic rice production. Selection of a resistant cultivar with high yielding potential is the most effective means to manage diseases. Use of conventional tillage and planting with resistant cultivars is the best means for control of straighthead.

Arsenic Uptake in Organic Rice Production Systems

McClung, A., Duke, S., Dou, F., Zhou, X., Chaney, R., and Gerads, R.

Arsenic in rice is known to be a problem in some rice-producing countries that have high levels of inorganic arsenic naturally occurring in water resources. However, it was never considered an issue for USA produced rice until international market surveys were published, indicating some USA rice samples were high in total arsenic content (a combination of inorganic and organic forms of arsenic). Since that time, an international limit of 0.200 ppm of inorganic arsenic (iAs), considered the toxic form for humans, in milled rice has been established. Some of the USA rice samples that were found to have high total arsenic had been produced under organic management systems. This was of concern to the organic industry as consumers consider organically produced foods to be safe and pesticide free. To address this issue, we conducted a series of studies to determine the impact of several organic cultural management practices on arsenic accumulation in rice.

Replicated field trials were conducted at Beaumont, TX during 2009-2013 on land that had been maintained under certified organic practices. Studies were conducted to evaluate the impact of variety, organic fertilizer product, fertilizer rate, and green manure crop on grain arsenic accumulation. In a cultivar study conducted over 3 years on conventionally (following 2 years fallow) and organically managed land (following winter green manure crops), we found similar levels of total arsenic (TAs) in brown rice between the two systems, 0.51 and 0.59 ppm, respectively. However, higher levels of TAs in milled rice were found under organic management (0.58 ppm) than under conventional management (0.39 ppm). Speciation analysis demonstrated that iAs contents were quite similar between the organic and conventional systems (0.15 and 0.18 ppm, respectively) and were relatively stable over years, but the organically-produced rice had much higher levels of organic forms of arsenic (oAs, DMA and MMA) which fluctuated over years. These results indicated the importance of assessing iAs through speciation analysis and not relying solely on TAs analysis as oAs contents can vary considerably. Thus, speciation was performed on milled rice of 7 of the 14 cultivars that were ranked low, intermediate and high in TAs. Varieties were very similar in iAs contents but differed significantly in oAs contents. The allelopathic germplasm PI 338046 had the highest iAs under the organic management system, whereas Sierra and Colorado had the lowest. Of the seven cultivars, there was a positive association of iAs and oAs contents with yield, plant height, maturity, and length of grain fill.

Six organic fertilizer products were compared in 2010. When applied at the same N level they did not differ in yield or TAs. One exception to this was Maxim Compost which produced significantly lower TAs and lower yield. This formulation had much higher phosphorus (3-10-1.5, N-P-K) than the other products and P is known to compete with As at cellular transport sites. As compared to the control (no fertilizer applied), there was a trend for increasing rates of fertilizer under organic management to increase yields and milled rice As accumulation, however, this was not always significant.

In all of the studies, year of production (includes weather, previous cropping history, and field site) explained most of the variability in yield and As accumulation. In general, higher yielding environments, whether a result of controlled (cultural) or uncontrolled (weather) effects, tended to result in higher As accumulation and was primarily driven by oAs. These results suggest that efforts to increase the nutrient value of the soil through green manure crops and/or organic fertilizer amendments may enhance microbial activity in the soil that make oAs more available for uptake by the plant but have little impact on iAs uptake. Our research has shown that in some years green manure crops and/or organic fertilizer amendments enhance yields and decrease pressure from some diseases, but this may also result in higher oAs accumulation and, thus, higher TAs. Choice of cultivar is the most effective means of maximizing yield potential and reducing susceptibility to diseases, while minimizing As accumulation under organic management.

Factors Affecting the Economics of Organic Rice Production

Watkins, K.B. and Mane, R.U.

Organic rice can be a profitable enterprise but poses many challenges not faced in conventional rice production. Much of the information that follows was gleaned from conversations with organic rice producers and sellers in Texas and Arkansas. One of the primary challenges of organic rice production is growing a rice crop without using inorganic inputs that are commonplace in conventional rice, such as inorganic herbicides, insecticides, fungicides and fertilizers. The absence of such inputs makes cultivar selection and good water management very important in an organic rice system. The primary fertility inputs in organic rice production are chicken litter and/or cover crops. Varieties with good weed or disease suppressive traits are more ideal than varieties susceptible to pests. Water is the one input that is most indispensable in organic rice production. Flood is the most effective means of controlling weeds, and good flood management can also reduce damage from diseases. Good flood control requires a consistent source of water and good control moving water across the field. The latter usually means precision leveling is needed. Organic rice fields are usually precision leveled and are generally no more than 16.2 ha (40 ac) in size to allow for good water control across the field. Organic rice levees are typically taller than conventional levees to allow for good control of grass weeds. Approximately one-third more water is applied to organic rice than to conventional rice. Production expenses are not as big an issue with organic rice as with conventional rice. This is due ironically to the absence of inorganic production inputs used in the organic rice system. The main component necessary for profitable organic rice production is a guaranteed price premium, as organic yields are typically much lower than conventional yields. Organic rice yields can range from 4,035 kg ha^{-1} (36 cwt ac^{-1}) to 6,053 kg ha^{-1} (54 cwt ac^{-1}), compared with state average conventional rice yields in 2015 of 8,294 kg ha^{-1} (74 cwt ac^{-1}) for Arkansas and 8,182 kg ha^{-1} (73 cwt ac^{-1}) for Texas. The organic rice producer must have a buyer or buyers already at hand in order to receive a price premium. The crop is typically sold by contract, and the buyer often dictates the type of rice cultivars to be grown. The price obtained for organic rice is generally twice that for conventional rice. Prices for organic rice in 2015 ranged from \$0.4850 kg^{-1} (\$22 cwt^{-1}) to \$0.5512 kg^{-1} (\$25 cwt^{-1}) in Arkansas and from \$0.5512 kg^{-1} (\$25 cwt^{-1}) to \$0.7716 kg^{-1} (\$35 cwt^{-1}) in Texas. The higher organic prices reported for Texas are usually obtained for aromatic cultivars. These prices compare with a price range of \$0.2315 kg^{-1} (\$10.50 cwt^{-1}) to 0.2756 kg^{-1} (\$12.50 cwt^{-1}) obtained for conventional rice at harvest in 2015.

There are a few barriers to entry in organic rice production. One cited barrier is the 3-year waiting period required for organic certification of rice ground. There is no established market for rice grown in this transition period and the producer must wait three years to obtain the organic rice premium. Another barrier to entry is the inability to obtain operating loans for organic rice. Organic rice also requires large amounts of paperwork for yearly inspection and certification. It is also hard for producers to grow both conventional and organic rice. It is best to segregate equipment for both rice products. Finally, organic rice must be grown in rotation either with other organic crops or with fallow ground. A 4-year rotation is typical for organic rice.

Abstracts of Papers from the Water Conservation Technologies for Sustainable Rice Production Symposium
Symposium Moderator: Y. Yang and L. Wilson

Water Management in Irrigated Rice: Coping with Water Scarcity

Lampayan, R.M.

Rice is the staple food for about 3 billion people, most of whom live in Asia. More than 90% of the world's rice is produced and consumed in Asia. Irrigated rice provides about 75% of total world rice production and is thus critical for food security. Irrigated rice production is dependent on vast amounts of Asia's developed water resources. However, current rates of exploitation of groundwater and surface water are unsustainable, with falling groundwater levels in some areas, while the flow of some major rivers dwindles to a trickle in some years. At the same time, populations are growing, the demand for rice is increasing, and cities demand increasing shares of available water at the expense of irrigated agriculture. Added to this, global climate is affecting and will increasingly affect irrigated rice production. Therefore, methods for producing more rice with less water are needed.

Irrigated rice is critical for the food security of Asia, but sustaining production, let alone increasing production to keep up with population growth, is seriously challenged by increasing competition for water. Climate change will further exacerbate the challenge. However, there is great potential to increase the amount of rice produced per amount of irrigation water supplied by closing the yield gap through a two-pronged approach: (i) adoption of improved varieties and management practices, and (ii) adoption of management practices that reduce the irrigation input to rice fields. Adoptable technologies for reducing irrigation input are now readily available. One technology is the alternate wetting and drying (AWD) technology which is now widely promoted in rice irrigated areas in Asia. This technology saves water by 20-30% without affecting yields, and reduces methane emissions by up to 70%. Other technologies such as laser levelling and dry seeding (with AWD) can also bring about large reductions in irrigation input, but their adoption will depend on the development of markets to supply and repair machinery and provide services on a hire basis, as well its affordability to small farmers. While there is great scope to reduce irrigation input to individual farmer's fields, the impacts of this on other water users have hardly been considered. Adoption of irrigation water reducing technologies can bring great benefits to many small farmers, such as reduced cost of pumping, higher yields at the lower ends of canal irrigation schemes, and expansion of rice production to lands which previously could not be irrigated. However, the effects on outflows of water from the irrigation areas also need to be considered.

Overview of Conventional and Advanced Water-Conserving Systems Used by Mid-South Rice Producers

Massey, J., Anders, M., and Vories, E.

Mid-South rice producers have worked steadily for decades to reduce the amount of irrigation and labor required to successfully grow a rice crop. A majority of rice is now grown on fields that have been precision-graded to have uniform slopes of less than 0.2%. The most comprehensive study of irrigation use for rice production in the mid-South was conducted by the Yazoo Mississippi Delta Water Management District (Stoneville, MS; www.ymd.org) that measured seasonal irrigation use on a total of 300 rice fields between 2002 and 2013. Their data indicated that irrigation applications made to non-graded fields using cascade (levee-gate) flood distribution averaged 1037 mm with a standard deviation of 304 mm. This amount was not different ($p=0.6029$) from the 981 ± 321 mm applied to straight-levee (i.e., precision graded) fields using cascade flood. Use of multiple-inlet rice irrigation (MIRI) significantly reduced ($p=0.0038$) irrigation use in straight-levee fields to 795 ± 276 mm relative to straight-levees alone. At 574 ± 307 mm, zero-grade fields received significantly less ($p=0.0106$) irrigation than straight-levee fields using MIRI and remains the most irrigation-efficient rice production system currently used in the Mid-South. Producers have been able to extend the irrigation savings of MIRI to nearly those of zero-grade by using alternate wetting-drying (AWD) flood management. Moreover, advances in weed and disease control have allowed producers to successfully produce rice using center pivot irrigation using similarly low amounts of irrigation. Both AWD and pivot irrigation have potential to significantly reduce methane emissions and arsenic levels in rice grain.

Opportunities for Producers Using Advanced Water-Conserving Rice Irrigation Systems to Access Carbon and Other Premium Rice Markets

Anders, M.M.

Nearly all the rice producing states in the U.S. are experiencing irrigation water restrictions to the extent rice acreages have begun to decline. As rice is one of the major users of irrigation water, there is an increased focus outside the rice community on highlighting its role in declining water supplies. Over the last few years, there has been a body of research published indicating rice can be produced without a continuous flood and still be profitable. Alternate wetting and drying (AWD) has emerged as a viable water management strategy that reduces irrigation water use, grain arsenic and mercury content, and methane gas emissions. These combined benefits have opened opportunities for farmers to receive additional incomes through NRCS programs, a new carbon market, and specialty rice markets. More attention needs to be taken to make sure producers are aware of these markets. Along with this, a standard format of "yield adjusted water efficiency" needs to be adopted along with plant breeding and management research programs that will support producers who choose to enter these specialty markets.

Understanding On-Farm Reservoir-Tailwater Recovery Systems for Irrigation-Challenges and Opportunities

Reba, M.L., Farris, J.L., Leonard, E., Wren, D., and Ozeren, Y.

Declines in water levels of the Mississippi River Valley Alluvial Aquifer in the Lower Mississippi River Basin exceed recharge rates. The region receives approximately 1270 mm (50 in) of precipitation annually. Storage of surface water for on-farm use has increased in the region in an effort to offset groundwater decline. Reservoir/tailwater recovery system construction in the state of Arkansas has steadily increased since the 1980s. Current estimates suggest there are approximately 300 systems in Arkansas. Concerns with these systems include erosion of interior levees, mitigation of erosion, the cost associated with maintenance, and water quality. Detailed erosion measurements from wind-induced waves will be presented. Generalized erosion measurements from an inventory of a subset of systems will illustrate how orientation and mitigation strategies impact erosion. Finally, an assessment will be presented for system water quality that focuses on location of sample sites. Improved understanding of the challenges and opportunities with these systems will impact irrigation potential into the future in the largest rice producing state in the U.S.

Achieving Multiple Sustainable Intensification Goals through Alternate Wetting and Drying Irrigation Management

Linquist, B., Anders, M., Adviento-Borbe, A., Carrijo, D., and Lahue, G.

Agriculture is increasingly under pressure to produce more, while at the same time limiting negative environmental impacts. Rice systems, which provide more calories for human consumption than any other crop on earth, have high greenhouse gas emissions and water use relative to other crops. Alternate wetting and drying (AWD) irrigation management, which introduces aerobic cycles during the growing season, has the potential to reduce both greenhouse gas emissions and water use – along with other benefits such as reduced grain arsenic concentrations and positively affecting mercury cycling. We will discuss how to manage water in rice systems to achieve these benefits along with high yields, based on research conducted in the U.S. and Europe and meta-analysis results. Importantly, we will also discuss some of the challenges and limitations of implementation and identify regions where adoption may be easier than others.

Modeling Approach to Analyze Water Savings with Different Water Conservation Technologies

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

Objective: The objective of the study was to develop a web-based rice water conservation analyzer to evaluate field- and regional-level costs, water savings, and yield benefits associated with implementing different on-farm conservation measures in the Lower Colorado River basin of Texas, United States.

Methods: The water conservation measures evaluated in the analysis include precision leveling, multiple inlets, conservation tillage, lateral improvement, tailwater recovery, and a production system based on growing high-yielding water efficient cultivars. The water conservation analyzer includes a crop development module and a water balance module. The crop development module uses a thermal time-driven phenology model to time water management events, including flushing and flush drainage for the main crop, and permanent flood, flood maintenance, and drainage before harvest for the main and ratoon crops. The water balance module simulates daily water balance for each rice field within the Lower Colorado River basin, as affected by the degree of implementing different conservation measures. The water balance module includes site-specific estimation of soil saturation deficit, evapotranspiration, percolation, seepage, rainfall, irrigation, and tailwater. It was verified and calibrated using 2000 and 2002 weekly irrigation records for the Lakeside and Gulf Coast irrigation districts, and validated using 2001, 2003, and 2004 weekly irrigation records.

Results: The conservation improvement that offers the most water savings is tailwater recovery, followed by adoption of high-yielding cultivars, multiple inlet, precision leveling, and conservation tillage. Water savings from lateral improvement varies depending on the extent of existing laterals in the irrigation districts.

A Modeling Approach to Analyze Costs and Benefits with Different Water Conservation Technologies

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

The objective of this paper was to evaluate the costs and benefits of different water conservation technologies in the rice production districts of the Lower Colorado River basin of Texas.

On-farm rice water conservation measures that were evaluated include precision leveling, multiple inlet systems, conservation tillage, lateral improvement, tailwater recovery, and the use of a production system that is based on growing high-yielding water efficient cultivars whose delayed maturity affords a greater growth potential and a higher grain yield but which normally prevents the production of a second crop. The costs of implementing conservation improvements include soil movement for precision leveling; irrigation pipes, water gates and their installation for multiple inlet systems; cultivation and herbicide-based weed control for conservation tillage; underground pipes and their installation or weed control for lateral improvement; and reservoir construction, irrigation pumps, pipes, and value of land that is lost for tailwater recovery systems, and maintenance and operation costs for each conservation measure. Cost sharing, amortization, and lifetime average cost were also considered for capital investment involving loans. The cost to develop high yielding cultivars is not considered. The benefits include water savings from each improvement and yield gains from precision leveling. The costs and benefits were modeled at an individual field level and were aggregated to the turnout, sub-district, and district levels. The partial net profit was calculated as the difference in yearly benefits and costs. Model verification involved comparing model outputs with expected costs and benefits for each improvement. Model validation involved comparing simulated cost, benefit, and partial net profit with expected values based on cost and benefit data from producers who have implemented conservation improvements. Precision leveling provides the best overall economic benefit for all three districts. Growing high yield cultivars offers the greatest yield benefit for Gulf Coast, which has a low ratoon crop percentage, but results in the greatest yield loss for Garwood, which has the highest ratoon crop percentage. The conservation measures that save most water are tailwater recovery and growing high yielding water efficient cultivars, while tailwater recovery systems have the highest costs.

Using Functional Genomics to Identify Markers for Grain Zinc Accumulation in Rice

Stangoulis, J., Warnock, N., De Courcy-Ireland, E., Rey, J., Mallikarjuna, S., Reinke, R., and Dingkuhn, M.

Zinc (Zn) deficiency is a world-wide problem in many populations where rice is a major staple food. Biofortification is a plant breeding strategy aimed at improving the nutritional content of staple foods, such as rice. To guide and accelerate the breeding of Zn biofortified rice, the development of molecular markers is a high priority.

To develop suitable markers, we are utilizing a functional genomic strategy comprised of three different but complementary approaches based on association mapping, Zn-protein identification and gene expression analyses.

The PRAY Indica diversity panel was grown by IRRI in the 2012 and 2013 wet and dry seasons and Zn quantified by XRF analyses. The panel was genotyped with 24,000 markers and genome-wide association mapping performed, yielding significant SNP associations. The stability of these associations will be tested before validation in breeding populations, and the genes underlying these associations are also being determined.

Candidate genes have also been identified through various proteomic approaches to identify Zn-proteins in the rice endosperm. To date, these approaches have been indirect, investigating links between protein content and Zn phenotype, but we are now shifting towards a direct method utilizing LC-ICP-MS to separate proteins and identify those with bound Zn.

Key questions evolving from this work are whether candidate genes show higher expression at the optimum loading stage for Zn into the grain and whether these genes can be monitored by expression of the candidate genes? To date, we are still unsure of the optimum loading time during grain filling. In collaboration with IRRI staff, we quantified Zn and global gene expression during grain development in genotypes that vary in grain Zn at maturity. This aimed to identify the critical time of loading Zn into the developing seed and will allow us to identify genes whose expression is correlated to Zn loading and which are differentially expressed between high- and low-Zn lines. It is anticipated that these time- and genotype-based comparisons of Zn and gene expression will elucidate the genes affecting Zn accumulation. Genes found to be differentially expressed will be further investigated for their ability to regulate grain Zn levels.

This transcriptomic data will also allow us to examine expression levels and patterns of candidate genes identified from GWAS and protein studies, as well as known metal homeostasis genes.

In all three approaches, areas of the genome found to be associated with the Zn phenotype will be interrogated to identify genetic markers. The ability of these markers to predict Zn phenotype will then be tested directly in breeding populations, with the ultimate aim of identifying genetic markers to increase endosperm Zn content.

Grain Quality and Value Enhancement in Rice Breeding Post-Harvest Research

Bautista, R.C.

Both grain quality and value enhancement have become critically important to hybrid rice breeding programs. Historically, increasing yield and quality were the driving forces in rice breeding; growing demand for high quality rice has necessitated renewed and focused efforts in hybrid rice breeding to address the changing market. This presentation focuses on research in grain quality including both pre- and post-harvest processes impacting grain quality pertaining to physicochemical property characteristics and product value enhancements. Research focus includes pre- and post-harvest property characterization to understand single-kernel and bulk sample physicochemical properties relating grain quality to environmental conditions and the physiology of a developing grain, agronomic practices affecting maturity, drying and milling processes, and sustainability.

Adding Industrial Value to U.S. Rice through Grain Quality Improvement

Park, W.D.

The goal of rice quality research is to solve problems and take advantage of opportunities. This was exemplified by pioneering work by the Rice Quality Lab at Beaumont using traditional tools to overcome quality problems in varieties such as CP231 and to combine the high yield of semidwarfs with excellent grain quality. We have subsequently identified the genes and specific DNA base changes responsible for many of the traditional quality traits, and have simplified and accelerated screening. However, a key challenge is to move beyond traditional quality traits and create new value. Over the last 20 years, my lab has focused on making healthy rice that people actually want to eat. Working with a corporate partner and Anna McClung of the USDA, we developed varieties that were specifically tailored to work with a proprietary process to make brown rice that cooks in 5 minutes rather than the traditional 30-45 minutes. It was preferred by consumers in side-by-side tests with traditional brown rice and has been commercially successful. Working with the same corporate partner, we subsequently developed methods to identify optimal feedstock for production of high quality 90-second microwave-ready rice. Having made brown rice that cooks quickly, our next objective was to enhance its nutritional value by increasing fiber content. Using breeding/genetics alone, several groups have found it difficult to make high fiber rice that consumers actually like – i.e. that does not taste like cardboard. However, by using a combination of genetics plus processing technology, we and a corporate partner were able develop brown rice that has almost twice as much fiber as traditional brown rice, is liked by consumers, and cooks in 90 seconds. It was the first non-fortified rice product to qualify for an official U.S. “good source of fiber” claim and has been commercially successful. What is next? We again have a new set of tools and technology. Notably, tools such as CRISPR/Cas9 allow quick, easy, but precise editing of essentially any gene in any organism. This technology can be directly applied to the genes we already know are critical for rice quality and is a powerful research tool. It is also a regulatory challenge since it can be done in such a way that leaves no foreign DNA or other “fingerprints.” These new genetic tools are likely to become increasingly important for creating new products and new value in rice but have the potential to be even more powerful when combined with the appropriate types of process technology. Thus, the other “what is next” is to find optimal ways to combine genetics and processing technology. The optimal combination will differ between products, markets, and regions and will change with introduction of new varieties and other factors that affect costs and production such as drought and trade policy. This is a complex problem, but it is one that can be systematically approached.

Abstracts of Papers from the Crop Consultants Update Symposium
Symposium Moderator: M.O. Way

2015 Texas Rice Production Season

Mock, C.

The state of Texas started 2015 in a severe drought for the fourth year in a row. Many rice producers were unable to plant due to lack of irrigation water. Irrigation companies are starting the practice of monitoring producers' water use. Results at the Gulf Coast Water Authority show producers used from 55 cm (1.8 feet) to over 120 cm (4 feet) applied water depth for first crop production.

During the 2015 crop production season, excessive rainfall occurred at many locations. Main crop yields were reduced. Excessive smut occurred at many locations and the brown plant hopper caused significant damage in the ratoon crop.

California 2015 Rice Season: Drought, Worms and Record Yields

Espino, L.

The 2015 rice season started with California experiencing its third year of drought. As of April 2015, water level in major state reservoirs ranged from 17 to 62%. Snowpack conditions were at 2% of average. There was uncertainty regarding water allocation to rice growers. When allocations to irrigation districts were made, these were between 50 and 75% of their normal allotment. Planted acreage was reduced from 550,000 and 425,000 acres in 2013 and 2014 respectively, to 375,000 acres in 2015.

In late June, a severe armyworm outbreak started in some areas of the northern Sacramento Valley. In some fields, large sections were severely defoliated. Insecticides usually effective at reducing armyworm populations did not work as expected, most likely due to the large size of the worms (5^{th} and 6^{th} instar) and their high numbers. A Section 18 registration for the insecticide methoxyfenozide (Intrepid) was obtained in case a second outbreak occurred. At heading, armyworms were present but not at the densities observed earlier. Several fields recovered from the injury; however, many growers reported yield losses.

Several instances of potassium deficiency have been observed across the Sacramento Valley in the past few years. Deficiency symptoms are not only being observed near the foothills, where red soils are potassium deficient, but in other areas where soil potassium was thought to be present at adequate levels. Sustained high yields during the past few years may be mining potassium and may require adding potassium fertilizer into fertility programs. Recent research has revised the thresholds for potassium deficiency, becoming more conservative.

The spread of herbicide resistant weeds continue to cause problems. Propanil resistant smallflower umbrella sedge seems to be more prevalent than in previous years. A resistant screening project is being conducted to differentiate between resistance and application problems. Propanil resistant watergrass has also been reported. Propanil is one of the few clean up herbicides rice farmers can use, therefore instances of resistance to propanil are very worrisome.

Overall, yields were very good. The current USDA yield estimate for California is close to 9,700 kg/ha, with yields as high as 14,500 kg/ha being reported.

Rice Production Practices in Southwest Louisiana before and after Clearfield

Fontenot, B.D.

Before the introduction of the Clearfield Technology, the suppression of red rice dictated every decision we made in the field. Many agronomic practices resulting in higher yield were not implemented because we had to use water to prohibit the germination of red rice seed. Clearfield changed the way we grow rice and allowed us to increase yield significantly.

2014 and 2015 Rice Stink Bug Threshold Evaluations

Crane, G.

During 2014 and 2015, Dr. Mo Way and I conducted large scale evaluations of rice stink bug thresholds. All treatments were applied by air using Tenchu 20 SG as the insecticide. Sweep counts, percent peck, rice grade, and loan value were used to determine effects of rice stink bug. The data indicate that current thresholds for rice stink bug need to be increased.

Weed Management Challenges in Texas Rice Production: A Consultant's Perspective

Bradshaw, G.C.

For Texas rice producers and consultants, weed management is one of the most critical and complex aspects of successful production. Less than optimum weed control can result in significantly reduced grain yields due to competition and grade discounts due to the presence of weed seeds. Additionally, control costs can vary widely dependent upon the weed species present in a particular field and the overall management practices and timings which are utilized. Weed management therefore can have a major influence on the ultimate profitability of a rice crop. Weed control is continually changing due to resistance to commonly used herbicide modes of actions, population shifts and new weed species becoming more problematic. Command has been a widely used foundation grass herbicide for over 15 years. However several grass species which exhibit tolerance have become more widespread over the past few years. These species are well controlled within the first 2 weeks after application, but tend to break through as the soil concentration declines. This is especially true on lighter soils where the Command rates must be kept low in order to decrease the potential for unacceptable rice injury. Additionally, due to the extensive use of ALS chemistry, waterhemp has been selected for resistance to this class of chemistry. Alternative management programs are being used where waterhemp is a concern. Infestations of alligatorweed are continually growing throughout the Texas rice belt. The most common means of dispersal is by movement of vegetative parts on implements, especially precision grading equipment, and from infested canal systems. Heavy infestations combined with the rapid growth rate creates a challenge for weed management.

Since many times these situations are occurring simultaneously in a field, herbicide programs must continually evolve as the need dictates. Due to the variable nature of the weed spectrum, control programs need to be tailored to the individual field. Additionally, herbicide tank mix antagonism must be considered when deciding upon a control option for a wide array of weed species. Several herbicides which have been registered in the last 10 years, such as Grasp, Regiment, Sharpen and Clincher, have considerable value in managing these problematic weed situations.

The Ratoon Rice Crop: A Decade of Research in Louisiana

Harrell, D.

Ratoon rice (*Oryza sativa* L.) production in the USA is predominately practiced along the Gulf of Mexico-Coastal Plains area of Texas and Louisiana. The economic advantage of producing the ratoon crop is highly significant to producers in the region and has become increasingly more important to production budgets. Historically, the ratoon rice crop yields one-third of the first crop yield. However, in 2015, ratoon yields in Louisiana commonly yielded one-half of the main rice crop yield. This increase in the average ratoon yield was due, in part, to both the favorable growing conditions in 2015 and to the advancement of research derived ratoon agronomic practices in the past decade.

Agronomic practices such as ratoon stubble management have played key roles in increasing ratoon yields. Stubble management practices such as reducing the stubble height to approximately 20 cm by either post-harvest flail mowing or bush-hogging has shown to: significantly increase ratoon yields consistently by 900 kg ha^{-1}, reduce the incidence of cercospora, even out grain maturity and increase grain quality. However, the practice does delay grain maturity by two weeks as compared to un-manipulated stubble. Stubble manipulation by post-harvest rolling has also shown similar benefits as mowing and research has shown that both manipulation practices force ratoon regrowth to originate from the crown node of the stubble. Panicles derived from the crown have been shown to be larger, have more grains per panicle, and have a greater number of filled grains per panicle.

Ratoon fertility has also been a focus of ratoon research over the past decade. Application timings and rates of nitrogen fertilizer, coupled with proper water management, have been shown to be an important key to maximizing ratoon yields. Research with phosphorus (P) and potassium (K) fertilization in Louisiana has also shown that current soil test based fertilizer P and K recommendations are only valid for the main rice crop. The ratoon rice crop requires an additional 35 kg ha^{-1} to maximize ratoon yields when the initial soil test indicates that the soil falls into the "very low," "low," or "medium" soil test P or K categories.

The Use of UAS in Cropping Systems: A Novel Tool for Rice Research and Extension

Jochum, M. and Jo, Y.

With advanced sensors and software coupled with lower costs for platforms, Unmanned Aerial Vehicles (UAVs) now offer tremendous opportunities for future use in the agricultural sector. Through the use of fixed or rotary wing UAVs, rice farmers, agronomists, extension agents and researchers can survey large areas of rice crops in high resolution and real time with little effort and low budget. This novel capability allows them to make better informed decisions for proper and timely management practices. Through an intensive literature review coupled with a collaboration between Texas A&M Agrilife Extension and Research, Texas A&M Plant Pathology and Microbiology, and Texas A&M Corpus Christi Civil Engineering, this presentation will deliver a succinct background and basic knowledge on the use of UAVs in monitoring rice cropping systems. This presentation will discuss the following topics:

• Describe, compare and discuss the different types of fixed wing and multi-rotor unmanned aerial vehicles.

• Discuss the capabilities of UAVs in terms of autonomous preprogrammed flight, payload carrying capacity, and flight duration.

• Take a look at the potential use of different sensors onboard the platform.

• Deliver a brief synopsis on the different kinds of imagery (RGB, IR, multispectral, hyperspectral) and the advantages/disadvantages of using each type.

• Describe the latest software capabilities using UAV based images in measuring distances, photogrammetric triangulation for image stitching, elevation modeling, and georeferenced orthomosaic exporting.

• Discuss the possible future of UAV applications in rice research and extension (crop surveying, NDVI based biomass estimation, yield estimation IR thermography, entomological research, plant pathology).

Abstracts of Papers from the Role of Climatic Stress on Rice Yield and Grain Quality Symposium

Symposium Moderator: L. Wilson

Physiologically-Based Demographic Models for the Analysis of Weather and Climate Change on Tri-trophic Systems

Gutierrez, A.P. and Ponti, L.

Mechanistic, weather-driven physiologically-based demographic models (PBDMs) build conceptually on the idea that all organisms are consumers and all have similar resource acquisition functions and allocation priorities; a notion that allows use of the same resource acquisition model and birth-death dynamics models to describe explicitly the biology across trophic levels. The analogous inflow and outflow processes across trophic levels have similar shapes, but the units are species specific. Per capita resource acquisition (i.e. the supply, *S*) is a search process driven by organism demand (*D*), with allocation of *S* occurring in priority order to egestion, conversion costs, respiration, and reproduction, growth, and reserves. Considerable behavior and physiology can also be included in these models.

This biology is used to parameterize age-mass (and other variables) structured multi-species population dynamics models (e.g., distributed maturation time models) that can be used to assess the effects of weather on resource acquisition and allocation on trophic interactions. When embedded in a GIS, the models can be used to simulate prospectively the effects of weather and climate change on the geographic distribution and relative abundance of the interacting species.

Tri-trophic models can be used in ecological and/or bio-economic analyses of natural and agricultural systems at the local and regional level under observed and climate change scenarios. In bio-economic analyses, the tri-trophic model becomes the objective function used to assess the effects of different system components on the stability and economic viability of the system.

Yield Gap Assessment of U.S. Rice Systems

Linquist, B., Espe, M., Cassman, K., Yang, H., Guilpart, N., Wart, J.V., Grassini, P., Anders, M., Beighley, D., Espino, L., Harrell, D., Linscombe, S., Mckenzie, K., Mutters, R., Walker, T., and Wilson, L.T.

It is often suggested that grain yields in highly intensified agricultural systems are at or near the yield potential. However, many of these assessments are based on comparisons to achieve yields, which can bias the estimated yield potential in situations where yields have plateaued below full yield potential. Our objective was to estimate the yield potential and the associated yield gap in U.S. rice production systems, which are amongst the highest yielding rice systems globally. Using the ORYZA physiological crop model, we estimated yield potentials and up-scaled these findings according to the Global Yield Gap Atlas protocol. Following this protocol, 91% of the harvested area in U.S. rice production was contained in eight different climate zones. Using buffer zones around 14 reference weather stations, we were able to represent 87% of total harvested area in the U.S. The ORYZA model, calibrated and validated to simulate yield potential for two representative U.S. rice varieties (M-206 for California and Clearfield XL745 for the southern U.S.), was used to simulated rice yield potential from 2004 to 2014 within each of these buffer zones.

For our purposes, the attainable yield potential is 15% of the maximum yield potential, and the yield gap is the difference between the attainable and observed yields. Therefore, within each climate zone, our estimated attainable yield potentials were compared to area-weighted average reported yields to determine the yield gap. Averaged across all climate zones and years, the maximum yield potential averaged 12.5 t ha^{-1}, thus the estimated attainable yield potential was 10.6 t ha^{-1}. For this same time period, observed average yields were 8.3 t ha^{-1}. Yield gaps ranged from 1.16 to 3.43 t ha^{-1}. The zones with the smallest yield gaps were northern California and the western zone of Texas, while the largest yield gaps were in southern California, southern Louisiana and in northern Arkansas/southern Missouri. Contrary to previous studies, these estimates suggest there is room for increased yields in US rice production systems.

Impact of Climate Change on Rice Production in Southern Asia

Li, T., Angeles, O., and Laborte, A.

Rice is a staple food for more than half of the world's population and about 67% of the total rice consumers are in South and Southeast Asia. The rice food security in these areas is important to global food security, local social stability, and population reduction of hunger and poverty. However, rice production is threatened by the increasing frequency of drought, heat waves, typhoons, rainstorms, submergence, and the rising sea level brought about by climate change. It is crucial to evaluate the potential impacts of climate change on rice production for strategic decision-making on adaptation and mitigation. To understand the impacts of climate change on rice production in Southern Asia (including South and Southeast Asia), the rice crop model, ORYZA v3, was employed to predict rice production under the climate change best future scenario , RCP2.6. The model simulations were conducted for 11 modern varieties pyramided with multiple abiotic and biotic tolerant traits for adapting to harsh environments. Site-specific data for weather, soil, and rice planting seasons were used. The current rice-cultivating regions in Southern Asia were gridded in 5×5 arc-minute resolution, corresponding to the available soil data. The downscaled climate projection of coupled global climate mode (CGCM) was provided in 15 arc-minute resolution. Simulations for every variety in each rice grid cell were designed with two water management schemes--fully irrigated and rainfed -- with uniform agronomic management, full nutrient supply, and assumed free from biotic stresses. The average predicted grain yields of all varieties were used to quantify the impacts of drought, heat, cold, and submergence under climate change.

In 30 years, from 2016 to 2045, the potential rice grain yield determined by radiation and air temperature will increase by an average of 0.02% per year over all rice areas in Southern Asian region. This is because of the considerable CO_2 elevation (~60ppm) and slight increase of air temperature (~1 ^{o}C). A yield increase of ≥0.1% per year will occur in 11.6% of the areas, while decrease will come in 14.4%; and 64.6% of the rice-cultivating areas will have a yield increase less than the average. The significant increases (> 0.1% per year) were mainly predicted at the northern part of Southern Asia region, while the significant decreases (>0.1% per year) will occur in South Asia.

The average change of attainable yield of rainfed rice in Southern Asia will be -0.02% per year in the next 30 years, which emphasizes the drought will threaten rice production in the future even with the most favorable AR5 scenario –RCP2.6. The attainable rainfed rice yield will increase in 42.8% of rice areas although the increase will be ≤0.1% per year, while it will decrease annually for ≥0.1% at 32.3% of the rice areas in Southern Asia.

In the next 30 years, if the local season of rice growing won't be adjusted accordingly, the severe drought (yield loss ≥ 75%) would happen every other year in 23.2% of the rice areas. Severe drought with frequency of every 3, 5, and 10 years will impact 28.9, 30.8, and 32.3% of rice-growing areas in Southern Asia, respectively. All severe drought stresses are reproductive drought, and the vegetative drought stress won't result in yield loss by >25%, and about 0.5% of the rice areas have reproductive and vegetative drought to cause yield loss by >25%.

Heat stress that could result in 50% yield loss is classified as severe. The severe heat stress with frequency of every other year, every 3, 5, and 10 years will strike 17.0, 18.2, 18.2 and 18.9% of the rice areas in Southern Asia. The combined stress of drought and heat could also threaten a large part of the rice-cultivating areas. For yield loss of 25%, the combined heat and drought stress, with frequency of every other year, every 3, 5, and 10 years, will affect 18.0, 21.7, 23.3, and 25.3% of the rice areas, respectively. The cold stress resulting in early crop failure before flowering won't exist, but the low temperature during flowering resulting in spikelet sterility will happen every 10 years in 5% of rice areas. If we assume that flooding may occur when the cumulative rainfall is more than 150 mm in five consecutive days, with frequency of every other year, every 3, 5, and 10 years, submergence could potentially affect 0.2, 0.3, 0.6, and 1.2% of rice areas, respectively.

In summary, 39.9% of the total rice-producing areas in Southern Asia are vulnerable if at least one type of abiotic stress reaches severe level in every 5-year frequency, resulting in significant yield loss. This study only considered the projected weather data under RCP2.6. Further simulations are needed for other RCP scenarios to fully understand the impacts of climate change on rice production in Southern Asia.

Effects of Elevated Temperature on Rice Growth, Yield, and Reproductive Traits

Boote, K.J., Baker, J.T., Allen, L.H., Gesch, R.W., Snyder, A.M., and Prasad, V.

Elevated temperature during grain-set and grain-filling of rice is a potential problem during heat waves and under projected climate change as it may shorten the duration of grain-filling and reduce spikelet fertility, thus reducing yields. The goal of this paper is to present results of a series of experiments conducted on rice grown from sowing to maturity under a wide range of temperature treatments in sunlit, controlled-environment chambers at the University of Florida. Five experiments were conducted with IR-30 cultivar (indica) with fixed daytime and fixed nighttime temperatures of 25/18, 28/21, 31/24, 34/27, 40/33ºC (square wave, day/night). One experiment was conducted with M-103 (japonica) and IR-72 (indica) using diurnally varying temperature cycles of 28/18, 31/21, 34/24, 37/27, 40/30ºC (Tmax/Tmin). The optimum temperature for rice yield was 25ºC daily mean, which is 2-3ºC below mid-summer temperature in the Deep South. Above 25ºC, yield and grain harvest index (HI) declined gradually at first (associated with shorter grain-filling) and then declined progressively more rapidly, reaching zero yield and zero HI (associated with failure of spikelet fertility) at 35ºC. The decline in HI, with only small decline in biomass production, indicates that reproductive processes were disrupted much more so than biomass assimilation. Spikelet fertility (percent filled grains) declined progressively from 29ºC, falling to zero at 35-36ºC mean daily temperature. These results agree closely with that of Japanese scientists who found that spikelet fertility declines above 33ºC Tmax, maximum daily temperature, reaching zero fertility at 41ºC Tmax. For rice producers, this means that days with Tmax above 33ºC will reduce spikelet fertility and yield. There were no apparent differences among indica and japonica types for heat sensitivity, although one cultivar, N-22, demonstrated a moderate degree of heat tolerance, when compared to other lines in a temperature gradient greenhouse study in which temperatures were elevated above ambient by 4.5ºC. We believe that elevation of both day and night temperatures are equally a problem as the temperature effect is most likely on the pollen formation/generation phase over the 6 to 8 days prior to anthesis and the day of anthesis, which we have observed on other cereals such as sorghum which has exactly the same heat sensitivity as rice. The AgMIP-Rice teams are presently re-evaluating their rice crop models against these results to improve model parameterization for elevated temperature effects and to improve model ability to predict yield under weather and climate variation. One of our concerns is that the models use air temperature as a driver and most do not predict foliage temperature, yet we know that foliage temperature will vary as a function of vapor pressure deficit at a given air temperature. With further improvement such simulation models can be used as strategic tools to evaluate the consequences of climate change on crop production, as well as to evaluate shifts in management practices to mitigate the effects of weather and climate change.

In Silico Ideotyping on Traits Involved with Processes and Aspects Often Ignored in Climate Change Studies

Confalonieri, R., Paleari, L., and Cappelli, G.

Beyond their role in supporting crop and cropping system management, crop models are increasingly used within breeding activities, for the identification of key traits for specific agro-climatic conditions and the quantification of the performances of new ideotypes. Until now, model-based ideotyping studies have been mainly focusing on traits enhancing yield potential, such as those involved with canopy architecture or photosynthetic efficiency. However, the overall performance of the cropping system in terms of profitability relies - to a large extent - on the impact of biotic and abiotic stressors (e.g. pathogens, cold spells). This highlights the need for dedicated programs targeting the improvement for resistance/tolerance traits. This is especially true in light of the expected increase in the frequency and intensity of weather extremes associated with climate change projections. Moreover, in light of the raising importance of quality attributes in determining actual economic and processing value of crop productions, quality-related traits are also increasingly catalyzing the attention of breeders in most production districts worldwide.

The analysis was performed using a dedicated simulation platform (i.e., ISIde) and was focused on the definition and evaluation of rice ideotypes improved for traits involved with the resistance/tolerance level to biotic and abiotic stressors and with the grain quality of productions. *In silico* ideotypes were tested at 5 km spatial resolution under current conditions and climate change scenarios, centered on 2030, 2050 and 2070. Future projections were derived using two general circulation models – GCM, GISS-ES (NASA) and HadGEM2-ES (Hadley Centre, UK) – for two contrasting IPCC AR5 scenarios (RCPs, Regional Concentration Pathways, IPCC 2013) – rcp 2.6 (+2.6 W m^{-2}, CO_2 up to 420 ppm in 2100), rcp 8.5 (+8.5 W m^{-2}, CO_2 up to 936 ppm in 2100). The study focused on the most important

European rice district (i.e., Northern Italy, more than half of EU rice production), using the most representative rice varieties as genetic background to design the ideotypes. Simulations were performed using the WARM model.

Concerning biotic and abiotic stressors, our results clearly demonstrate that – under the conditions explored – breeders should focus on increasing resistance to blast disease, since ideotypes improved for such trait obtained clear yield increases (i.e., more than 10%) regardless of the climate scenario considered. Increasing tolerance to pre-flowering cold shocks inducing spikelet sterility instead, would lead to sizeable benefits only for *Indica*-type cultivars under current climate conditions, whereas no relevant yield increases are expected after 2030, and, in general, for *Japonica*-type varieties. Our analysis also confirmed the relevance of genetic improvement for quality traits under climate change scenarios.

Evaluating Rice Germplasm for Adaptation to Climate Change

Ziska, L.

It will be necessary by 2050 to generate sufficient food to feed an additional two billion individuals. Agricultural production is under increasing pressure by global anthropogenic changes, including rising population, diversion of cereals to biofuels, increased protein demands, and climatic extremes. Because of the immediate and dynamic nature of these changes, adaptation measures are urgently needed to ensure both the stability and continued increase of the global food supply. Although potential adaption options often consider regional or sectoral variations of existing risk management (e.g., earlier planting dates, choice of crop), there may be a global-centric strategy for increasing productivity. In spite of the recognition that atmospheric carbon dioxide is an essential plant resource that has increased globally by ~25% since 1959, efforts to increase the biological conversion of atmospheric CO_2 to stimulate seed yield through crop selection is not generally recognized as an effective adaptation measure. In this presentation I will focus on rice and address ongoing USDA and University efforts to begin to select for CO_2 responsiveness with respect to increasing seed yield. Overall, while technical hurdles remain, active selection and breeding for CO_2 responsiveness among rice lines may provide one of the simplest and direct strategies for increasing global yields and maintaining food security with anthropogenic change.

Mitigating the Impact of Climatic Stress through Phenotypic Trait Selection

Wilson, L.T., Medley, J.C., Yang, Y., and Yan, Z.

Four analyses were conducted to address the impact of climatic stress in rice yield performance.

· *Multi-state analysis of the effects of climatic variables on rice crop yield*
· *Multiple field analysis of the impact of planting date on environmental stress*
· *Experiment addressing the impact of climatic stress on reproduction and survival processes*
· *Analysis of whether rice genotypes can be selected to mitigate the negative effects of climate change*

A six-state analysis of 66 years of yield data shows 89% of yield variability can be explained by a number of climatic variables. Yield increases the higher the ˚D > 10˚C, days with $T_{max} \geq 33.3$˚C, daily average RH ≥ 80, cumulative hourly daily respiration, minimum daily hourly respiration, and daily solar irradiance during pre-reproductive development but decreases the greater the rainfall or days with $T_{min} \geq 23.3$˚C. Yield also increases the greater the days with $T_{max} \geq 33.3$˚C, daily average RH ≥ 80 and daily respiration during reproductive development but decreases greater the ˚D > 10˚C, minimum hourly respiration, rainfall, and solar irradiance.

Analysis of about 10,000 fields of main crop commercial data shows yields progressively increase for rice harvested the 27th to 31st week of the year and progressively decrease through the 44th week. The decrease for fields harvested after the 31st week appears due to increased exposure to hotter summer months by the growing rice.

A 2-year analysis of 15 genotypes shows tiller density, spikelets per panicle, and grain produced per spikelet decreased when exposed to excessively high temperatures. In contrast, panicles produced per tiller increased largely as a result of fewer tillers surviving the hotter temperatures, resulting in less competition for light and metabolites.

Whether rice genotypes can be selected to mitigate the effects of climate change on yield was addressed using RicePSM (population simulation model), which is structured around 30+ potential rates for major birth, ageing, growth, senescence, light capture, respiration, and allocation processes. These primary phenotypic traits are near invariant and interact with the climatic and edaphic environment to determine yield performance and resultant secondary plant traits, such as plant height or tiller density, which in contrast are highly variable. Three scenarios were addressed each for a 30-year duration: 1) current weather, 2) current + 2˚C approximating the CSSM A2 2035 scenario, and 3) same as #2 but planting dates shifted based on suitability of estimated soil temperatures. For each scenario x year three genotypes were simulated varying in factorial combination four primary phenotypic traits (panicle node, potential rate of phytomer production, potential grain weight, potential leaf size) each at five levels. Each E x G x T combination was in turn simulated for 10 planting dates and two soil types (30 and 60% clay), for a total of 3.375 million simulations. The greatest yield variability was explained by genotype (43%), G x T interaction (16%), environment (14%), and trait (12%). Two genotypes when averaged across selections yielded less under climate change, while one yielded more. The third has a combination of traits that produce a relatively higher sink strength, which reduced photosynthesis feedback inhibition allowing for increased yield under conditions of higher climatic stress. The shift to earlier planting under climate change mitigated a significant amount of the associated yield loss. The results suggest it is highly feasible to select genotypes that out-yield current genotypes when grown under the CSSM A2 2035 scenario.

Rice Adaptation to Day and Night Heat - Consequences for Modeling

Lafarge, T., Julia, C., Peraudeau, S., and Dingkuhn, M.

Considering the mean global temperature increase of 0.7°C from the start of the industrial era and the prediction window of additional increase of 1 to 3.7°C by the end of the century, adaptation through crop improvement and adjustment of cultural practices is essential. One way of achieving this challenge is to better take into account the plant response to temperature into crop models. In the case of rice, mostly grown in tropical and subtropical regions, the increase in temperature goes with systematic yield reduction which makes this challenge even more critical. Two main situations need to be analyzed: the impact of (i) daytime heat on spikelet sterility and (ii) nighttime temperature on respiration. (i) Coping with heat stress at day time involves different options that account for the ability of plants to escape (early anthesis time), avoid (panicle cooling through transpiration) or tolerate (presence of key genes) heat at flowering. First, variability in the time of day of anthesis was correlated with the mean of climatic variables calculated for the 7-day period before flowering, over four distinct field locations and seasons and four contrasted varieties. The best predictive variables (negative correlations) were T_{min} and VPD, with high values of both being associated with early times. Second, depending on conditions, panicle temperature varied between 9°C below and 2°C above air temperature at 2 m. A significant positive correlation was obtained between spikelet sterility rate and maximum panicle temperature at flowering, whereas no correlation was obtained with air temperature. By extrapolation, this correlation predicted minimal sterility with a panicle temperature of 30°C, and 50% sterility with a panicle temperature of 33-34°C. Third, a genome-wide association study of the sterility rate of 167 traditional and modern varieties (grown for six consecutive days at 37°C between 8 am and 2 pm at anthesis) detected 91 significant associations grouped into 12 independent regions located on eight chromosomes. The highest heat tolerance was detected for N22, an *aus* variety from India, and Peh Kuh, a traditional *indica* variety from Taiwan. (ii) Global temperature increase has been higher at night than at day time and night temperature is predicted to increase by 3°C by 2050. While no escape or avoidance pathway can address the effect of high night temperature on respiration as it occurs at night when the plant cooling system is minimal and mostly at any time during plant cycle so that the plant cannot really escape it, tolerance is seen as a major option. As a preliminary step, the focus was conducted here on the change of respiration with temperature of 2 to 4 contrasted varieties grown in field and controlled environments. While the increase of night respiration with temperature rising from 21 to 31°C was 2.4-fold without acclimation, it was only between 1.2 and 1.7-fold with acclimation. In the same way, the maintenance respiration, which was estimated by assimilate starvation at 34% of the night respiration, increased by a factor of 1.49 when temperature rose from 21 to 31°C. These figures are lower than the common assumption of the Q10=2 rule that overestimates the effect of increasing night temperature on respiration in acclimated conditions. Even if the cost in carbohydrates of night respiration over crop duration varied from 8 to 20% of the potential shoot dry matter depending on the conditions, the additional burden due to increased night temperature was only 1 to 7%. As a general conclusion, avoidance (for daytime stress only) and tolerance (for both day and night time stresses) appear as the main genetic improvement pathways to cope with the thermal component of climate change. A Q10=1.5 rule seems closer to the reality to account for respiration changes with temperature into crop models where the estimation of canopy temperature is essential to predict spikelet sterility.

Abstracts of Papers from the Blast Symposium
Symposium Moderator: X. Zhou, Y. Jia, and Y. Wamishe

Texas Rice Blast Update

Zhou, X.G.

Rice is an important agricultural commodity in Texas, with a crop value of more than $160 million annually. Rice blast, caused by *Magnaporthe oryzae*, is one of the most devastating diseases of rice worldwide. The pathogen causes leaf blast, node blast, neck blast and panicle blast, which can cause up to 100% yield loss under the most conducive conditions. Fortunately, severe outbreaks of rice blast have not been observed in Texas for many years. In recent years, however, rice blast has reemerged in Texas. The objective of this presentation was to update the occurrence of rice blast in Texas and discuss its potential causes.

Outbreaks of rice blast occurred in each of the past four years in Texas. In 2012, leaf blast took place on 165 hectares of the rice variety CL261 in Jefferson County, causing a significant loss in yield and quality. In 2013, neck blast occurred on 10 hectares of the rice variety Colorado in Jefferson County. In 2014, leaf blast, node blast, neck blast and panicle blast severely occurred on a total of 461 hectares of Antonio, Presidio and Jupiter (medium grain) in Chamber, Jefferson, and Victoria Counties. In 2015, there were several outbreaks of leaf blast on more than 121 hectares of Presidio in Jackson, Wharton and Victoria Counties. The outbreaks of rice blast appeared during the months of June and July each year, which apparently resulted from prolonged rainy days. Outbreaks of rice blast caused considerable damage to Texas rice in 2012 to 2015, with an estimated direct loss of more than $720,000.

Isolates of *M. oryzae* were collected in these epidemic years and race identification assays were conducted on international differentials. Three races (IB49, IB17, and IC17) have been identified. These three races are among the ten most common races present in Texas and other states. Preliminary results of this research indicate that the current races of *M. oryzae* in Texas are still the same as before and there are no new races associated with the outbreaks of rice blast in recent years. The outbreaks of rice blast in Texas apparently were due to a combination of variety susceptibility and favorable weather conditions. All the varieties Antonio, CL261, Colorado, Jupiter and Presidio, which suffered damages from rice blast in the epidemic years, are susceptible to one or all of the three races. None of the rice varieties has the major genes such as *Pi-ta* that are resistant to the three races of *M. oryzae*.

Arkansas Rice Blast Update

Wamishe, Y.A.

Rice blast is a sporadic disease caused by the fungal pathogen, *Magnaporthe grisea*. Given favorable weather and inadequate crop management practices, the pathogen can infect rice seedlings and later developmental stages beyond heading. This fungus infects most parts of rice plant parts including leaves, leaf collars, panicle necks, panicle rachis and kernels. The fungus may spread with seeds or wind and overwinters in seeds and rice residues. Under blast favorable environmental conditions, near 100% grain yield loss can occur with severe seedling leaf blast or panicle neck rot on susceptible rice cultivars when no control measures are applied. Conditions that allow prolonged leaf wetness such as shade from trees, overcast or frequent rain are favorable for the pathogen's spore germination. After successful germination and penetration in the tissues of rice plants, sporulation follows. Newly produced spores are dispersed across the field with a gentle breeze and onto other rice fields to result in a broad blast epidemic. In 2014 and 2015, leaf blast appeared in the month of June. Blast was reported from 14 rice producing counties in 2014 either early June or late in the season on rice seedlings and headed rice, respectively. Jupiter was the most affected followed by CL151, CL261, Francis, Roy J, CL152, Caffey and Jazzman 2. In 2015, 16 counties reported blast on Jupiter as being the most affected followed by CL151. With the exception of a few isolated fields with severe neck and panicle blast, Arkansas avoided severe blast epidemics in both years using proper flood depth and timely application of protective fungicides in fields planted with susceptible varieties.

Louisiana Rice Blast Update and Management

Groth, D.E.

In 2012, there was a major blast epidemic in Louisiana that was primarily on the varieties CL261 and CL151. It was followed by two years of light blast disease pressure. However, in 2015, severe blast reappeared in Louisiana and rice producers struggled to control the disease. Even with a cold winter that killed most rice from 2014, blast got an early start in 2015. Most of the fields with severe leaf blast had lost their floods sometime after permanent flood. Severe rotten neck blast developed on CL151 but not Jupiter. Fungicide use was high with most susceptible varieties treated with at least a single heading application. Most of these applications were effective in suppressing blast except in a few situations where rain occurred soon after application, fungicides were applied late, or a different mode of action fungicide with poor blast activity was used. Several fields that were sprayed correctly had poor control, indicating too much pressure for the fungicide or fungal resistance to the strobilurins fungicides. Rotten neck blast appeared on Antonio, Caffey, Cheniere, CL151, CL152, CL161, CL163, CL172, CL261, CL271, Cocodrie, Cypress, Jazzman 2, LaKast, Mermentau, Presidio, and Rex in experimental lots at multiple locations. The races present have not been identified at the time of this submission. Several cultural practices contributed to the severe blast, including planting blast-susceptible varieties in tree-lined fields or with light sandy soil, failure to maintain floods, and late plantings.

Precise Genome Editing in *Oryza sativa* and *Magnaporthe oryzae* Using CRISPR/Cas9

Yang, Y., Xie, K., Minkenberg, B., Guo, X., Chen, Y., and Wheatley, M.

The bacterial cluster regularly interspaced short palindromic repeats (CRISPR)/CRISPR-associated protein 9 nuclease (Cas9) system has recently emerged as an efficient and versatile genome editing tool for various animal, plant and microbial organisms. In this study, we have demonstrated precise genome editing and targeted mutagenesis in both rice (*Oryza sativa*) and rice blast fungus (*Magnaporthe oryzae*) with the CRISPR-Cas9 system. The engineered guide RNA (gRNA) was shown to direct the Cas9 nuclease for precise cleavage at the desired genomic sites and introduce specific mutations (insertion or deletion) in transgenic rice plants at a high efficiency by an error prone non-homologous end joining repairing mechanism. In addition, polycistronic tRNA-gRNA synthetic genes have been constructed to facilitate multiplex genome editing for simultaneous mutation of multiple genes, chromosomal fragment deletion, and other more sophisticated applications. With the genome editing approach, transgene-free rice mutants with single or multiple gene mutation could be readily obtained by selfing or backcrossing of genome-edited transgenic rice lines with the wildtype plant. By developing and utilizing specific CRISPR/Cas9 tools for fungi, simultaneous mutation of three effector genes was achieved in *M. oryzae* via the homology-dependent repair mechanism. Our study has shown that the CRISPR/Cas9 technology can serve as a powerful tool to elucidate the molecular mechanism of the rice-*Magnaporthe oryzae* interaction and to facilitate the development of rice cultivars with improved blast resistance.

Molecular Mechanism and Marker-Assisted Breeding of Rice Resistance to *Magnaporthe oryzae*

Wang, G.

Rice blast, caused by the fungal pathogen *Magnaporthe oryzae*, is a devastating disease of rice and a model pathosystem for plant-microbe interaction studies. We aim to elucidate the molecular mechanism of rice resistance to *M. oryzae* at the molecular level and use the information for blast resistance breeding. We cloned the blast resistance (R) genes *Pi2, Pi9* and *Piz-t* that encode homologous NB-LRR receptor proteins in rice and the AvrPiz-t gene in *M. oryzae.* Using molecular and biochemical methods, we identified several AvrPiz-t-interacting proteins (APIPs) and characterized their function in the PAMP-triggered immunity (PTI) and Piz-t-mediated immunity. Among them, APIP6, a RING finger E3 ligase, degrades AvrPiz-t and is a positive regulator of PTI. The second RING finger E3 ligase APIP10 is not only a positive regulator of PTI but also a negative regulator of Piz-t-mediated resistance. We also found that the transcription factor APIP5 negatively regulates cell death and disease resistance to *M. oryzae* and is essential for the stability of the Piz-t protein in rice. In addition, we have successfully used marker-aided selection to transfer the *Pi9* gene into the high-yielding hybrid rice lines.

Rice Resistance Genes and Blast Management

Jia, Y.

Rice blast disease has been a significant crop pathogen in the Southern USA. More incidents of crop damage due to blast have been reported in the past three years as compared to immediate previous years. Thus far, broad spectrum fungicides utilized with responsible cultural practices have been effective in controlling both blast and sheath blight diseases. However, the use of fungicides increases production costs and also brings concerns for the environment. Deployment of blast resistance genes thus far identified in rice is the most economical and environmentally friendly method to prevent blast disease. Since 2000, the Dale Bumpers National Rice Research Center (USDA/ARS) molecular plant pathology laboratory has been searching for new resistance genes from rice germplasm and tagging them with genetic markers. This allows rice breeders to incorporate the resistance genes into advanced breeding lines through a marker assisted breeding effort. A combination of forward and reverse genetic methods coupled with next generation DNA sequencing has been used for this study. Most recently, DNA markers for a major blast resistance gene *Pi66(t)* in the *Indica* rice variety Dee Geo Woo Gen [also the source of the semidwarf gene (SD1)], and *Pi9* were identified. To date, additional major resistance genes, *Pi-ta/Pita2/Ptr(t), Pi-b, Pi-kh(m), Pi42(t), Pi43(t),* and *Piz*, and the minor resistance genes (QTL) *qBLR8, qBLR10-1, qBLR10-2, qBLR10-3,qBLR12-1,* and *qBLR12-2* have also been identified in U.S. rice germplasm. All have proven to be effective in preventing infections by rice blast in the Southern USA.

Hybrid Rice R&D at IRRI

Xie, F.

IRRI has been playing an important role in hybrid rice research and development in the tropics. Significant progress has been made in the last 10 years at IRRI on aspects of increasing hybrid yield and yield heterosis, increasing yield of seed production with improved outcross of female parents, resistance to stress and capacity building. The IRRI hybrid rice program is supported by the Hybrid Rice Development Consortium (HRDC), which is a collaboration and partnership between public research institutes and the private sector for developing hybrid rice products. Such collaboration is essential for dissemination of hybrid rice technology, promotion of research products and sustainability of scientific research. A large number of rice hybrids and parents with improved traits have been generated from such collaboration and partnership, and they are shared with partners for hybrid rice development and commercial rice production in Asia.

Breeding and Commercializing TGMS Hybrid Rice in Eastern Africa

Mann, J., Sanni, K., Wafula, E., and Corbett, J.

The TGMS or 2-line hybrid rice system depends on temperature differences to modulate the fertile/sterile status of the S line (2 line female). In temperate countries, it is necessary to use the normal summer season for breeding and seed production, and a winter nursery for line advance and S line seed multiplication. The seasonality caused by latitudes higher or lower than about 5° makes it nearly impossible to plant seed production more than one time a year, or multiply and maintain seed stocks more than once per year. Within the tropics, opportunities exist to do both seed production and parent line multiplication more than once per year. However, few S line hybrids have been developed in the tropics, and to date, no rice hybrids have been developed and released in Africa. The opportunity to develop commercial S line hybrids in Africa certainly exists, and the extra one MT/ha of yield will have a significant impact on both large and small farmers in the region.

In the tropics the situation is different, in that temperatures are not dependant on seasons but rather depend mostly on altitude. At the equator, mean monthly temperatures seldom vary by more than 0.5°C, making it possible to do most breeding operation and seed production multiple times per year. This temperature consistency takes years off the time to market for new products, and greatly reduces the costs associated with a commercial start up. The conceptual "aha" moment came when two of the authors were working on a commercial rice farm in 2004/5 which sat astride the equator in western Kenya.

The selection of locations which provide ideal temperatures for each breeding and commercial activity was the first and most critical step in establishing a potentially successful seed company. We turned to aWhere, Inc. of Wheat Ridge, CO, to create gridded surface maps of Eastern Africa. For every 9-km square grid, we have a virtual weather station showing daily weather data for the past 30 years. In addition, on-line tools calculate a risk profile for seed production at a given Critical Temperature S line, allowing us to determine when and where to plant for any given operation.

When breeding operations started in 2006, we used desktop-based software to select two locations for initial operations. While we preferred to be located close to the equator in the coastal lowlands of Kenya, the security situation caused us to move nearly 3° south to Malindi, the warmest town with good security and access to appropriate infrastructure. This has become the company headquarters and the main site for selection of steriles and critical temperature. Our current second location is just east of Kisumu, on Lake Victoria. Malindi has a mean temperature of 27°C, and Kisumu an average mean temperature of 24°C. We are currently searching for a third location with an average mean temperature of 25.5°C to be used for critical temperature selection.

We have analyzed every grid of 9x9 km in eight Eastern African countries to determine logical hybrid seed production locations and locations for optimum parent seed increase. As we move into our commercial phase, we have begun to seek areas with both the appropriate risk profiles and security, water, land and infrastructure. We have locations pinpointed in areas in both Tanzania and Kenya. On the breeding front, we have developed on contract some 2,000 S lines. Within East Africa, we have developed and tested over 2,000 hybrids, and in all of the 10 locations used to date, the best hybrids show yields exceeding best local checks by 2,500 kg/ha or more. Eight hybrids are in registration trials in three East Africa countries. Hybrids East Africa Ltd is currently operating on development funds managed by the African Agricultural Technology Foundation, while its sister company, Afritec Seeds Ltd, is receiving development funds from FoodTrade, ESA.

Development of Environmentally-Sensitive Male Steriles for Hybrids in Louisiana

Molina, F., De Guzman, C., and Oard, J.

The Louisiana rice industry generates ~ 400 million dollars each year toward our state economy. Louisiana varieties are typically bred as pure lines, but hybrid (F_1) varieties have the potential to increase grain yields 15% or more over conventional sources. A primary goal of the LSU AgCenter Hybrid Breeding program is to breed elite cross combinations (hybrid varieties) through development of environmentally sensitive male sterile and stable, fertile pollinator lines. Extensive multi-location yield trials in Louisiana have demonstrated high grain and head rice yields for candidate hybrids, but improvements in maturity, lodging, and grain chalk are needed. To address these challenges, an extensive crossing and selection program was initiated between Chinese sources of male sterility and elite Louisiana varieties. Specifically, crosses were made in 2013 resulting in the creation of 129 F_2 populations that were evaluated in field plots in 2014. Numerous male sterile and fertile plants were identified with improved maturity, grain type, smooth leaf, and compact plant canopy. Selected material was planted in 2015, and ~ 400 environmentally sensitive male sterile plants were identified with a range of maturities and desirable plant type. Future research in the next two years will advance selected material, genotype male sterile lines with DNA markers, and evaluate commercial value of new male sterile lines by creation and testing of new hybrid combinations.

Detection of a Major QTL and Evaluation of SNP Markers Affecting Photoperiod and Thermosensitive Genetic Male Sterile Rice

De Guzman, C., Molina, F., Camacho, R., Esguerra, M., Galam, D., Sanabria, Y., Li, W., and Oard, J.

Two-line hybrid rice breeding involves the use of genetic male steriles to achieve high grain yields vs. pure line varieties. The objectives of our research were to investigate inheritance of photoperiod, thermo-sensitive genetic male sterility (PTGMS) under field plot conditions, evaluate SNP-based markers and to map additional QTLs for hybrid rice breeding applications. PTGMS parental lines 2008S and 2009S were 100% pollen sterile under Louisiana field conditions. A total of 1149 F_2 and 1249 BC_1F_2 plants derived from 2009S and 2008S crosses to fertile tropical japonica lines were randomly sampled in separate studies from 2012-2014 to determine fertile: sterile plant segregation ratios. Based on pollen sterility, 2009S F_2 and BC_1F_2 population ratios fit a 3 fertile: 1 sterile single gene recessive model while 2008S F_2 and BC_1F_2 population segregation ratios fit a 15 fertile: 1 sterile two-gene recessive model. Sterile plants genotyped with a SNP marker at the PTGMS 2-1 locus predicted 86 to 97% of sterile phenotypes in the 2009S F_2 and BC_1F_2 populations. The 2008S genotyping using SNP markers at pms1 (t) and pms3 loci showed that marker main effects and their interactions explained 54% of the observed variation. QTL mapping using selective genotyping identified LOC_Os07g47990 that significantly affected pollen sterility and explained 31% of the observed variation in 2008S. All results indicated that the single gene and two-gene recessive SNP-based markers can be used for successful hybrid development under Louisiana field conditions.

Integrating Molecular Breeding into Rice Variety Development Process

Famoso, A., Oard, J., Utomo, H., and Linscombe, S.

Rice breeding and variety development has been one of the central activities at the LSU AgCenter H. Rouse Caffey Rice Research Station over the last 100 years. Over 50 rice varieties have been released, contributing to the steady yield increases achieved by Louisiana rice producers. To help ensure these rates of gain continue, new breeding technologies are being explored, validated, and integrated into the core variety development activities.

One aspect of these activities is the establishment of a high-throughput SNP genotyping lab that will facilitate the number of data points, turnaround time, and cost necessary to integrate within the logistical context of an applied breeding program. This talk will provide an overview of the research plans and breeding strategies being explored to efficiently integrate molecular markers at various stages of the breeding process. Specific focus will be on molecular breeding strategies, breeding timelines and resource allocations, as well as the establishment of the SNP lab and a core set of SNP markers.

Kompetitive Allele Specific PCR (KASP) Marker-Assisted Selection in a Rice Breeding Program

Boyett, V.A., Thompson, V.I., Sha, X., Moldenhauer, K.A.K., Wisdom, D.K.A.,
Bulloch, J.M., and Moldenhauer, H.H.M.

With four rice breeding programs and cooperative extension activities, the molecular genetics lab at the University of Arkansas Rice Research and Extension Center (UA RREC) has been performing DNA marker-assisted selection (MAS) for the advancement of elite rice cultivars for over 14 years. During the history of MAS at the center, the vast majority of DNA markers have been simple sequence repeat (SSR) and insertion-deletion (InDel) markers. A few important trait markers, such as those markers linked to grain cooking quality, were single nucleotide polymorphism (SNP) markers.

Running SNP markers on an ABI Genetic Analyzer has been problematic. Cross-priming and preferential amplification happened more often than not, and in many cases, the problem was so severe that the data could not be analyzed. A newer technology, Kompetitive Allele Specific PCR (KASP), shows definite promise in resolving these issues.

Developed over 10 years ago, KASP is a *Fluorescence Resonance Energy Transfer* (FRET)-based endpoint detection platform capable of detecting SNP and InDel markers. The technology has been tested at the UA RREC for about a year for SNP analysis on markers linked to the traits of cooking quality, leaf surface texture, Clearfield herbicide resistance, and the rice blast resistance gene *Pi-ta*. The technology was used on eight genotyping projects at the center in 2015. Amplification was robust and the data was interpreted easily without any of the previous issues such as cross-priming. Detection of the alleles was accomplished on the FLUOstar Omega SNP platform directly in the lab. In the genotyping projects involving MAS to predict grain cooking quality, the data from the two different chemistries matched for every sample, giving a higher degree of confidence in the phenotype prediction. Future plans are to develop KASP assays linked to more important agronomic traits and to start using KASP assays tailored more specifically to the hybrid rice breeding program.

Rice SNPvisor: a New Initiative to Characterize and Validate Breeding-Relevant SNP Haplotypes for the U.S. Rice Community

Thomson, M.J.

Tremendous advances have been made in molecular genetics and genomics across the rice research community, yet few breeding groups have fully integrated molecular breeding tools into their programs. The availability of high resolution single nucleotide polymorphism (SNP) data has enabled genome-wide association mapping across diverse germplasm panels, leading to valuable information on SNP haplotypes (i.e. patterns of SNP markers at genetic loci that correspond to specific alleles) that are predictive for key traits. When combined with whole genome sequence data for thousands of rice accessions and recent advances in cloning genes underlying agronomic traits, we now have an excellent opportunity to identify SNP haplotypes at beneficial alleles for rice improvement. Along with low-cost SNP genotyping platforms, these resources can enable more efficient targeted selection at major genes for rice breeding programs.

Even with these recent advances, however, a community-wide effort is needed to further characterize, validate, and make accessible information on SNP-tagged alleles, so breeders can take advantage of high-throughput SNP genotyping to accelerate their marker-assisted selection programs. Many genome-wide association studies (GWAS) results and potentially beneficial alleles at cloned QTLs have not been validated across different sets of germplasm and across multiple environments. A concerted effort is needed to compile and share trait-predictive SNP haplotype and marker validation information across different germplasm groups, which will enable breeders to access the most relevant SNP markers for their programs, while at the same time highlighting gaps where additional SNP marker validation activities are required. A new initiative called "RiceSNPvisor" is proposed to provide rice breeders with information and advice on breeding-relevant SNP haplotypes, with an initial focus on the U.S. rice community, through compiling published data on SNP associations and guiding future efforts at validating SNP haplotypes in U.S. rice germplasm. This initiative is at the planning stage and participation and feedback from the rice community is greatly appreciated. The ultimate objective is to enable rice breeders to more readily employ high-throughput SNP genotype data and imputation to track targeted SNP haplotypes at major genes for large-scale marker-assisted selection across their mainstream breeding pipelines.

New SNP-Based Markers for Grain Chalk in Rice Identified by Whole Genome Sequencing and Selective Genotyping

Esguerra, M., Berger, G., and Oard, J.

High incidence of kernel chalk has greatly reduced U.S. long-grain quality of rice for farmers, millers and traders resulting in significant export decline and revenue loss. Recent introductions of hybrids and high temperatures during grain filling were deemed as major causes of chalky grains considered a complex trait controlled by numerous genes with small effect. Several QTLs/genes have been reported to be associated with chalk, most of which are genotype dependent or discovered through mutation experiments. Goals of the research described here were to first identify and then evaluate candidate markers associated with chalkiness through development of allele-specific DNA markers from whole genome sequences of elite varieties with extreme chalk phenotypes. The RiceCAP SB5 mapping population was evaluated for chalk over two years in 2013 and 2014 in three Louisiana and Arkansas environments. Selective genotyping of 199 SNP markers of 20 low-chalk and 20 high-chalk lines from SB5 identified 49 SNPs on 11 chromosomes significantly associated with chalk (R^2 =10% to 55%) in one to three Louisiana and Arkansas environments. Ten markers on three chromosomes were significant in all three environments, five of which were novel (one each on chromosomes 2 and 3 and three on chromosome 6). Validation experiments showed that the 49 selected markers correctly predicted chalk phenotypes with overall 96% accuracy for 11 elite inbred varieties. Additional validation experiments are planned to genotype various indica and japonica lines with both low and high chalk values.

QTL Mapping for Salinity Tolerance Using Ultra-High Density SNP Markers

De Leon, T., Linscombe, S., and Subudhi, P.K.

Rice is one of the most important cereals that feed more than half of the world's population. Since salinity is a major abiotic stress affecting rice productivity in many parts of the world, identification and utilization of QTLs for salt tolerance can accelerate development of salt-tolerant rice varieties. Many QTLs for traits related to salinity tolerance have been mapped. However, most of those QTLs are still covering huge chromosomal segments that make extraction of candidate genes difficult. In this study, we phenotyped and genotyped 189 F_6 recombinant inbred lines developed from a cross between Bengal and Pokkali. Large and small effects QTLs were mapped for traits related to seedling salinity tolerance. Our result showed that some of the QTLs were located within previously reported QTLs, while other QTLs were flanking a gene. The saturation of markers in our linkage map increased the resolution of our QTL mapping and offers potential for fine mapping and candidate gene extraction.

Cold Stress Response Genetic Networks in Rice: Complementation, Epistasis, Epialleles, and Transgressive Phenotypes

De Los Reyes, B.G.

It is now fully appreciated that any further improvements in stress tolerance and yield potentials of rice will have to rely on the ability to create complex genomic configurations that could lead to novel biochemical and physiological attributes. While the answer to the '9-billion people question' (9BPQ) may be quite overwhelming, a possible component of the solution to this puzzle may be evident from the conventional wisdom in plant genetics, if we are to boldly re-examine the classical concepts within the context of the recent paradigm shifts in genomics, network biology, and epigenetics. In this project, we are exploring a more contemporary view of the enigmatic phenomenon of transgressive segregation, within the context of stress tolerance phenotypes. By comparative genomic, regulomic, and epigenomic analyses, we have uncovered global patterns indicating that transgressive phenotypes for cold tolerance in rice may be configured through ideal complementation effects involving epistatic transcription factors and their downstream regulons, small regulatory RNAs and their target regulatory genes, or through changes in the patterns of DNA methylation in recombinants. These mechanisms lead to gene expression signatures that are neither of the two parents.

Dissecting Cold Tolerance in Rice as Revealed by Association Mapping

Shakiba, E., Jodari, F., Edwards, J.D., Baldo, A.D., Duke, S.E., Korniliev, P., McCouch, S.R., and Eizenga, G.C.

Cold stress is an important abiotic stress which negatively affects morphological development and seed production in rice (*Oryza sativa* L.). At the seedling stage, cold stress causes poor germination, seedling injury and poor stand establishment; and at the reproductive stage cold decreases seed yield. Identification of genetic sources of tolerance to cold stress in rice could have a positive impact on production of rice in regions where temperature limits rice yield.

A collection of genotypically and geographically diverse rice accessions known as the Rice Diversity Panel 1 (RDP1) was screened to identify the genetic sources of cold tolerance at the seedling and reproductive stages. For the seedling stage, the experiment was arranged in a randomized complete block design (RCBD) with three cold replications and two warm replications. After treatment, the accessions were categorized based on coleoptile length into three groups, high tolerance (coleoptile length >5 mm long), intermediate tolerance (coleoptile length <5 mm long), or no germination. This screening revealed only 17.7% of the *Indica* accessions were highly cold tolerant, whereas 51.5% of the *Japonica* accessions were tolerant. For the reproductive stage, 191 *Japonica* accessions were grown in a greenhouse, modified to test for cold tolerance. The plants were arranged in a RCBD with two replications and several agronomic traits were measured after cold treatment, including category of seed blanking (no seed produced), seed weight, and seed weight per panicle.

A Genome-Wide Association Study (GWAS) was conducted to identify the genetic variation associated with cold stress. The RDP1 accessions were categorized in five groups, *temperate japonica*, *tropical japonica*, *Japonica* (both *temperate* and *tropical japonica* subpopulations), *Indica* (both *indica* and *aus* subpopulations), and the complete

RDP1. The RDP1 was genotyped using a high density rice array (HDRA) which contained 700,000 single nucleotide polymorphism (SNP) markers. These genotypes were used in a GWAS pipeline, composed of Python (v2.6-2.7) and R (v2.15) scripts for conducting the linear mixed model analysis using the EMMA eXpedited (EMMAX) algorithm. Candidate gene discovery was conducted using the UCSC Genome Browser and the MSU7 annotation of the Nipponbare genome. Haplotype blocks were constructed for each of the five subpopulations across the genome to help evaluate candidate genes proximal to the GWAS hits.

The GWAS results revealed 47 regions, including seven in *temperate japonica*, six in *tropical japonica*, eight in *Japonica*, eight in *Indica* and 18 in all RDP1, associated with cold tolerance at the seedling stage. Several of these regions co-localized with previously reported QTLs associated with cold tolerance. The GWA analysis at the reproductive stage detected 17 regions, including 10 associated with seed weight, 10 with the seed weight per panicle ratio, and 7 associated with blanking (no seed produced). Of the 17 regions identified by GWA mapping at the reproductive stage, 11 were co-localized with previously reported QTLs for yield components and two regions were co-localized with previously reported QTLs associated with cold tolerance.

In summary, GWAS proved to be a powerful tool for exploring the genetic variation that underlies cold tolerance and GWAS can be used for complex quantitative traits like cold tolerance. These results also provide information that plant breeders can utilize in developing a new generation of cold-tolerant rice cultivars.

Generation and Characterization of Novel Genetic Variation in Rice for the Enhancement of Grain Quality and Agronomic Performance

Tai, T.H.

Induced mutants represent a key resource for the functional analysis of genes, but in crop plants such as rice, they can also have significant impact on the development of improved varieties to help feed and clothe an ever-increasing population. The overall goal of this project is to employ classical mutagenesis to induce genetic variation in rice that will be exploited for functional genomics and variety improvement. Building on previous experiences with seed mutagenesis, this research will result in the development of a new, open access, rice mutant resource consisting of genotypic (*in silico* mutation profiles) and phenotypic (primarily morphological and agronomic traits) data that are linked to seed resources for downstream applications. Exome sequencing will be employed to assess mutation densities generated using various mutagens, rice genotypes, and protocols in order to identify optimal conditions for the generation of mutants for forward and reverse genetic screens. Through evaluation of early generation and fixed mutant lines, mutations and mutant phenotypes that improve upon or define new traits of interest will be identified and made available to breeding programs. The methods and resources developed will provide a road map of how induced mutagenesis can be integrated both in the functional characterization of genes and in breeding of crop plants where enhanced variation will be necessary to overcome the challenges posed by a changing environment, diminishing resources, and increasing demand.

Advancing Marker-Assisted Breeding Lines and High Protein Rice Lines for Better Grain Shape, Uniformity, and Less Chalk

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

Improving grain quality is an important breeding goal in rice (*Oryza sativa*). Selection methods using DNA markers and physiochemical analyses can be used to develop high grain quality with specific physiochemical properties to meet target market segments and help the rice industry achieve maximum profitability in the vastly expanding global market. Grain quality is affected by milling, grain appearance, cooking, and eating quality. The two approaches described were used to improve grain uniformity, shape, and lower chalk among elite lines of high-protein rice. Induced mutation using mutagen ethylmethane sulphonate (EMS, 16 h) has resulted in a series of rice mutant lines possessing endosperm characteristics with altered grain appearance. Several genes associate with the trait alterations, such as dull loci *du-1*, *du-4*, *du (2035)*, *du (EM47)*, *du (2120)*, *Du6a(t),* and *Du7(t)* genes that regulate the expression of *Wx* through reduction of splicing efficiency and *FLORY* genes, including *flo2* and *flo6*, were evaluated. Genomic information obtained is used to develop DNA markers useful for selection purposes and basic knowledge to maintain specificity of milling quality. Population enhancement was also carried out to map out the genes for grain chalkiness. High-protein rice lines with better grain shape, uniformity, and less chalk were advanced through marker-assisted breeding, physiochemical analyses, and conventional field selections.

Why Develop *O. sativa* x *O. rufipogon* Chromosome Segment Substitution Line Libraries?

Eizenga, G.C., Singh, N., Shakiba, E., Ali, M.L., Kim, H.J., Declerck, G., Wright, M.H., Ahn, S.N., and McCouch, S.R.

Transgressive variation has been observed in rice (*Oryza sativa*) as an increase in grain yield in advanced backcross mapping populations derived from crosses between several adapted *O. sativa* varieties and a single accession (IRGC105491) of the ancestral parent, *O. rufipogon*. The phenomenon of hybrid vigor, related to transgressive variation, is often observed when the *O. sativa* subspecies (ssp.) *indica* is crossed with the *japonica* subspecies, confirming the importance of transgressive variation for increasing yield and food security. The objective of this study was to develop chromosome segment substitution line (CSSL) libraries to further dissect the transgressive variation identified in the aforementioned *O. sativa* x *O. rufipogon* mapping populations.

To develop the CSSL libraries, two adapted rice varieties, IR64 (*indica* subpopulation) and Cybonnet (*tropical japonica* subpopulation), were selected as recurrent parents to represent the subspecies *indica* and *japonica*, respectively. Based on previous phylogenetic analyses, one *O. rufipogon* donor parent (IRGC106148) clustered with *O. sativa* ssp. *indica* accessions, one (NIAS W1944) with *O. sativa* ssp. *japonica* accessions and the third (IRGC105567) only clustered with *O. rufipogon* accessions. Marker-assisted backcrossing was used to select the individual pre-CSSLs which were advanced each generation based on the targeted segments. Initially, two Illumina 384 SNP arrays, one for each recurrent parent, were designed for genotyping and subsequent selections. The second-generation of 384 SNP arrays were redesigned to replace SNPs that performed poorly and to decrease the size of monomorphic regions. Most recently, an Infinium 5,000 SNP array was used for high-resolution genotyping and provided between 1,069 to 1,952 (≈4-5 SNP/MB) polymorphic genome-wide SNPs per library. The CSSL libraries, with IRGC106148 and IRGC105567 as donors, have been advanced to the BC_4F_3 or BC_5F_3 generation and the two libraries with the W1944 donor, to the BC_3F_3. Currently, the CSSLs selected for each of the six libraries are being genotyped using genotyping-by-sequencing (GBS) technology.

Once complete, each CSSL library will consist of 60-90 lines, with each line having the targeted wild donor segment and less than 5% donor DNA in the background, in most cases. Collectively, the complete set of CSSLs for a given library will represent the entire genome of the wild donor parent in the background of either IR64 or Cybonnet. Thus, the six CSSL libraries will provide complete coverage of the three divergent *O. rufipogon* genomes in either an *indica* or *japonica* background, and will be among the most densely genotyped rice CSSL libraries.

To illustrate the usefulness of CSSL libraries for identifying genes underlying agronomically important traits, four to six segregating F_2 lines derived from the heterozygous pre-CSSL containing the specific targeted wild segment, were phenotyped in the greenhouse for several traits, including days to 50% heading, plant height, culm color, presence of bent culms (elbows), plant type, number of tillers, lodging, panicle type, presence of awns, hull color, and pericarp color. The genotypes of the F_2 families were examined to determine if the phenotypic segregation corresponded to the genotypic segregation of the targeted wild segment. In those families where there was correspondence, the CSSLs homozygous for the targeted segment will be used to fine map the particular trait and identify the candidate gene(s) underlying the segregating trait.

In the future, we will use these CSSL libraries to understand the genetic basis of transgressive variation, especially as it relates to grain yield. The libraries also will be used to identify novel genes, alleles or QTL contributed by the wild donor, characterize genetic interactions between wild donor and divergent elite cultivated background, and broaden the gene pool of cultivated rice.

Identification of Sheath Blight-Resistant Rice Germplasm from the USDA Rice Core Collection

Jia, Y., Gibbons, A., and Sookaserm, T.

Sheath blight (ShB), a disease caused by the fungus *Rhizoctonia solani*, is the most damaging rice disease in the southern USA. The absence of genetic resistance to the sheath blight fungus forces growers to use fungicides which increase total production costs. The USDA rice core collection consists of 1700 unique rice varieties representing 70% of genetic diversity of the USDA world rice collection. All rice varieties represented in the USDA core collection were evaluated for sheath blight resistance utilizing 2- liter polyethylene terephthalate (PETE) softdrink bottles as environmental chambers. This greenhouse investigation identified 52 unique rice varieties resistant to sheath blight disease. The 52 resistant rice varieties were evaluated under two independent field trials conducted at the Dale Bumpers National Rice Research Center in Stuttgart, AR, in 2013 and 2015, respectively. All identified varieties were planted in three-row plots (N=3) with the plots being arranged in a randomized complete block design. Lemont and Jasmine 85 were utilized as the susceptible and resistant controls, respectively. Plants were inoculated during the vegetative growth stage when first rice internode measured 12.5 mm (½ inch). At 30 days post-inoculation, the ShB disease severity ratings of individual rice plants were visually scored using a 0 to 9 scale. Plants scored as 0 to 4 were considered to be resistant; those scored as > 4 to 9 were deemed susceptible. All disease ratings for each plot were verified three times prior to harvest. With the exception of three rice varieties, all previously identified ShB-resistant varieties were resistant to sheath blight in both trials under field conditions. These findings suggest that the softdrink bottle method is sufficient to identify sheath blight resistant germplasm and this was confirmed with 49 germplasm lines from the USDA rice core collection.

Development of Sheath Blight-Resistant Lines Using Genomic and Standard Breeding Methods

Sanabria, Y., Galam, D., Groth, D., and Oard, J.

Rice sheath blight disease is a major constraint to high grain yields and good milling quality with few resistant varieties available in most rice growing regions of the world. The objective of our research was to develop sheath blight-resistant rice with desirable height and maturity from multiple sources by leveraging SNP-based markers derived from whole genome sequencing coupled with standard breeding practices. Forty-five of 136 SNP markers, previously identified in QTLs on chromosomes 2, 6, 8, 9, and 12, each explained a relatively large proportion of variation (R^2 = 0.18 - 0.89) in extreme resistant and susceptible phenotypic groups of the RiceCAP SB2 mapping population. Eight of the selected markers on chromosomes 6, 8, 9, and 12 were used in marker-assisted backcrossing with seven donor and three recipient sources. Twenty-eight BC_2F_1 individuals containing four SNP haplotypes were subjected to *in vitro* callus culture to develop 45 doubled-haploid (DH) lines with improved height and maturity. Eight DH lines containing five haplotypes on chromosomes 2, 6, 8, 9 and 12 showed ~ 20% increased resistance with comparable height and maturity vs. elite susceptible parents in three field and greenhouse environments. Several new nsSNPs combinations for sheath blight-resistance were described for the first time in this study. In a subsequent investigation, 18 of 25 known resistant inbred lines contained six haplotypes of the selected SNP markers. Results from this study indicate that disease resistant rice with improved agronomic traits can be developed using whole genome sequencing combined with standard breeding approaches.

The Race Shift of *Magnaporthe oryzae* Occurred within 50 Years in the United States

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

Rice blast disease caused by *Magnaporthe oryzae* is one of the most destructive diseases of rice. Infection of the races of *M. oryzae* can be prevented by the corresponding major resistance (*R*) gene in rice. However, the races of *M. oryzae* in the commercial fields can rapidly change to overcome resistance maintained by the corresponding *R* genes in rice. To direct the deployment of *R* genes in the USA, an international race differential system consisting of eight rice varieties, Raminad Str. 3, Zenith, NP125, Usen, Dular, Shataotsao, and Caloro was used to determine the race identity of 563 field isolates collected from 1959 to 2014. Based on disease reactions to differential rice varieties, a total of 39 different races was identified. Among 39 races, 19 were present once with a frequency of 0.0018 (1/563), 5 were present twice with a frequency of 0.0036 (2/563), 2 were present three times with a frequency of 0.0053 (3/562), 4 were present five times with a frequency of 0.0089 (5/563), respectively. The remaining 9 races were present from 6 to 144 times with frequencies ranging from 0.0107 (6/563) to 0.2558 (144/563). Overall, the races IG-1, IH-1 and IB-45 in 1970s; IC-17, IB-1 and IB-49 in 1980s, IC-17, IB-1 and IG-1 in 1990s, IB-1, IC-17 and IA-1 in 2000s, and IB-17, IB-1 and IB-49 in 2010s were most commonly found. To follow up on these findings, rice genomic regions harboring novel *R* genes to the current most commonly found races, IB-17, IB-1, and IB-49 will be identified using association mapping with the mini and Pita cores.

Molecular Genetics of Association between Seed Dormancy and Plant Height in Rice

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

Despite years of detached genetic research on seed dormancy or plant height, it is unclear whether they share molecular or physiological pathways regulating the trait development. The previous research in rice (*Oryza sativa*) revealed that seed dormancy was associated with plant height and the association was accounted for by two clusters of quantitative trait loci (*qSD1-2/qPH1* & *qSD7-2/qPH7*). This research aimed to: 1) clone the clustered loci to know if associations arise from pleiotropy or linkages; and 2) to characterize the QTL underlying genes for molecular mechanisms regulating the development or release of seed dormancy. Map-based cloning of *qSD1-2/qPH1* identified a single gene encoding a gibberellin (GA) oxidase (*GA20ox2*), which is the same as the Green Revolution gene *semidwarf1*. *GA20ox2*'s expression in seeds during early development increased GA accumulation to promote tissue morphogenesis and maturation programs; whereas *GA20ox2*'s loss-of-function mutants reduced the GA content, which decelerated seed developmental programs, including endosperm genesis, dehydration, physiological maturity, and acquisition of germination capability. Map-based cloning of *qSD7-2/qPH7* also identified a single gene (*SD7-2*) encoding a predicted protein kinase. *SD7-2* was expressed highly in dormant, imbibed seeds and its overexpression enhanced seed dormancy and also reduced plant height. The SD7-2 protein displayed a kinase activity *in vitro* and interacted with the rice DELLA protein SLR1, a master regulator of GA signaling, suggesting that *SD7-2* controls dormancy and plant height through the hormone signaling pathway. Allelic variants isolated from the cloned genes can be used to manipulate the associated traits in rice breeding.

Progress in Breeding for Conventional and Clearfield Medium-Grain and Long-Grain Rice in Arkansas

Sha, X., Beaty, B.A., Bulloch, J.A., and Moldenhauer, K.A.K.

To reflect the recent changes of the Arkansas rice industry and streamline the delivery of new and improved rice varieties to better serve the rice industry, the revitalized medium-grain breeding project expanded its research areas to include both conventional and Clearfield medium-grain and semidwarf long-grain rice, as well as hybrid rice. Current research objectives include 1) Developing improved conventional and Clearfield medium-grain and semidwarf long-grain rice varieties with increased rough rice and head rice yields, disease resistance, and improved processing and cooking characteristics; 2) Developing adapted male sterile, maintainer, and restorer lines through the introgression of hybrid traits from various sources into elite semidwarf Arkansas long-grain genotypes; and 3) Maintaining high quality and pure headrow and breeder seed for foundation seed production. Elite breeding lines/varieties from collaborating programs, as well as lines with diverse genetic origins, have been constantly collected, evaluated, and incorporated into the current crossing blocks for programmed hybridization. To improve the efficiency and effectiveness, maximum mechanized operation, multiple winter nursery generations, and new technologies, such as molecular marker-assisted selection (MAS), have also been rigorously pursued.

In last three years, our breeding population has been drastically expanded to meet different breeding goals. Our 2015 field tests included 493 F_1, 597 space-planted F_2 populations, and 53,450 panicle rows. Over 900 breeding lines were evaluated in various yield trials at three Arkansas locations, and approximately 3,000 yield plots were planted and harvested. A total of 592 new crosses were made for both pureline and hybrid rice breeding. Three winter nurseries have been planted in Puerto Rico. The conventional medium-grain experimental line RU1301021 performed very well in Arkansas Rice Performance Trial (ARPT) and Uniform Regional Rice Nursery (URRN) in last 4 years. It matures 5 to 6 days earlier than Jupiter and has excellent yield potential, good milling, superior grain quality, and improved blast resistance and straw strength. Foundation seeds of this line should be available to Arkansas seed rice growers in 2016 once being approved by the Division of Agriculture, University of Arkansas. A number of promising long- and medium-grain breeding lines, either Clearfield or conventional, are currently going through expedited purification and increase for potential release in the future.

Breeding for Water-Saving and Drought-Resistant Rice (WDR)

Luo, L.

Rice is the staple food for most of Chinese people and has played a very important role in China’s food security in history. However, rice production is facing the big challenges such as large amounts of fresh water consumption and yield loss because of drought stress, as well as the methane emission. It is urgent to develop new varieties of rice, which cannot only save the fresh water resources, be resistant to drought stress, and reduce carbon emissions but also to achieve high yield potential with acceptable grain quality.

Upland and lowland rice (*Oryza sativa* L) are two of the most important rice ecotypes adapted to agro-ecosystems with contrasting soil-water conditions. Upland rice, domesticated in the water –limited environment, contains valuable drought-resistant characters but has been less applied in the rice breeding programs. Water-saving and drought-resistance rice (WDR) is a new type of rice varieties integrating both high yield potential and good grain quality from the current lowland rice and water-saving and drought-resistance from upland rice.

In the past years, several upland rice accessions were used as donor parents in WDR breeding programs. A drought-resistant CMS line and several WDR varieties were developed and released to the farmer, providing significant water saving and drought resistance abilities in farmer’s field. The whole-genome resequencing studies indicated that there are obvious genomic variations between WDR and its upland (or lowland) parents. A total of 110 drought-resistant candidate genes were cloned and studied on its functional genomes.

Genetic and Environmental Effects in the TeQing-into-Lemont (TIL) Population under Flooded and Alternating Wet-Dry Conditions

Edwards, J.D., Teaster, N., Scheffler, B., and McClung, A.M.

Over the last decade there has been growing concern regarding sustainability of U.S. rice production due to multi-year droughts and depletion of ground water resources. There is a need for research to develop rice varieties that are optimized for production using less irrigation water. One rice production system that has been found to use less irrigation water is intermittent flooding, also known as alternate wetting-drying (AWD). Although adjustments may need to be made regarding weed management, nutrient utilization, and disease control, without season-long flooding, AWD is a viable option that is being used in regions of the world where *indica* germplsm is grown. Currently, there has been limited research in the USA on the role of genetics in controlling yield response under AWD systems. The goal of this study is to use a set of *indica* into *tropical japonica* chromosome segment substitution lines (CSSLs) to 1) assess the impact of *indica* introgressions on yield components when grown under the AWD system, 2) evaluate the genetic by environment (GxE) effects between the two systems, and 3) identify candidate loci/genes that may be useful for maintaining or improving yield under AWD.

The rice (*Oryza sativa* L.) population used in this study consists of 123 CSSLs developed by backcrossing the *indica* donor parent "TeQing" with the *tropical japonica* recurrent parent "Lemont." The study was conducted over two growing seasons in Stuttgart, AR. The two irrigation treatments included the typical season-long flood and an AWD system in adjacent fields. Plots were arranged in randomized block design with four replications. Each plot consisted of a single row of ~10 plants seeded in hill plots on 30 cm centers. After stand establishment, the AWD field was allowed to dry to approximately 22% before it was reflooded. The flood remained for 3 days then the field was drained and allowed to dry to 22% soil moisture before repeating the cycle. Two representative plants from each plot were tagged at the early tillering stage and were monitored throughout the season prior to harvest. Phenotypic traits assessed included plant height, days to heading (DTH), number of tillers, number of panicles, number of mature panicles, main panicle length, number of unfilled (blank) panicles, number of seeds per main panicle, weight of seed on main panicle, weight of 100 seed, total yield per plant, and kernel characteristics. The latter included length, width, and % chalk as determined on brown rice using an image analysis system. Temperature and rainfall were tracked on site by two weather stations. In addition, leaf surface temperature of the parentals was measured using a thermal imager for multiple leaves from each plant taken along the middle portion of the leaf blade whose surfaces faced the camera.

The CSSLs were previously genotyped with 178 SSR markers. Many background introgressions were detected by single SSRs, suggesting that higher genotyping coverage could reveal additional background introgressions and better define the size of previously detected introgressions. Thus, for this study, the CSSLs were re-genotyped using genotyping-by-sequencing (GBS) to gain higher marker coverage; DNA was extracted and barcoded GBS libraries were prepared and sequenced on two lanes of an Illumina HiSeq2500.

The statistical model tested the effects due to genotype, year, replications, and irrigation treatment as well as interactions between genotype by treatment, and genotype by year. For the mapping parents, Teqing and Lemont, the genotype effect was significant for all traits (14/14). The year effect was significant for all traits except kernel length and width (12/14). The irrigation effect was significant for DTH, height, kernel length and width, 100 seed weight, primary panicle seed weight, and total yield. There were significant genotype by irrigation interactions for height, total tillers, total panicles, and total mature panicles. There were significant genotype by year interactions for all traits except grain width and number of unfilled panicles. In the CSSLs, significant quantitative trait loci (QTL) were detected for all traits in both flooded and AWD conditions. Significant QTL for a differential response between irrigation treatments were found for height, kernel chalk, 100 seed weight, primary panicle seed weight, tiller number, panicle number, total mature panicles, and number of unfilled panicles.

Irrigation treatment did influence yield components, however, the effect was generally far lower than the year-to-year differences. Loci that underlie genotypic differences for the most part were consistent between the AWD and flooded conditions. However, certain loci appear to have a differential effect across treatments and will be investigated further for their potential in breeding for production under AWD.

Genetic Interactions Controlling Heading Date and Response to Photoperiod in Cultivated Rice

Subudhi, P.K., De Leon, T., Chai, C., Karan, R., Parco, A., and Singh, P.

Heading date in rice is a key agronomic attribute for improving crop yield and adaptation to different seasons and geographical areas. The objective of this study was to investigate the genetics of heading date and response to photoperiod using two recombinant inbred line (RIL) populations involving two rice cultivars, Bengal and Cypress, and one photo-insensitive red rice accession, PSRR-1, and a chromosome segment substitution line (CSSL) population of PSRR-1 in Bengal background. Heading date was evaluated under natural long day field conditions. Four to seven quantitative trait loci (QTLs) accounted for 47 to 58% of phenotypic variation for this trait in above RIL populations. Several of these QTLs were validated in CSSL population. Two photosensitive CSSLs were identified in both cultivar backgrounds and *Hd1* allele of red rice in both lines increased sensitivity to photoperiod. Molecular marker analysis revealed that the day neutral nature of the red rice accession may be due to genetic interaction between *Hd1* and a locus on chromosome 7. Sequence variation and transcript abundance further supported this conclusion. Understanding the genetic basis of hidden diversity underlying heading date variation and photoperiod sensitivity will facilitate exploitation of wild and weedy rice in breeding program.

Inheritance of Resistance to the Herbicide Quizalofop-p-butyl in Rice

Camacho, J., Linscombe, S., and Oard, J.

Red rice is a noxious weed that can cross-breed with commercial rice varieties to create a major challenge for the southern U.S. rice industry. Clearfield rice varieties resistant to imidazolinone herbicides are grown in large acreages in the southern U.S. to eliminate red rice infestations, but out-crossing between Clearfield varieties and red rice threatens the long-term viability of this technology. The BASF company has recently developed "Provisia" rice based on resistance to the herbicide quizalofop-p-butyl. Alternate plantings of Clearfield and Provisia rice may help delay or eliminate development of red rice that is resistant to Newpath or Provisia herbicides. Our recent inheritance studies in the field, greenhouse, and laboratory indicate that resistance to quizalofop-p-butyl is controlled by a single dominant gene that segregates in a Mendelian fashion in various genetic populations with no maternal cytoplasmic effects. DNA-based markers were developed that corroborated segregation of resistance in multiple genetic populations. Resistance to quizalofop-p-butyl has been transferred into different breeding stocks for development of both inbred and hybrid varieties. It is anticipated that the Provisia technology will complement the Clearfield system to create a successful and prolonged stewardship program for red rice control in the southern U.S. and other rice growing regions.

Molecular Advances to Improve Seedling Establishment under Different Environmental Stress Conditions

Septiningsih, E.M. and Tabien, R.

Rice improvement in the direct seeded rice (DSR) regions can be accelerated by selecting suitable key traits. Tolerance to flooding during germination conditions or anaerobic germination (AG) is an important trait for DSR. This trait allows rice seeds to germinate and survive under flooding stress due to heavy rains right after sowing. Weed invasion, a major problem for DSR, can also be significantly controlled by rice varieties having AG tolerance. A major QTL for AG tolerance in rice, *qAG-9-2*, derived from Khao Hlan On, a landrace from Myanmar was successfully fine-mapped to a 50kb-DNA fragment. Through over expression and loss-of-function mutant studies, a trehalose-6-phosphate phosphatase gene, *OsTPP7*, was confirmed as the causal gene underlying the QTL. This gene is involved in trehalose-6-phosphate (T6P) metabolism, central to an energy sensor that determines anabolism or catabolism depending on local sugar availability. Under AG stress, *OsTPP7* escalates sugars and amino acid pools, promotes anaerobic metabolism and increases transcripts associated with elongation growth. It is expressed in germinating embryos, coleoptiles and young roots, all sink tissues that depend on reserve carbohydrates for proliferation. OsTPP7 activity may increase sink strength in proliferating heterotrophic tissues by indicating low sugar availability through increase T6P turnover, thus enhancing starch mobilization to drive growth kinetics of the germinating embryo and elongating coleoptile, which consequently enhances AG tolerance. Marker-assisted breeding to introgress this gene into some elite lines has been conducted. Early uniform crop establishment under cold temperature is another important trait for DSR, especially in the temperate regions. Different sets of germplasm will be explored to further investigate the genetics mechanism underlying this trait. Further, gene(s) underlying uniform crop establishment under cold temperature can be combined with tolerance of anaerobic germination and improved seedling vigor to provide more robust crop establishment under DSR ecosystems.

Anaerobic Germination of U.S. Released Rice Varieties and Elite Lines

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

Direct seeding (DS) is the only planting method in the U.S. and it is gaining popularity in major rice growing areas in the world since it can reduce production costs. Direct seeding can be practiced in various ways, such as dry seeding by broadcasting, dibbling or drilling dry seeds on dry or unsaturated soils or wet seeding in wet puddled soils using pre-germinated seeds. One of the major constraints in the wide adoption of DS has been the poor germination and seedling establishment due to uncontrolled water level in unleveled land, flooding due to rain after seeding and poor drainage. The anaerobic condition that limits oxygen supply in flooded soil reduces field emergence. Tolerance to anaerobic germination (AG) is a critical trait in direct seeding. Development of varieties for DS with tolerance to AG was formerly hindered by limited donors but the recent mass screenings identified several donors and the target genes localized. In U.S., limited screenings have been done and the response of released varieties and elite lines to AG is limited or unknown. This study aimed to evaluate AG tolerance of newly released U.S. varieties and promising elite lines from different state breeding programs. Entries at the 2015 Uniform Rice Regional Nursery (URRN) were evaluated in a three replication anaerobic germination (AG) test. The 200 entries were divided into five sets. The first four sets had 34 test lines while the last set had only 30. Each set had two checks, Rondo and a cold tolerant germplasm found poor and best, respectively, in initial AGT. Ten seeds of each entry were seeded in plastic trays with 36 cells. The hole of each cell was covered with filter paper to hold the seeds and these were covered with 2.54 cm fine sand after dropping the seeds in each cell. Each tray was submerged in 10 cm water for 21 days under ambient room temperature. An unreplicated test for germination was also conducted to test viability of the seed lots. Seedling counts were gathered at the end of the test. A second test was done to re-evaluate 33 selected best entries after the initial test. The same set up was followed. Emerged seedlings and germinated seeds were counted, and seedling height, root, coleoptile and mesoctyl length were measured after 21 days of submergence. Results indicated significant variation in percent emergence among 200 entries. In 23 released varieties included, all except two had some seedlings, with six having at least 50% emergence. In the remaining elite lines, 58 had at least 50% emergence. Since all of these varieties and lines were not specifically screened for AG tolerance during development, segregation for tolerance is probable. Although the number of entries varies by state, all programs had elite lines with at least 50% emergence. Louisiana had the highest number of lines with good AG tolerance and more than half of these had the CL gene. Re-evaluation of 33 best lines showed similar significant variation in seedling emergence. The seedling heights varied, as did the root, coleoptile and mescotyl length. All 33 entries had no to very short root, with elongated coleoptile ranging 2.17-4.87 cm. Majority of the seedling height was the length of the coleoptile itself. Mesocotyl ranged from 0-1.43 cm. These results confirm reports that limited oxygen supply limits root growth and enhances shoot development, with coleoptile being much longer to reach the water surface and get oxygen for diffusion to root and primary leaf.

Introducing the Newly Released GRIN-Global (webinar)

Reisinger, M., Bockelman, H.E., and Eizenga, G.C.

The Germplasm Resources Information Network (GRIN) is an information management system that curates data for the USDA-ARS genetic resource collections. GRIN was developed in the late 1980s and has been incrementally improved over the past 25 years. A major revision was recently deployed to service the U.S. National Plant Germplasm System (NPGS), which curates more than 575,000 active plant germplasm accessions important to both U.S. and global food and agriculture. The new genebank management system is called GRIN-Global. It is being developed with international partners as freely available software that can help harmonize information management and allow more rational maintenance and utilization of collections. Several institutions in countries outside the U.S. are already using GRIN-Global. The NPGS began using GRIN-Global on November 30, 2015. It consists of two interconnected applications- the Curator Tool (CT) and the Public Website (PW). The CT is a Microsoft Windows desktop application that allows NPGS staff to enter and modify data on accessions and manage daily workflows, especially order request processing. The PW is an internet browser based application that allows clients and customers to search the database for a wide array of information, and request germplasm.

The interfaces for both the CT and PW are significantly different from the prior applications used by the NPGS. Hence, user training and outreach are an important component of making the transition to GRIN-Global. New features and functions have been added, and more will be forthcoming. The evolution of GRIN-Global must occur within the context of significantly increased federal oversight and emphasis on security issues for .gov information management systems.

A member of the GRIN-Global Development Team will demonstrate the Public Website for the Rice Technical Working Group. Emphasis will be on strategies for searching the collections and how to request germplasm using the new interface. The PW search page is available at https://npgsweb.ars-grin.gov/gringlobal/search.aspx?

The Art of Crossing Rice

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

New varieties are developed using artificial rice hybridization. Because rice is a self-pollinated plant having a perfect flower, all plants can be used as either the male or female. In this process, selected female and male plants are crossed together to produce the desired F_1 seed. For best results, this occurs in a protected area, which in our case is the greenhouse. Parental lines are planted in the field at a certain time interval for the synchronized flowering. Female plants are potted and taken to the greenhouse for the emasculation process. During the emasculation, the male parts of the flower, which are called anthers, are removed or sterilized for a successful cross to take place. A hot water method was used that consists of placing the plant in water that is at a 45ºC temperature for 5 minutes. The plant was then removed from the water and the excess water was shaken off to allow the anthers to emerge from florets. Then the florets with the anthers exposed are snipped at an angle to facilitate the pollination. The florets that didn't open up are snipped off completely. A glycine bag is placed over the female panicle and the plants are taken to the greenhouse to await for pollination. The panicles of the male parent are picked from the field each morning and brought into the greenhouse to sit in a semi-controlled temperature and humidity environment to encourage blooming. At the time of flowering, the glycine bag is removed and the pollen from the male parent is dusted over the emasculated female panicles to make the cross. The glycine bag is put back over the newly pollinated panicle and left to produce hybrid seeds, which you should be able to see in approximately a week. A successful cross will be ready to harvest in about 30 days from the date of pollination.

Yield Increase Rate of Calrose Cultivars Developed by the Rice Experiment Station from 1976 to 2015

Samonte, S.O.P.B., Andaya, V.C., Jodari, F., Andaya, C.B., Sanchez, P.L., and McKenzie, K.S.

The Rice Experiment Station (RES) at Biggs, CA, has been breeding for high yielding and high quality rice cultivars since 1912. Successful cultivars produced by RES include the tall traditional Calrose and the semidwarf (*sd-1*) Calrose 76, which is a mutant selected from Calrose after irradiation. The semidwarf stature of RES-released cultivars can be traced back mostly to Calrose 76 (released in 1976) or IR-8 (released by IRRI in 1966). To evaluate the success of the breeding program or the presence of a yield plateau, the estimation of grain yield increase rates due to cultivar releases was essential. The objective of this study was to determine the yield increase rate due to the release of 31 semidwarf cultivars by the Rice Experiment Station from 1976 to the 2015.

Thirty-one semidwarf cultivars developed by RES from 1976 to 2015, including new releases medium grain M-209 and waxy short grain Calmochi-203, were evaluated in replicated yield tests conducted in 2014 and 2015. Yield increase rates were estimated from the 2014, 2015, and the combined 2014 and 2015 data.

There were significant differences among the grain yields of 31 semidwarf cultivars in the 2014, 2015, and the combined 2014 and 2015 yield tests. When averaged across 2014 and 2015 data, Calrose 76 yielded 7,690 kg/ha, while cultivars CM-203 and M-209 (released in 2015) averaged 10,160 and 10,520 kg/ha, respectively. Grain yields increased by at least 2,470 kg/ha. Grain yield increase rates were estimated at 36, 54, and 42 kg/ha/year from the 2014, 2015, and combined 2014-2015 yield tests, respectively. The positive yield increase rates indicated the success of the rice breeding program of RES in continuously improving grain yields of conventional semi-dwarf cultivars. This perennial study is useful in tracking the performance of RES-released cultivars and in accounting for genotype x environment interactions that are common in yield trials.

A Field Operation Protocol for a Highly Mechanized and Efficient Rice Breeding Program

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

Advancements in technology have allowed breeding programs to become more efficient. In previous years, it has taken large crews of people to prepare seed to plant, plant the plots, perform field maintenance, harvest, and process seed after harvest and collect data. This is not only expensive to the program due to labor costs but also it is time consuming and human error becomes a factor. Also, additional land to use for growing field tests is difficult to obtain and costly to maintain so every effort must be made to utilize the land that is available. To facilitate this efficiency and expand rice variety development, the medium-grain breeding program at the University of Arkansas has incorporated new technology and practices into its program including the following: 1) Precision leveling of plot ground to reduce levees; 2) Global Positioning System (GPS) autopilot for precision tractor driving; 3) Harvestmaster weight and moisture collection system for the combine; 4) Tractor mounted fertilizer spreader and pesticide sprayer. Over the years, our three fields have been precision leveled but due to repeated tillage and levees in the field, we have re-leveled two of them since 2013. This has allowed the number of levees in our field to be reduced by half allowing more of the land to be utilized. Precision leveling has also promoted easier and more uniform water management. The addition of the autopilot system on the tractor has greatly reduced the number of flags used to mark plots for planting, allowed for straighter, more uniform planting eliminating wide gaps and narrow gaps between plots for reduced border effect. It is also used when spraying to eliminate spray overlap and missed streaks. The tractor mounted sprayer and fertilize spreader have replaced backpacks and shoulder-carry bag spreaders. The tractor's speed can be set to be constant, unlike trying to walk a constant speed while carrying a backpack and hand boom or a bag spreader. Before the Harvestmaster system was installed on the combine, yield plots had to be bagged on the combine and then weighed and moisture taken in the lab at a later date to calculate yield. Now the weight and moisture of each plot is recorded when the plot is cut. The yield data is available immediately after the test is harvested. This has been probably the best improvement to the program to date. While no system is totally foolproof and without its problems, the addition of new technology has dramatically reduced the time, labor and error involved in rice breeding resulting in a greater capacity of lines to be evaluated and higher quality data.

Free and Open Source Tools for High Throughput Rice Phenotyping and Data Storage

Edwards, J.D.

Commercial automated phenotyping systems are cost prohibitive for many research programs. Free tools can be repurposed to provide automation when integrated into a conventional plant phenotyping program. These include barcoding for identification of individuals, semi-automated image processing to evaluate plant growth, and streamlined field data collection to populate phenotype databases. We have evaluated several open source tools in plant genetics research activities, and will discuss the implementation and results. Barcoding is useful for tracking materials, preventing misidentification, and rapid data collection. Items that may be labeled with barcodes include seed envelopes, pots in the greenhouse, field plots, petri plates for germination, tissue collection containers, DNA samples, PCR primers and PCR plates. Barcodes may be the conventional 1D type or 2D QR code type, and each has advantages and disadvantages. The 1D barcodes can be read with standard laser-based barcode scanners. The length of the 1D barcode increases linearly with the amount of information stored and may not fit on seed envelopes or tubes. 1D barcodes that become damaged cannot be read. 2D barcodes can store substantially more information for the amount of space they occupy. They have built in error correction so that even if part of the barcode is damaged, it may still be read. The level of error correction in a 2D QR code is adjustable, and use of the highest level or error correction is recommended for non-optimum conditions such as greenhouse or field use. 2D barcodes require a device with a digital camera to read such as a smart phone or tablet. We have successfully used barcoding to assist in rapid inventory, verifying the correspondence of seed pack and pot, or plant and collected sample, and image identification.

Image processing techniques can be used on large numbers of digital photographs taken of plant growth over time. Processing these images and extracting useful information is challenging, and automated methods are needed with minimal levels of user intervention. One application of image processing is to estimate the leaf area of a plant as a non-destructive proxy for above-ground biomass. The GNU Image Manipulation Program (GIMP) is useful for point and click operations such as selecting only the plant leaves in an image and removing any non-leaf background. Pipelines using the Linux command line tool ImageMagick have been developed to further process many images simultaneously to calculate pixel area of selected regions of the image. A 2D barcode contained in an image can be extracted using the ZBar barcode reader and corresponding package in the Python language. This is useful for automatically identifying and renaming images based on the contained barcode information. The barcode can also be used for calculating the area of a known object in the image (e.g. the 2D barcode itself printed to a standard size) for use in converting pixel counts to area-based measurements in known units.

Data collection and storage is another challenge that can be addressed with open source tools. We have implemented a database for rice breeding and genetic research (Ricebase). This is a relational database that inherits its architecture from the publically available code of the Sol Genomics Network (SGN) database. The database schema includes the community developed Chado natural diversity module. Breeders tools include pedigree tracking/parsing/drawing, storage of accession related phenotype data and molecular data including conventional molecular markers and large-scale next generation SNP data. A genomic selection module provides breeding value predictions directly from the database when phenotypic and molecular data are available. Experimental designs are integrated with the Android tablet app Fieldbook to directly import and export data collected on tablets in the field.

Together, collections of open source tools can help to reduce errors and increase efficiency in plant breeding and genetics research. Just as open source software benefits from the freely shared cooperative efforts of many individuals, research groups may benefit from sharing their methods, software pipelines, and experiences using these free tools.

A Rapid DNA Extraction Method Modified for Rice Tissues that Yields Quality DNA

Moldenhauer, H.H.M., Boyett, V.A., Thompson, V.I., and Jin, X.

In the genetic analysis of rice tissues, it is necessary to obtain DNA of sufficient quality to perform PCR-based applications. Some analysis methods, such as Kompetitive Allele Specific PCR (KASP), work better with DNA that is cleaner with fewer PCR inhibitors. Many commercial kits for DNA extraction exist that result in clean DNA, but the kits tend to be expensive and yield only small quantities of DNA. We have adapted and optimized a high throughput, clean DNA extraction protocol for use with rice tissues. This method combines an economical CTAB DNA extraction method with a Qiagen MagAttract DNA extraction procedure in order to improve isolation yields. This method provided clean DNA of sufficient yield to perform a large number of PCR amplifications for capillary electrophoresis analyses and DNA of superior quality to be used with more delicate analyses including KASP.

Association Mapping of Rice Cold Germination with the USDA Mini Core

Zhao, H., McClung, A.M., Wang, X., and Jia, Y.

Assuring stand establishment is a critical first step in optimizing rice crop yields. Plant stand density can impact yield potential, incidence of some diseases, weed competition, and grain quality. Most rice production in the Southern USA is drill seeded in the spring. Planting can occur as early as February along the Gulf Coast and in March in the upper Mid-South area. Early planting is being driven by the desire to avoid fall inclement weather patterns on the Gulf Coast and interest in planting subsequent winter wheat crops in the upper Mid-South. Planting current rice cultivars early in the spring can result in yield losses due to delayed germination and slow seedling growth. Thus, breeders desire to have access to germplasm and genetic markers that can facilitate the development of new varieties that have cold tolerance at the planting stage and can be used in early planted rice production systems. The objective of this study was to use an association mapping approach to identify candidate genes for cold tolerance at the germination stage. In previous research, over 2000 different global rice accessions were evaluated for their ability to germinate under cold temperatures. The panel included the mini-core (~200 accessions) and the core (~1500 accessions) collections, along with ~400 additional accessions from temperate regions and ~100 breeding/mapping lines. Cleaned seed lots of each accession were surface sterilized and then thirty seeds were evaluated for germination using the ragdoll method with three replicates at 12°C and two replicates at 26°C. Percent germination was determined after 1 week at 26°C and after 1 month at 12°C in temperature controlled chambers. Cold germination index was based upon the ratio of germination at 12°C: germination at 26°C. As the study was conducted over a period of 3 months, repeated checks of the accessions Quilla 66304 (cold tolerant), Lemont (moderate tolerance), and Zhe 733 (cold susceptible) were included as a means of error control. Significant differences were found among the accessions for cold germination tolerance and 590 accessions were equivalent to the cold tolerant check Quilla 66304. Interestingly, these accessions originated from very diverse tropical and temperate growing environments. An association analysis was performed using the mini-core diversity panel genotyped with 154 genome-wide SSRs averaging 10 cM between markers. Results including QTLs associated with cold tolerance at germination and candidate genes will be presented. Subsequent analysis using GBS of the mini-core and accessions in addition to the mini-core panel having superior cold tolerance will be used to validate the initial findings.

Development of Low Temperature Germinability Markers for Evaluation of Rice (*Oryza sativa* L.) Germplasm

Hyun, D., An Lee, G., Jung Kang, M., Burkart-Waco, D., Kim, S., Yoon Kim, J., Chul Lee, M., Gyun Gwag, J., Gyu Kim, Y., and Tai, T.H.

Low temperature germinability (LTG) is an important trait for breeding of varieties for use in direct-seeding rice production systems. Although rice (*Oryza sativa* L.) is generally sensitive to low temperatures, genetic variation for LTG exists and several quantitative trait loci (QTLs) have been reported. Most notably, the major effect QTL qLTG3-1, which has been cloned, has been implicated in tissue weakening and likely contributes to germination vigor in general. The objective of this study was to develop molecular markers for use in selecting rice germplasm with enhanced LTG. A panel of japonica rice accessions (n = 180) from temperate regions in Asia was evaluated for LTG and genotyped with markers from qLTG3-1 and regions harboring other LTG QTLs. In addition to the evaluation of markers from previously reported LTG QTLs, an association analysis was conducted using SNP data generated by reduced representation sequencing of the panel. Eight SNP markers were found to be associated with LTG using general and mixed linear models. Two of these markers were in close proximity (~35 kb) to each other on chromosome 4 in a region previously reported. The remaining six markers represent novel candidates for LTG loci.

Molecular Genetics of Cold Tolerance at Germination and Seedling Stage in a RIL Population Involving U.S. Weedy Rice

Borjas, A., De Leon, T., and Subudhi, P.K.

Cold stress usually reduces seedling vigor and crop establishment in temperate and high altitude areas resulting in reduced rice production. To identify QTLs and markers that will be useful in breeding rice varieties with cold tolerance, QTL mapping was conducted in recombinant inbred lines (RIL) developed from a cross between a high yielding rice cultivar Bengal and a weedy rice accession PSRR-1. The RIL population was evaluated for germinating ability and seedling vigor under low temperature (13ºC) and optimum temperature (28ºC). Result of QTL mapping confirmed that cold tolerance is a complex trait controlled by many QTLs with phenotypic variance ranging from 3.5-12.7%. The QTL were clustered in six chromosomal regions. The congruency of QTL cluster on chromosome 11 with earlier studies suggests a potential target for cloning cold tolerance genes at germination and seedling stages. Moreover, this study demonstrated that weedy rice can be a valuable donor for desirable alleles to improve germination and seedling stage cold tolerance in rice.

Cis-Elements Involved in Calcium-Mediated Cold Stress Signaling Diverged between the AA and CC Genomes of the Genus Oryza: Potential Implications to Genomic Complementation and Transgressive Segregation

Dryer, A.J., Kitazumi, A., Kakei, Y., Kurata, N., and De los Reyes, B.G.

In addition to the cultivated rice (*O. sativa*, AA-genome), the genus *Oryza* also includes many wild species, such as the CC-genome O. *officinalis.* Although both the AA-genome and CC-genome species are known to exhibit very limited tolerance to low temperatures, our recent studies have generated evidence of transgressive cold tolerance phenotypes among the progenies of *O. sativa* and *O. officinalis*. Calcium-mediated signaling is among the most evolutionarily conserved mechanisms involved in cold stress response in flowering plants. Several key cis-elements used in the calcium-mediated transcriptional network, including the *ABRERATCAL*-like elements, have already been identified to play critical roles in such mechanism. We explored the possibility that transgressive cold tolerance phenotypes among the AA x CC progenies could be due to genomic complementation effects that lead to subtle changes but reconfigured regulatory networks. As an initial step to address this hypothesis within the context of calcium-mediated signaling and transcriptional network, we performed a genome-wide comparison of *ABRERATCAL*-like elements across the orthologous and non-orthologous subsets of cold-regulated genes in AA-genome and CC-genome. We also examined the entire complement of regulatory proteins involved in *ABRERATCAL*-mediated gene regulon. Our results showed that both the orthologous and non-orthologous subsets of cold regulated genes from AA-genome and CC-genome exhibit distinct *ABRERATCAL*-like element signatures, with many novel classes appearing to be unique to the CC-genome. Our results also showed that AA-genome and CC-genome have distinct but complementary subsets of cold-regulated Calcineurin-B and Calcineurin B/SOS3-like proteins involved in calcium signal-mediated gene expression. These findings support a hypothesis that regulon restructuring as a result of genomic complementation may be a possible mechanism contributing to reconfigured genetic networks in interspecific recombinants that exhibit transgressive cold tolerance phenotypes.

AA-Genome and CC-Genome Complementation in Oryza: Comparative Regulon Reconstruction by Network Analysis and Cis-Element Mining between *O. sativa* and *O. officinalis*

Kitazumi, A., Ohyanagi, H., Fujita, M., Kakei, Y., Toyoda, A., Fujiyama, A., Kurata, N., and De los Reyes, B.G.

Transgressive segregation occurs when progenies of two genetically diverse parents exhibit phenotypic attributes that are beyond the parental range. Our ultimate goal is to understand the molecular basis of this phenomenon, guided by the hypothesis that genome reshuffling during meiosis creates genetic complementation effects and regulatory network rewiring hence novel phenotypes. Our experimental system is comprised of a backcross introgression line population derived from a cross between the cultivated rice *Oryza sativa* (AA-genome, with ~30% survival rate under low temperature stress) and the wild species *Oryza officinalis* (CC-genome, with 40% survival rate under low temperature stress), which generated transgressive progenies with 80% survival rate under low temperature stress.

Our initial comparison of *O. sativa* and *O. officinalis* transcriptomes revealed that the AA and CC genomes use distinct subsets of regulatory transcription factors for their respective low temperature stress response networks. This fundamental difference suggests that the complexities of cis-element modules have diverged between the homologous AA and CC genomes as a consequence of sequence evolution. It also provides important insights into the potential role of regulon restructuring and elaboration created by genomic complementation to transgressive stress tolerance phenotypes in recombinants derived from AA and CC. Analysis of co-expression network configurations revealed several nodes and branches that are either conserved or diverged between AA and CC genomes. Most notably, the compositional complexities of the *DREB1A* network appeared to be highly (or most) conserved, while those of *TGA10* and *Myb4* networks were very distinct between the two genomes. The implications of those network similarities and differences between AA-genome and CC-genome within the context of genomic complementation, regulon restructuring, and transgressive cold tolerance phenotypes are discussed.

Assessing Foliar Ascorbate Content in the Rice Diversity Panel 1

Castillo-Gonzalez, S.E., Tibbs, M., Wilkie, A., Yeater, K., Edwards, J., McClung, A.M.,
Eizenga, G., McCouch, S., and Lorence, A.

Early spring plantings of rice can have poor stands due to cold temperatures. Our previous studies have shown that high vitamin C (ascorbate AsA) *Arabidopsis* lines are tolerant to cold stress. The rice diversity panel 1 (RDP1) represents the genetic diversity of *Oryza sativa* and has been extensively phenotyped and genotyped. We hypothesized that there are genetic differences in the RDP1 for foliar AsA content, and that high AsA content is associated with cold tolerance in rice at the germination stage. We determined significant differences ($p< 0.05$) in seedling foliar AsA content in the RDP1 which ranged two fold. To assess the correlation between AsA content with cold tolerance, we exposed 12 accessions that were high or low in foliar AsA, as compared to the Nipponbare check, to cold stress at the germination stage. Two out of three (66.7%) high AsA accessions were cold tolerant, whereas only three out of nine (33%) low AsA accessions were cold tolerant, as established by coleoptile length reduction (coleoptile at 12°C/coleoptile length at 30°C). While high AsA content is not the only factor in conferring cold tolerance, our results indicate that ascorbate supports this tolerance. We also associated the results of foliar AsA content by subpopulation using genome wide association studies (GWAS). Results from this analysis indicate that hits on chromosome 5 and 2 are promising genomic regions that can be further studied to identify candidate genes likely involved in the synthesis, degradation, or regulation of ascorbate content in rice at the seedling stage.

Herbicide-Tolerant Rice Lines Showed Promise in Drought Condition

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

Water as a farm resource is getting scarce worldwide, with declining quality and quantity. With the occurrence of drought prevalence due to climate change, it is becoming one of the biggest challenges we face in the future. Drought can cause cellular dehydration that affects crop productivity and performance. It is the single largest yield reducing factor particularly in rainfed production areas. Among cereals, rice is the most sensitive to drought, being one of the very few food crops that can be grown in flooded fields. Although lack of water affects rice at all stages, the reproductive stage has been the most sensitive to drought. The majority of semidwarf rice varieties suffer severe yield losses from drought at reproductive stage. Traits for abiotic stresses, such as drought, have become very important traits of interest.

A study was conducted during the 2014 and 2015 year addressing the effect of drought on previously identified herbicide-tolerant lines. Some of these lines were entries included in past yield trials using a 2x rate of glufosinate (Liberty) herbicide and grown in aerobic/rainfed conditions. Thirteen lines were planted in three replicated field plots to determine response of these selected lines to drought at reproductive stage. The plots were kept flooded until flowering stage. The same set of materials was grown in another block but water was not drained at flowering serving as a check. Results on yield reduction, milling traits and plant height were all collected for a 2-year period. Grain yield as expected was highly affected by drought at reproductive stage. All entries had yield reduction but the percent reduction varied with genotype. Plant height and milling traits were also affected by drought, but similar to grain yield, varied with genotype. These results indicate that drought at the reproductive stage can reduce grain quality.

Genetics Studies of Root Traits under Drought Stress in Rice

Bhattarai, U., Ontoy, J., Linscombe, S., and Subudhi, P.K.

Drought is the most important abiotic stress that limits rice production in many parts of the world. Both greenhouse and field experiments were conducted to study the root and shoot traits in rice under drought stress in a recombinant inbred lines (RIL) population derived from a cross between a drought-susceptible rice cultivar Cocodrie and a drought-tolerant rice cultivar N22. The plants were grown in 75-cm long plastic pots in greenhouse condition. Five-week old seedlings were exposed to drought stress by withholding water for one week. Root length significantly increased during water stress compared to control condition whereas shoot length, root mass, shoot mass, root volume, and number of tillers decreased under drought stress.

In another experiment, the same RIL population, along with parents, was evaluated in field condition to investigate the effect of drought stress at the reproductive stage. Irrigation was withheld 70 days after seeding to create artificial drought for three weeks. There was significant delay in flowering and reduction in plant height due to drought stress compared to the well-irrigated condition. Relative leaf water content decreased under water stress. However, there was increase in chlorophyll content (measured by SPAD meter). Correlation studies showed that plants with late flowering and short height were more tolerant to drought. Plants with high relative leaf water content showed better drought recovery and decreased leaf rolling and leaf drying. These phenotypic data will be integrated with the genotyping data of the RIL mapping population to map quantitative trait loci for drought tolerance traits in the future.

Identification and Characterization of Reduced Epicuticular Wax Mutants in Rice (*Oryza sativa* L.)

Tai, T.H.

Epicuticular wax forms the outermost protective barrier of the aerial surfaces of land plants and works in concert with other components of the plant cuticle to prevent uncontrolled loss of water and provide protection against an array of external environmental stresses. In this study, chemically-mutagenized populations of rice (*Oryza sativa* L.) derived from approximately 4,750 M2 families were screened for adhesion of water droplets resulting in a wet leaf/glossy (wlg) phenotype. Mutants were identified in 11 independently-derived M2 families. SEM analysis confirmed the association of the wlg phenotype with changes in the epicuticular wax crystals of these plants. The phenotypes of five of these mutants were confirmed to be the result of single recessive gene mutations. Evaluation of mutants from three of the 11 M2 families revealed significant reductions (> 50%) in surface wax content and increased cuticle membrane permeability.

Cold-, Drought-, and Herbicide-Tolerant Rice Lines Showed Variation in Anaerobic Germination

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

Direct seeding is getting popular in rice growing countries of Asia as an option to reduce the labor and cost in transplanting. In the U.S., however, it is the only method of planting rice. Direct seeding is very prone to poor stand establishment when flooding occurs after planting due to poor germination or emergence of weak seedlings. Most of the varieties are not developed for this stress although some programs have been recently initiated. Heavy rain after seeding can cause flooding that leads to an anaerobic condition or 'hypoxia.' The flood water limits oxygen supply to germinating seeds, and this condition is generally unfavorable among major cereal crops, including rice. Low oxygen during germination in flooded fields limits elongation of the coleoptile. Large-scale screening for tolerance to anaerobic germination (AG) has been done at the International Rice Research Institute and quantitative trait loci (QTLs) have been located from some tolerant genotypes. Reports have indicated that some genes for a particular abiotic stress were also effective for another stress. For instance, *SUB-1* gene for submergence was found also good for drought at seedling stage and the cloned gene for multiple stress, *OsMsr3*, was responsive to heat, drought, and cold stresses. A screening for AG tolerance was done to evaluate stress-tolerant germplasm/lines isolated from previous screenings for cold, herbicide and drought and some U.S. cultivars.

Eighty genotypes were seeded in trays with 200 cells in four replications. Five firm seeds for each entry were seeded per cell initially with 1 cm depth of sand. The seeds then were covered with of 1 cm sand. The trays were submerged in water with 10-cm depth from the sand surface and were kept at ambient room temperature for 3 weeks. Seedling emergence was gathered 14 and 21 days after seeding (DAS). Shoot, root, and coleoptile length were taken at the 21 DAS. Highly significant variations in seedling emergence, root, shoot, and coleoptile length were found among 80 entries. Several entries had 0% emergence but some had 90 to 95% at 14 and 21 DAS, respectively. Some entries were so tall with long roots (tallest shoot at 17.6 cm and longest root at 7.4 cm) and were able to emerge above the water surface after 21 days. The length of the coleoptile ranged from 0.1 to 3.8 cm. Antonio, Presidio, Wells, CL172, and Cheniere were the best among the tested cultivars while Rondo, IR29, IR28, IR64, and IR64 with Sub-1 gene had very poor seedling emergence. The majority of the best entries were the herbicide- and/or drought-tolerant lines, but the best entry was a cold-tolerant selection. It had the tallest shoot and longest root and coleoptile.

Genetic Analysis of Seedling Vigor in Temperate Japonica Rice (*Oryza sativa* L.)

Cordero-Lara, K.I., Andaya, V.C., and Tai, T.H.

Seedling vigor is an important trait for direct seeded rice (DSR) cultivation. In California, germinated rice seeds are seeded aerially onto flooded fields. Released varieties have very similar vigor under these conditions. M-203 and M-206 are medium grain temperate japonica varieties adapted for the California production environment. Evaluation of these two varieties under direct seeding into soil revealed that M-203 exhibits better vigor than M-206 under controlled conditions (12-hr photoperiod, constant 28°C) as well as in the greenhouse and outdoor basins. A recombinant inbred line (RIL) population (F_7; n = 178) developed from the cross M-203/M-206 was evaluated for seedling height 7 and 14 days after sowing (PH7 and PH14), growth rate (GR) and fresh weight of the aboveground biomass (FW).

Additionally the RIL population was evaluated under cold stress (13°C) and alternate temperature conditions (28°C/13°C) in a controlled environment. M-203 presented significantly better vigor than M-206 during the early stage of seedling growth (PH7) across all environments. Transgressive segregation was observed for all traits. Six RILs were identified as consistently exhibiting greater vigor than M-203 considering all traits measured in all growing environments. Preliminary genotyping was performed using 24 single nucleotide polymorphism (SNP) markers. The RIL population is currently being genotyped using a reduced representation sequencing approach and the resulting marker data will be used with the trait data to identify QTLs contributing to the difference in seedling vigor exhibited by M-203 and M-206.

Breeding Rice for Grain Quality Traits in Mississippi

Redoña, E., Smith, W., Dickey, Z., Fitts, P., Hollister, G., and Lanford, S.

Grain quality issues raised against U.S. rice in recent years make it imperative for U.S. rice breeding programs to reemphasize grain quality traits that could help restore lost markets and increase competitiveness in capturing new trade opportunities. Moreover, there is a need to cater to the demands for specific grain quality types used by the U.S. food processing industry. One focus of the rice breeding program of Mississippi State University (MSU), therefore, has been the development of 'dual-purpose grain quality type' varieties that can be used both for table rice and as raw material in the rice processing industry. Most southern U.S. rice varieties are long-grain types with intermediate levels of both amylose content and gelatinization temperature. Dual purpose long-grain types, on the other hand, could have both high amylose content and intermediate gelatinization that satisfy both the cooked rice preferences of Central American markets, where most southern U.S. rice is exported, and the improved canning stability and reduced washout losses preferred by the U.S. rice processing industry. Therefore, the MSU rice breeding program has used dual-purpose varieties with the 'Newrex/Rexmont/Dixiebelle' cook type extensively as parents in hybridization. Rexmont and Sabine, for example, two varieties that have been used extensively in the U.S. processing industry, have been utilized as parents 51 times in single and multiparent crosses made since 2011. A dedicated high amylose variety development pipeline emphasizing high amylose content, low chalkiness, and excellent milling traits, on the other hand, is used to identify breeding lines that outperform conventional long-grain and dual-purpose variety standards for both producer- and end-user-desired traits. In 2014/15, a high-amylose breeding line RU1104122 was identified for release as the first Clearfield® high-amylose variety, now marketed by Horizon Ag as CL163. Also, a new conventional-type breeding line RU1104077, with high amylose content, low chalkiness, and milling traits acceptable to all major U.S. rice millers, has been placed in the variety release pipeline. These new MSU rice breeding products provide additional options for the local rice processing industry and also have good potential for capturing value in the contract/identity preservation markets for boosting the overall export quality of US rice.

Uniformity of Milled Grains from Main and Ratoon Crops of Texas Elite Rice Breeding Lines

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

Typically, rice yields have been the predominant factor focused on in rice production. However, in recent years, there has been a shift, with grain quality becoming a key aspect of the crops' sale ability. Producers are paid less for poorer quality rice than for those which show exceptional quality in high % whole kernels and consistent size (length, width). The market also demands rice that is transparent and not chalky based on consumer preference. Varieties which show little difference in the quality from the main crop to ratoon crop are a great advantage to farmers. If no significant difference exists between the two harvests, both can be combined and sold as the same. Variation in the kernels is very rice variety specific and affected by management methods, weather conditions during the crop year and how the harvested rice is stored. Breeders have focused much attention on maintaining high yields but also in producing germplasm with high quality meeting the needs of the market. This study looked at 2 years of data focusing on specific grain quality traits of milled rice collected from main crop and ratoon. The study was conducted in 2014 and 2015 in Eagle Lake, TX. Thirty-five lines were evaluated for main crop and ratoon milling traits with three replications each. Milling percent total and percent whole grains were collected, as well as average grain lengths/widths per kernel. In addition, transparency of the grain was analyzed to determine the degree of chalkiness. Both main crop and ratoon were compared per line to determine if any differences existed between the two harvests, as well as differences between the two years. All analyses were conducted using the PAZ milling machine for milling estimates and Winseedle image analyzer for the grain dimensions and transparency grading.

Identification of Useful Grain Quality Characteristics in Rice Mutants using TILLING and Forward Genetics

Tai, T.H., Chun, A., and Yoon, M.

Rice (*Oryza sativa* L.) is unique among major cereal crops as the vast majority is used directly for human consumption, usually in the form of whole milled kernels. Climate change and consumer demand pose significant challenges to rice breeders with regard to maintaining and improving various grain traits that influence appearance, eating qualities, and utilization. Our objective is to employ Targeting of Induced Local Lesions in Genomes (TILLING) and forward genetic approaches to identify chemically-induced rice mutants with grains exhibiting novel cooking, eating, and processing qualities. Towards this end, we have recently identified over 60 putative mutations in 8 starch biosynthesis-related genes from a TILLING by sequencing screen of 2,048 Nipponbare M2 individuals. We have also visually evaluated brown rice grains from the M3 generation of approximately 2,000 Kitaake and 1,200 Nipponbare M2 lines. This has resulted in the identification of >15 putative mutants exhibiting opaque grains. Validation of the putative TILLING mutants and phenotypic characterization of the lines exhibiting altered grain appearance is underway.

Morpho-Genetic Analysis of Aromatic Rice Varieties from Iraq

Alawadi, H., Ibrahim, A., and Tabien, R.

Rice (*Oryza sativa* L.) is a basic food for more than half of the population in the world. One of the most important rice traits of quality characteristics is aroma. The main purpose of this study is to develop a high-yielding aromatic rice. For this, the Iraqi Amber (aromatic) varieties were crossed with a non-aromatic rice variety, 'Antonio' to generate a population for evaluating the aroma. Aroma characters will be studied in the F_6 generation, and the F_3 generation is currently grown in the greenhouse in Beaumont, TX. In the second study, agronomic and morphological traits in a set of Iraqi Amber varieties and two aromatic checks were evaluated. Preliminary data analysis shows that 'Amber43,' 'Amber.' and 'Amber33' had higher plant height. 'Amber Coarse' shows the highest number of tillers m^{-2}. Amber43 had the highest flag-leaf area index, and Amber 33 and Amber had the highest panicle length. The genetic diversity of these eight traditional aromatic rice varieties based on the phenotypic and molecular data is currently underway.

Lysine Succinylome Identification in Developing Rice (*Oryza sativa*) Seeds Revealed Involvement of Succinylation in Storage Nutrient Production

Meng, X. and Peng, Z.

Protein Lysine succinylation is a newly identified protein post-translational modification which is postulated to have a crucial role on the substrate protein functions and cellular signaling networks. However, only limited succinylation sites have been reported in plants, especially in cereals, and the function of protein succinylation is still largely unknown. In this report, we found that developing seed is the organ with intensive protein lysine succinylation in rice plants. Using affinity enrichment followed by mass spectrometry analysis, we identified 854 lysine succinylation sites in 347 proteins of developing rice seeds, which is the largest succinylome being identified from a single plant organ thus far to the best of our knowledge. Six distinguished succinylation motifs were found in the succinylation sites after motif analysis. Two of the motifs are common in both eukaryotes and prokaryotes while at least one is first reported in this study. Biological process analysis showed that 216 of the 347 proteins are related to metabolism, 132 proteins are related to response to stimulus. And 185 proteins and 177 proteins were identified having binding and catalytic activities, respectively. Further pathway-based enrichment analysis suggests that lysine succinylation is involved in diverse central metabolism pathways. Interestingly, the proteins related to seed storage, starch biosynthesis, lipid metabolism, and plant defense response were heavily succinylated as well. This systematic analysis provides a promising starting point for further investigating the roles of lysine succinylation roles in seed storage nutrient production and plant defense response.

Transcriptome Analysis of Two Red Rice Lines to Identify Candidate Genes Related to Seed Storage Quality

Mispan, M.S., Wettasinghe, R.C., Kottapalli, P., and Auld, D.L.

Red/weedy rice is a notorious weed in rice agro-ecosystem. This species is phenotypically intermediate between cultivated and wild rice. Phenotypic differentiation between red/weedy and cultivated rice has been widely studied and shown to have high potential genetic diversity to be utilized in rice breeding programs. Profiling the red/weedy rice seed transcriptome is crucial to investigate intermediate phenotypes and plays an important role in understanding weed growth and development. Also, it provides a tool to study the interaction and adaptation to various environmental factors, e.g. nutrients, pathogen, stress, and environmental changes.

A NGS based RNA-seq approach was employed to understand the seed transcriptome of two red/weedy rice lines and two popular cultivars. Two genetically diverse red rice lines, PI 653413, black hull color with awn, (BHA) ; PI 653436, straw hull color and awnless, (SH) and two *O. sativa* cultivars, Nipponbare, GSOR100 (*japonica* group) and IR64, GSOR30140 (*indica* group) were used in this study. Ten seeds were ground in liquid nitrogen to a fine powder and three biological replicates of each genotype (12 samples) were used in RNA isolation. Total RNA was extracted using Spectrum Plant Total RNA kit (Sigma -Aldrich St. Louis MO, USA) according to the manufacturer's instructions with minor modifications. After isolation, the yield and purity of RNA were analyzed with a ND-1000 Spectrophotometer (Nano Drop Technology, Wilmington, DE, USA). Only RNA samples with 1.8 - 2.2 ratio of absorbance 260/280 nm were used in further analysis.

The cDNA libraries were prepared following the TruSeq RNA Sample Preparation v2 low sample (LS) protocol guide (Illumina Inc., San Diego, CA USA). The libraries were quantified using a Qubit® 2.0 Fluorimeter (Life Technologies, Grand Island, NY, USA), and the quality was analyzed with the TapeStation 2200 (Agilent, Palo Alto, CA, USA) using D 1000 tape to validate the purity and to estimate the insert size. Validated and indexed cDNA libraries were denatured and normalized in NaOH and sequenced on Hi-Seq 2500 (Illumina Inc., San Diego, CA, USA) using HiSeq ®Rapid SBS V2 kit(200 cycles) and HiSeq ®Rapid SBS V2 cluster kit. A total of 551,046,377 reads were obtained from the 12 indexed libraries. These reads were mapped on the rice genome using QSeq module of Lasergene genomic suite 11.2 (DNA STAR, Inc., Madison, WI, USA). The differentially expressed genes among the seed transcriptomes of four genotypes were identified with greater than 2 $\log_2$ fold changes at 95 % confidence level (FDR $\leq$ 0.05).

Field Production of Rice Male Sterile Lines for DNA Marker-Assisted Selection of Grain Quality

North, D.G., Moldenhauer, K.A.K., Boyett, V.A., Thompson, V.I., Jin, X.,
Blocker, M.M., Northcutt, C.H., and Berger, G.

Hybrid rice has been a hot topic of discussion for the agricultural community for years. The advantages are numerous, but the most noticeable is the yield increase of 15 to 20%. However, the discussion is not always about higher yields. Higher yield is important for farmers but so is the grain quality once the seed is taken to the mill. Hybrid rice sometimes lacks the grain quality alleles to allow for this desired trait. Thanks to marker-assisted selection (MAS), one may assess the genes associated with this trait and other important traits. Marker-assisted selection can reveal how pure a line is. Before MAS is performed in the molecular genetics lab, rice tissues for genotyping must be produced. In this study, the lines were selected, planted in the field, maintained for growth, and mature leaf samples were collected for MAS. The lines were planted as space plants, which are mapped out in the field to give space in-between each plant of every line selected. This way each plant can be flagged and numbered without being too close to another plant. The rice was maintained in the same manner as how a farmer would maintain it. Soon after the rice was fertilized and flooded, each plant was flagged, numbered, and two or more leaves were taken from each. The leaves were collected in labeled manila coin envelopes and kept on ice for delivery to the molecular genetics lab's -80°C freezer for later processing for MAS.

Process of DNA Marker-Assisted Selection for Rice Grain Quality

Thompson, V.I., Boyett, V.A., Moldenhauer, K.A. K., North, D., Jin, X., and Berger, G.

Marker-assisted selection (MAS) is a great asset to the Hybrid Rice Breeding Program at the University of Arkansas Rice Research & Extension Center (UA RREC). A large number of rice male sterile lines was developed for the Hybrid Rice Breeding Program, and MAS was used in a backcross scheme to characterize the lines on a molecular level with simple sequence repeat (SSR) and single nucleotide polymorphism (SNP) markers. Genotyping was conducted to predict phenotype for several important traits and to fingerprint the lines.

Mature leaf tissue from the second backcross generation was harvested from field plots and submitted to the Molecular Genetics lab for DNA MAS on grain cooking quality to select those male sterile lines with long grain quality. Both SSR and Kompetitive Allele Specific PCR (KASP) markers were used to select 59 lines from the original population of 589. The 59 lines were then narrowed down to 46 lines. The final 46 lines were screened with additional markers. Twenty-three markers were used to characterize the lines. Twelve markers were trait-linked. The 46 lines were determined by MAS to be ready to use as parents in hybrid breeding schemes.

Exploring the Potential Use of SNPs for Tropical Japonica Rice Breeding in Mississippi

Redoña, E., Smith, W., Fitts, P., and Dickey, Z.

The advent of genomics has resulted in the development of single nucleotide polymorphism (SNP) markers that are now increasingly used in the molecular breeding of crops, including rice. SNPs are efficient, stable, and suitable for breeding and genetics applications requiring high throughput and high resolution. For example, SNPs have been found useful for association mapping, linkage mapping, genetic diversity analysis, and marker-assisted selection. We conducted a preliminary survey on the level of SNP polymorphism among 101 varieties/breeding lines that comprise a portion of the active breeding germplasm used in the Mississippi rice breeding program. Almost all of these belong to the tropical japonica subspecies and knowing their molecular genetic diversity would help in the efficient planning and execution of potential breeding strategies. Leaf samples collected from each cultivar at 4 to 5 weeks after planting were submitted for DNA extraction and SNP analysis using the magnetic bead-based chemistry and KASP genotyping chemistry, respectively, provided by a genotyping service company. Potentially useful SNPs for tropical japonicas were initially distilled from a published SNP database that included 97 tropical japonicas. In this, 5,912 SNPs that were polymorphic among tropical japonicas were reduced by LD pruning to 1,054 SNPs with an average interval of 329,000 base pairs across the 12 rice chromosomes. From the 1004 successful KASP genotyping assays, 736 SNPs were selected having >80% call rate and >0.05 minor allele frequency. SNP markers with high polymorphic information content (PIC) values were identified that may be useful for molecular breeding applications. Genetic distances among the 101 cultivars based on SNP data were also determined. The SNP genotype X cultivar matrix generated will be useful for developing crossing plans and marker-assisted strategies to improve Mississippi rice varieties.

Identification of Putative Functional Nucleotide Polymorphisms in California Ancestral Cultivars using Exome Capture and Next-Generation Sequencing

Tai, T.H., Henry, I.M., Nagalakshmi, U., Broy, R., Lieberman, M., Ngo, K., and Comai, L.

Targeted sequencing is an approach in which specific genomic regions of interest are sequenced in order to reduce costs and increase the depth of sequencing coverage compared to whole-genome sequencing. In exome sequencing, the targets are protein-coding regions of the genome (i.e., the exome) which are selectively captured and sequenced. This enables more cost-effective detection of sequence variation that may correspond to functional differences in genes. In this study, three ancestral varieties (Caloro, Lady Wright, and Colusa) of Calrose-type rices were subjected to exome sequencing to identify single nucleotide polymorphisms (SNPs). For comparison, some modern California (L-202, M-204, M-205, and M-206) and southern U.S. long grains (Cypress, Dixiebelle, and Sabine) were also sequenced. SNPs that may impact gene function and can be converted to low-cost DNA markers have been identified.

Digenic Epistatic QTL-Mapping of Traits Related to Salinity Tolerance

De Leon, T., Linscombe, S., and Subudhi, P.K.

Salinity tolerance has long been regarded as a complex trait controlled by many genes. Several QTL mapping studies have been done but possible interaction of genes controlling salinity tolerance has been rarely investigated. In this study, we utilize the genotyping-by-sequencing (GBS) technique to genotype a recombinant inbred line population from Bengal x Pokkali cross to map epistatic QTLs for seedling salinity tolerance. While most additive QTLs associated to salinity tolerance have small effects, our result showed that digenic epistatic QTLs contributed significant phenotypic variation to salt tolerance. This study therefore emphasized the importance of epistatic QTLs in understanding the genetic complexity of salinity tolerance.

Post-Transcriptional Regulation of Nuclear Factor-Y-alpha Transcription Factor by miR169 in Transgressive Progenies of the Salt-Tolerant Rice Cultivar Pokkali

Gendron, J.M., Kitazumi, A., Gregorio, G.B., and De los Reyes, B.G.

The mechanistic basis of transgressive stress tolerance phenotypes has remained quite elusive even in the era of high resolution QTL mapping and genome-enabled biological interrogation in rice breeding. A previous study identified positive transgressive segregants for salinity tolerance amongst a population of F_8 recombinant inbred lines (RILs) derived from IR29 x Pokkali. The novel salt tolerance phenotype exhibited by certain transgressive RILs was independent of the effects of the major QTL Saltol derived from the salt-tolerant donor parent Pokkali, which functions in regulating shoot Na+/K+ homeostasis. In this study, we explored the possibility that salinity-tolerant RILs that transgressed the inherent physiological attributes of the donor Pokkali were consequences of network rewiring brought about by the coupling or uncoupling of trans-acting regulatory RNA (miRNA) and their target regulatory transcription factors from either parents. Novel expression signatures of the nuclear factor-Y-alpha transcriptional regulator in transgressive salt-tolerant RILs correlated with the transgressive expression of miR169, a regulatory RNA known to be involved in both abiotic and biotic stress responses. The nature of rewired regulatory networks and the physiological consequences of such miRNA-transcription factor coupling in relation to novel mechanism of salinity tolerance are discussed.

Response Variability across Diverse Rice Accessions under Rising Temperature and Increasing Atmospheric Carbon Dioxide

Wang, D.R., Bunce, J.A., Tomecek, M.B., Gealy, D., McClung, A.M., McCouch, S.R., and Ziska, L.H.

Evaluating variability of rice response to concurrent increases in CO_2 and temperature forecasted for future climates is a prerequisite step towards characterizing the genetic architecture underlying this response. Expanding on previous single cultivar studies, we evaluated 11 biogeographically diverse rice accessions (Nipponbare, Geumbyeo, Jefferson, IL 43-1-2, Shirkati, WAB 56-104, DJ123, Teqing, IR64, AR-1995-StgS, and IRGC105491) for yield and growth related traits under two CO_2 conditions (400 and 600 µmol mol^{-1}) and four temperature regimes (29°C day/21°C night; 29°C day/21°C night with additional heat stress at anthesis; 34°C day/26°C night; and 34°C day/26°C night with additional heat stress at anthesis). We aimed to address the following questions: 1) What are the overall effects of CO_2, temperature and their interaction on distinct rice lines, and do they support past findings on single cultivars? 2) Is there response differentiation within rice, and how does that relate to known genetic differentiation? 3) Are some accessions more resilient than others? Overall, we find that high carbon dioxide and high temperature act antagonistically and report differential response to CO_2 x temperature interaction between INDICA/INDICA-like and JAPONICA rice accessions.

The Effect of Temperature during the Panicle Differentiation with the Interaction of Calcium on Straighthead of Rice

Singh, S., Pokharel, M., Ntamatungiro, S., and Huang, B.

Straighthead is a physiological disorder that causes floret sterility and poor grain development in rice which results in yield loss. It represents a potential threat to U.S. rice production because of its unknown causal factors and susceptibility of widely grown cultivars in the southern major rice producing region. As high temperature during the panicle differentiation period can cause floret sterility in rice, it was essential to investigate the possible effects of high temperature on straighthead. Areas of Pine Bluff fall in the region of Arkansas with very hot weather in summer. There were about 29 days with daily highest temperature over 33°C, which temperature could result in floret sterility, between July and August in 2015 which coincides with the panicle differentiation period of most varieties of rice. Straighthead of rice will be increased if rice is exposed to a high temperature during the panicle differentiation period. Forty-four inbred and breeding lines were examined to investigate the effect of temperature during panicle differentiation with the interaction of calcium application on rice straighthead. Fields treated as control 0-Ca (0 tones lime/acre), Ca_I (2 tones lime/acre), and Ca_II (4 tones lime/acre) differed in the lime application rates. Individual panicles of varieties for each treatment were randomly tagged in each plot to record the date of heading so they can be inferred to the panicle differentiation time. Panicle differentiation temperatures were recorded 21 days prior to heading date because in rice panicle differentiation occurs 20 to 25 days before panicle heading. Daily temperature was collected from NRCS Scan Site which is about 50 meters away from the field. The data showed that high temperature during the panicle differentiation period can be an attributing factor to straighthead and effect of increasing panicle differentiation temperature can be reduced with lime application at some level. Varietal response to lime application was different as susceptible varieties showed higher response than moderately susceptible and resistant varieties.

Response of Straighthead Resistant and Susceptible Rice Varieties to Naturally Occurring and Induced Straighthead and Its Relationship with Soil and Plant Nutrients

Pokhrel, S., Ntamatungiro, S., Huang, B., and Li, Y.

Straighthead is a physiological disorder in rice which causes grain sterility and due to unfilled grains rice panicles remain upright. Rice yield can be totally lost when a highly susceptible variety is planted. The straighthead-like symptoms can occur naturally in some soils and frequently occur when susceptible rice varieties are grown on soils with a history of use of monosodium methanearsonate (MSMA), which is an arsenic containing herbicide. Arsenic is not an essential element and can be toxic to both plants and animals in high concentration. A rice field located at UAPB Farm where straighthead occurred naturally and a rice field at the National Research Center near Stuttgart where straighthead is induced by applying 6.7 kg MSMA/A were used to study soil, water and plant factors attributable to straighthead. Straighthead susceptible and resistant rice varieties were planted in a randomized complete block design with four replications at each location. Soil, plant and water samples were collected at different rice growth stages. Plant height, straighthead rating and rice panicles were taken at physiological maturity. Rice varieties did not show straighthead symptoms in 2014 at the natural site contrary to the previous four years. Straighhead was severe in susceptible varieties at the site where straighthead was induced by application of MSMA. Analysis of plant samples showed high arsenic (As) concentrations in susceptible rice varieties and high calcium (Ca) concentrations in roots and aboveground plant parts of resistant rice varieties. Analysis of irrigation water revealed that the concentrations of all the tested elements were low (0.05-18.82 mg/kg). Analysis of soil before flooding revealed that the concentrations of tested elements in the natural site ranges (0.33-480.4 mg/kg) and in the induced site ranged 5.85-848.17 mg/kg. The results will be important in our understanding of the differences in straighthead occurrence in natural and induced conditions and in developing straighthead-resistant varieties on the UAPB natural site.

Straighthead Testing for Selection of Parent Lines and Hybrid Combinations at UAPB in 2011-2012

Huang, B. and Yan, Z.

To evaluate the straighthhead disease resistance in different materials in the soil where straighthead naturally occurred in the past years, 47 rice lines, including 24 inbred lines and 22 hybrid combinations, were chosen for straighthead and agronomy characters testing in straighthead naturally induced soil at University of Arkansas at Pine Bluff for 2 years (2011-2012). Cocodrie was used as the check in this study. The data analysis results of 2011 showed that the yields of nine entries were higher than the check 'Cocodrie' and eight of the nine entries had straighthead scores 0-2, and 1 entry with a straighthead score 5. The rest of the entries had lower yield than check and with straighthead score 4-6. The yield was negatively related to the straighthead score (r=0.9178). The data analysis results of 2012 showed that the yields of 16 hybrid combinations were higher than the check 'Cocodrie' with straighthead scores 0-3. The other six hybrid combinations and inbred Francis had lower yields than the check and with higher straighthead score from 4 to 6. The yield was negatively related to the straighthead score (r=0.6141). Compared to Francis and Cocodrie, the yield of these combinations showed their straighthead resistance to some extent. The yields of the top two combinations, 893/123 and 8/2/Rondo, were 10, 385 and 10,002.1 kg/ha (9263.7 and 8922.5 lbs/acre), and 46.0 and 40.7% higher than check, respectively.

Avr Gene-Based Diagnosis of *Magnaporthe oryzae* and Its Application in Resistance Gene Deployment for Controlling Rice Blast Disease

Selisana, S.M., Yanoria, M.J., Quime, B., and Zhou, B.

The avirulence (Avr) genes in the fungal pathogen, *Magnaporthe oryzae*, causing the devastating rice blast disease have been assumed to be the major targets subject to mutations to evade the recognition by so-called resistance (R) genes. These R genes are widely utilized as the most effective and economical resource for controlling rice blast disease. In this study, we developed and validated an Avr gene-based diagnosis tool for determining the virulence spectrum of rice blast pathogen population. A set of 77 single-spore field isolates was pathotyped using LTH derived international rice blast differential lines (IRBLs). Based on the reactions to the IRBLs, isolates were clustered into 20 virulent races except four isolates that have lost their pathogenicity, suggesting that the diversity of pathogen population in the test site was relatively narrow. In addition, the haplotypes of seven cloned Avr genes were determined by PCR amplification and sequencing, if applicable. *AvrPi9* was present whereas *Avr1-CO39* and *AvrPia* were absent in all isolates. A varying percentage of *AvrPiz-t* (2.7%), *AvrPita191C/194H* (loss-of-function haplotype, 13.7%), *AvrPii* (86.3%), and *AvrPik* haplotypes [-D (20.5%), -E (1.4%), and -F (5.5%)] were identified. The deduced avirulence/virulence of each isolate showed quite high consistency with its pathotype to all IRBLs except IRBLzt-T, IRBLkp-K60, and IRBLta-K1. Moreover, the existence of additional *Pi19* gene in these three lines was deduced by comparing their reaction patterns with IRBL19-A, which in turn was able to explain the cause of discrepancy on the avirulence/virulence reactions by Avr-gene diagnosis and pathotyping. The merit of Avr gene-based diagnosis tool is that it is a precise, R-gene specific, and IRBL-free assessment that can be used for monitoring the virulence spectrum of rice blast pathogen and predicting effectiveness of respective R genes in rice.

Analysis of Rice Blast Resistance Genes in Mississippi Rice Breeding Germplasm

Zhang, Y., Perez, L.M., Xing, S., Redona, E.D., and Peng, Z.

Blast caused by the fungus *Magnaporthe oryzae* is a serious disease of rice in Mississippi and other rice growing states in the U.S. Profiling of blast resistance genes available in a breeding program is an important step for host resistance breeding. Knowing which genes are possessed by both existing varieties and promising genetic donors would allow the generation of crosses and populations that would segregate for the maximum number of resistance genes.

A total of 99 Mississippi rice breeding materials including released varieties, advanced breeding lines, and donor parents were surveyed through DNA fingerprinting using seven blast resistance molecular markers, including *Pi-ta*, *Pib*, *Pi54*, *Pik-m*, *Piz*, *Pik*, and *Pik-s*. Results showed that 78% of the breeding materials being actively used in the Mississippi breeding program have at least one or a combination of two to four genes in their genetic background. Most of the varieties have *Pik-m* (36.4%), followed by *Pik* (31.3%) and *Pi54* (23.2%) while nine varieties harbor *Pib* and/or *Piz*. Of these, the released variety Jupiter has *Piz* while JES has *Piz*+*Pib*+*Pi54*+*Pik*. Ten varieties/lines have at least three to four resistance genes while only three cultivars have four resistance genes. Combinations to develop F_1 crosses are being designed to generate varieties with the maximum number of resistance genes, as well as introduce new genes to widely adopted cultivars in Mississippi.

Abstracts of Papers on Plant Protection
Panel Chair: Xin-Gen Zhou

The Role of Moisture on Bacterial Panicle Blight Disease of Rice

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

Bacterial panicle blight (BPB) disease of rice is caused by one or more *Burkholderia* species. Bacterial panicle blight has been considered to increase in hot and dry summers particularly under extended high night temperatures. BPB is one of the most threatening diseases of rice production in Arkansas and other southern rice producing states. In 2010 and 2011, late-planted conventional rice fields were hit the hardest with BPB. Unlike the prior two years, the rice season of 2012 was hotter and drier resulting in very low BPB disease incidence in Arkansas. Only two commercial rice fields, each with Jazzman 2 and CL111, were reported having substantial BPB. Infections in these fields were higher in areas near tree lines and waterways. That same year, experimental plots established in an open field and planted with artificially inoculated seeds revealed near 100% BPB incidence in a susceptible rice cultivar, Bengal, within a week after tropical storm "Isaac" had passed through. Such field observations led to studying the role of dew on development of BPB disease of rice. Three sets of tests showed dew as a favorable factor for rice BPB disease development. 1) Of 70 rice entries grown in the field in 2014, uprooted at boot-split from the field, transferred to greenhouse pots and spray-inoculated with *Burkholderia glumae* between heading and flowering rice developmental stage, 97% failed to show BPB symptoms until after they were kept in a dew chamber. 2) In 2015, rice cultivar "Wells" that was spray-inoculated with *B. glumae* suspension at flowering and kept in a dew chamber for 55 hours, resulted in a fully failed grain with severe symptoms of BPB disease. In contrast, the same variety inoculated in a similar way and on the same day in a field during the dry week of July continued filling the grains with less symptomatic discoloration that started 2 weeks after inoculation. 3) In repeated greenhouse experiments, nearly 50% of the florets of CL151 showed symptom of BPB 2 weeks earlier when plants were spray-inoculated at flowering and kept in a dew chamber overnight than plants left on a bench after inoculation. These three experiments on head inoculation agreed with prior field observations underlying the importance dew as one of the environmental factors that favored BPB epidemic years.

Rice-based Culture Media for Growth and Sporulation of *Cercospora janseana*

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

Cercospora janseana is the casual agent of narrow brow leaf spot, which can cause significant damage to rice in epidemic years in the U.S. In vitro studies are essential to better understand the biology of this fungal pathogen and to develop effective strategies for management of this disease. The fungus grows very slowly and produces little conidia in common agar media. The objective of this study was to develop a cultural medium that was able to stimulate the growth and sporulation of the fungus.

In vitro assays were conducted to evaluate various plant tissue-based agar media in comparison with common agar media for their effects on the radial growth and sporulation of *C. janseana*. The only agar medium was incorporated individually with each of the following components: extracts of dried rice leaves, stems, and hulls; dried straw extract; fresh rice leaf extract, dried extracts of barnyard grass leaves and sorghum leaves. Potato dextrose agar and clarified V8 (20%) media were also included in this study. All the media were also incorporated with 0.001 g/liter of thiamine and 2 ppm of streptomycin sulfate. Petri plates containing various media were plated with a disc of 1-week-old actively growing mycelium of a isolate of *C. janseana* at the center and incubated at 28ºC under the 12/12h (light/darkness) cycle. Radial growth was measured at weekly intervals for 2 weeks and sporulation was measured at the end of 2 weeks. Among all the media tested, dried rice leaf extract, dried barnyard grass, fresh rice leaf extract and V8 media consistently provided greatest radial growth of the fungus while V8 medium produced maximum sporulation.

Survey of Rice Blast Race Identity for Blast Resistance Gene Identification in the USA and Puerto Rico

Jia, Y. and Lin, M.

Rice blast disease is a significant threat to stable rice production in the USA and worldwide. The major resistance gene (*Pi-ta*) located within a cluster of resistance genes on rice chromosome 12 has been demonstrated to confer resistance to the rice blast disease. Katy, a rice cultivar released in 1989, was the first rice variety incorporating the *Pi-ta* gene cluster. Since 1989, Katy has been used as the *Pi-ta* gene cluster donor resulting in the development of more than 10 commercial rice cultivars in the Southern USA. In order to direct breeding for blast resistance, a set of international differential rice cultivars were used to determine the race identity of rice blast field isolates, and the effectiveness of the Katy derived *Pi-ta* gene cluster in conferring resistance to rice blast disease. The varieties used in our efforts included: Raminad Str. 3, Zenith, NP125, Usen, Dular, Shataotsao, Caloro, Katy, and M202 (the latter, a blast susceptible control). From 2012 until 2014, blast fungal samples were obtained from three primary sources: 1) Diseased rice leaves and/or panicles from commercial rice fields, 2) Three rice experiment stations in the Southern USA, and 3) The winter nursery in Puerto Rico (2015). Diseased samples were placed on well-moistened filter-paper under continuous fluorescent lighting for a period of 12 hours. Subsequently, the conidia were identified with a dissecting microscope, and transferred to water agar plates for purification. Purified spores were grown on filter-paper laid on top of oatmeal media to produce sporulated mycelia. Upon mycelia maturation, the filter papers were desiccated and stored long term at -20°C. Testing rice variety resistance to blast requires inoculating an oatmeal culture with a small section of filter paper containing the mycelia of selected blast fungal isolate. The plate cultures were grown under fluorescent light for 7 to 10 days in order to produce spores for the inoculation. A total of 74 selected isolates representing 10% of blast collections were evaluated. A total of nine blast races, IB1, IB17, IB49, IB53, IC1, IC17, IC21, IG1, and IE1 were identified. Among them, IB1, IB49 and IC17 were more commonly found than other races. Katy was resistant and M202 was susceptible to all 74 blast isolates. Katy is known to contain *Pi-ta* and *Pi-ks* and M202 contains *Pi-ks*. These data suggest that the *Pi-ta* gene cluster in Katy is still effective in preventing blast disease in the USA.

Growing Distribution of Strobilurin-Resistant *Rhizoctonia solani* on Rice in Southwestern Louisiana

Lunos, A., Hollier, C., Brooks, L., and Harding, S.

The decline of Quadris sheath blight management in Acadia Parish, Louisiana, during 2011 prompted azoxystrobin sensitivity investigation. Azoxystrobin fungicide resistance was confirmed, but only within 40 km of the first problem site (resistance origin). A broader survey was conducted during 2013 and 2014. Symptomatic rice tissue was collected from 38 commercial fields in southwestern Louisiana to create an isolate collection of *R. solani* anastomosis group I-IA. Isolates were then tested separately for azoxystrobin, pyraclostrobin, and trifloxystrobin sensitivity using an *in vitro* colony diameter assay on agar plates to determine the effective fungicide concentration (EC_{50}) that inhibits mycelial growth by 50% relative to maximum and minimum responses. Azoxystrobin resistance was found in seven fields, all within 40 km of the resistance origin, whereas two of the six fields with an intermediate sensitivity were beyond this range. Pyraclostrobin resistance was also identified in seven fields, one of which was located over 40 km away from the origin. Three of the four pyraclostrobin-intermediate fields were also outside the 40 km range. Trifloxystrobin resistance could not be identified because no significant differences were found between the trifloxystrobin EC_{50} values. Among the different fungicides tested, there was no significant difference between mean azoxystrobin and pyraclostrobin EC_{50} values, but both were significantly higher than the trifloxystrobin treatment mean. These results imply that strobilurin resistance distribution is increasing while trifloxystrobin could be a possible alternative for managing azoxystrobin-resistant isolates of *R. solani* in southwestern Louisiana rice fields.

Brassica Cover Crop as Soil Biofumigant for Management of Sheath Blight in Rice

Zhou, X.G., Handiseni, M., and Jo, Y.

Sheath blight caused by *Rhizoctonia solani* AG1-1A is the most important disease in rice that can cause significant losses in grain yield and quality in the southern United States. Sclerotia and mycelium in infected plant debris of the fungus survive between crops in the soil and serve as primary inoculum. Infection starts when sclerotia or infected plant debris floats to the water surface after rice fields are flooded and come into contact with the sheaths of plants. Currently, sheath blight is controlled primarily by the use of fungicides at the stages from panicle differentiation to heading. Excessive use of fungicides can cause negative impacts on the environment and lead to the potential development of fungicide resistance. Biofumigation using brassica plants (*Brassica* spp.) has the potential to serve as a new environmentally friendly option for management of the disease. Brassica plants contain glucosinolates, producing the gaseous isothiocynates that are toxic to *R. solani* and many other soilborne pathogens. Through this biofumigation process, brassica cover crops may suppress sheath blight by reducing primary inoculum in soil. The objective of this research was to 1) *in vitro* screen brassica species for suppression of mycelium of *R. solani*, 2) evaluate the effects of brassica amendment rate on the suppression of mycelium and sclerotia, and 3) determine the efficacy of brassica cover cropping for management of sheath blight in the field.

In vitro assays were performed on agar plates to evaluate biofumigation activity of the macerated tissues of 11 brassica and other related species with different soils from Texas, Arkansas and Mississippi on mycelium growth of *R. solani*. All 11 plant samples evaluated significantly inhibited mycelium growth compared to the untreated control. Four mustard (*B. juncea*) cultivars, including Brand 199, provided most consistent and significant (> 90%) inhibition in all the three soils evaluated. *B. juncea* cv. Brand 199 was selected to further evaluate the effects of amendment rate [0, 0.2, 0.4, 0.8, 1.6 or 3.2% plant tissue (wt/ wt)] on mycelium growth, sclerotium formation, sclerotium viability and the aggressiveness of sclerotia on detached rice leaves. All brassica amendment rates (0.2 to 3.2%) reduced mycelium growth and the formation of sclerotia from mycelium compared to the non-amended control (0%). The inhibition of mycelium growth and the formation of sclerotia increased with the increase of the amendment rate. The viability (germination) of sclerotia was significantly reduced at the amendment rates of 1.6% plant tissue (wt/wt) or above after the sclerotia were exposed for 14 days or more. The aggressiveness of sclerotia, measured as the length of sheath blight lesions developed from sclerotia on the detached rice leaves, was significantly reduced at the amendment rate of 0.4% plant tissue (wt/wt) after the sclerotia were exposed for 7 days.

A field trial was conducted in *R. solani*-infested rice plots in Texas in 2011, 2012 and 2013 to evaluate the efficacy of brassica cover crop for control of sheath blight. This trial was conducted as a randomized complete block design with four replications. There were two cover crop treatments: brassica 'Caliente 199' and fallow (no cover crop). The brassica crop was planted in the fall (2012 and 2013) or early spring (2011) and incorporated into soil at least four weeks before the planting of rice. Severity of sheath blight was assessed approximately 1 week before harvest. Plots were harvested using a plot combine and grain yield determined. Severity of sheath blight was significantly lower in plots seeded to brassica cover crop than in plots left fallow in all three years evaluated. The brassica cover cropping also resulted in a significant yield increase in 2013. This is the first report to demonstrate the biofumigation activities of brassica plants on mycelium and sclerotia of *R. solani* and the field efficacy of brassica cover cropping for suppression of sheath blight. Brassica cover cropping can be a new management option for sheath blight in rice.

Comparative Evaluation of the Old and New Fungicides against Sheath Blight of Rice

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

Arkansas produces nearly 50% of the rice in the United States of America. Sheath blight is among the top diseases of rice caused by *Rhizoctonia solani* AG1-1A, the same fungal strain that causes aerial web blight of soybean and also infects corn. With high input rice production and soybean or corn as rotation crops, incidence of sheath blight has been increasing. Sheath blight can cause lodging and possibly substantial yield and quality losses making fungicide treatment inevitable. When fungicides having the same mode of action are applied frequently and without rotation, the results could be pathogen's insensitivity/tolerance/resistance. The objective of this study was to examine fungicides containing different modes of action for use in rotation to control sheath blight disease on rice. Five fungicides with three different modes of actions were tested on artificially inoculated plots of rice cultivar, CL151. Fungicides tested included: Sercadis (fluxapyroxad), Quilt Xcel (azoxystrobin + propiconazole), Quadris (azoxystrobin), Stratego (trifloxystrobin + propiconazole) and Tilt (propiconazole) at the following rates: 0.5, 1.5, 0.9, 1.4, 0.44 L/ha (6.8, 21, 12.5, 19, and 6 fl oz/acre), respectively. Control plots were untreated with fungicides. All treatments were in a complete randomized block design replicated four times. Sheath blight disease ratings were recorded five times in the season of 2015. A disease rating scale of 0 to 9, where 0 represents no disease and 9 severe disease were used to measure vertical (plant height) disease progress. Horizontal (plant to plant) disease progress was estimated from percentage diseased plants approximately 1 m (3 feet) length from middle rows of each plot. AUDPCs (Area under Disease Progress Curves) for disease severity were calculated at each disease-rating time interval to compare treatment efficacy against sheath blight. Total AUDPC of Stratego was significantly different from Sercadis and Quadris but not from Quilt Xcel. Tilt showed significant difference from the untreated control but lower efficacy to control sheath blight compared to the other fungicides. Sercadis, Quilt Xcel and Quadris were significantly different from the untreated control but not from one another. This suggested the possibility of using Sercadis, Quilt Xcel and Quadris alternatively in rotation to slow down development of fungicide resistance by the pathogen. There was no significant difference in milling quality among treatments. Yield data were inconsistent among replications of the same treatment due to lodging caused by wind in some of the plots. Overall, the study suggests repeating the experiment across years coupled with studies on economics of fungicide use to control sheath blight disease of rice.

Fungicide Efficacy for Rice Narrow Brown Leaf Spot

Moncayo, L., Zhou, X., and Jo, Y.

Cercospora janseana causes narrow brown leaf spot (NBLS) in rice. In vitro fungicide sensitivity assays and fungicide field evaluations were performed for understanding the fungicide efficacy for control of NBLS in Texas rice growing regions. Conidia germination of five *C. janseana* isolates collected from Texas rice fields were assessed for determining fungicide sensitivities to quinone outside inhibitors (QoI), demethylation inhibitors (DMI), succinate dehydrogenase inhibitors (SDHI), methyl benzimidazole carbamate (MBC) and dithiocarbamate fungicides. The effective fungicide concentration that inhibited 50% of conidia germination (EC_{50}) was determined. *C. janseana* isolates presented various sensitivities to different fungicides. Conidia germination was not affected by DMI. Sixty percent of the QoI fungicides tested failed to inhibit conidia germination, with >10 µg a.i. ml^{-1} of EC_{50}. Two isolates were resistant to MBC fungicide thiophanate methyl, and four isolates were resistant to dithiocarbamate fungicide mancozeb. In the case of SDHI, conidia germination of all five isolates were not inhibited by flutolanil but highly sensitive to the other active ingredient fluxapyroxad. Under rice field conditions in 2012 and 2014, QoI, DMI and SDHI fungicides were evaluated for control of NBLS. The field evaluations indicated that fluxapyroxad and DMI fungicide propiconazole alone or in combination with QoI most effectively decreased NBLS severity and subsequently resulted in the highest yield. Efficacy of QoI fungicide azoxystrobin alone was not effective in reducing NBLS severity. Consequently, lower yields were harvested compared with other fungicide treatments although they were still significantly greater than the untreated control. The inconsistency of fungicide applications for NBRL that has been reported in the southern Rice Belt regions in the United States is associated with reduced fungicide sensitivities of *C. janseana*.

Survey and Identification of Panicle Blanking Bacteria in Arkansas

Mulaw, T., Wamishe, Y.A., Jia, Y., Gebremariam, T.A., Belmar, S.B., and Kelsey, C.D.

Outbreaks of bacterial panicle blight (BPB) of rice in recent past years have resulted in severe yield losses in the Southern United States including Arkansas. Bacterial species, *Burkholderia glumae* was identified as the main causative agent among others causing BPB in rice. The symptoms of BPB include sheath rot, panicle blighting, panicle blanking, seed discoloration and significant yield loss. Despite its economic importance, the bacteria causing BPB are poorly understood compared to other important plant pathogenic bacteria due to limited research on BPB. The major objective of this study was to collect and evaluate samples of fully or partially blanked rice panicles using cultural and molecular approach and to identify the *Burkholderia* species that may have been associated with the panicle blanking in Arkansas counties in year 2015. About 165 rice panicle samples that either showed some level of blanking or brown floret discoloration were collected from ten rice growing counties in Arkansas. Seeds were plated on a semi-selective medium CCNT at 38°C for 48 h and purified based on morphological characteristics of *B. glumae*. DNA was extracted from each pure isolates for molecular identification primarily using *B. glumae* specific primers. Of 165 field samples collected 72 (44%) of the samples were considered positive for *B. glumae* visually on CCNT culture medium.

However, molecular approach using specific primer confirmed that only 45 (27%) samples of the diseased rice panicle samples were attributed to *B. glumae*. All 72 isolates were also tested for *B. gladioli* using specific primers. However, none tested positive to *B. gladioli* indicating that *B. glumae* is the major causal agent of BPB disease of rice in Arkansas. Based on this study, 73% of the samples were tested negative for *B. glumae* suggesting other causes of panicle blanking and discoloration. Results also suggested the use of molecular technique as valid to complement visual and cultural identification of *B. glumae*. Overall, this study underlines the importance of molecular technique to increasing accuracy and dependability of disease identification from field samples where symptoms can be caused by different environmental factors.

Efficacy of Insecticidal Seed Treatments in a Replant Scenario

Way, M. and Pearson, R.

Occasionally rice farmers have to replant in the spring because of poor stands due to blackbird damage, chinch bug injury, herbicide phytotoxicity, seedling disease, too low seeding rate, poor land preparation and inability to adequately drain fields during seedling growth. Many farmers apply an insecticidal seed treatment to control rice water weevil and a number of other insect pests. We wanted to answer the question: if a farmer applies an insecticidal treatment to the first planted seed, does he/she have to treat the replant seed or can he/she rely on residues from the first planted seed to protect the replant seed?

Experiments were conducted for 3 years (2011, 2014 and 2015) at the Beaumont Center. Experiments were designed as a randomized complete block. Treatments were replicated four times. Plot size was 1.22 m by 5.5 m (4 ft by 18 ft).Treatments included Dermacor X-100, NipsIt INSIDE and CruiserMaxx Rice applied at recommended rates for a seeding rate of 89.7 kg/ha (80 lb/acre). Plots were drill-seeded and flushed to encourage germination and seedling growth. In addition, plots were surrounded by metal barriers in 2 of the 3 years. Metal barriers were installed immediately after planting and pushed down in wet soil immediately following the initial flush. This procedure minimized movement of insecticide among plots because the barriers formed a seal around the plots. Once rice emerged, all plots were sprayed with glyphosate to kill rice which created a replant situation. Once rice died, barriers were removed and plots replanted with insecticide-treated or untreated seed. After planting, barriers were reinstalled. For the experiment conducted without barriers, procedures were the same as above minus the barriers. About 3 weeks after flood, plots were sampled for rice water weevil (5, 10 cm by 10 cm deep soil cores removed per plot and washed through fine mesh screening to recover larvae and pupae). This sampling was repeated about 4 to 5 weeks after flood. Once rice reached soft dough, whiteheads (an indication of stalk borer activity) were counted in the middle four rows of each plot. At maturity, rice was harvested with a small plot combine.

Results for 2011: all seed treatments significantly reduced rice water weevil numbers on both rice water weevil sample dates compared to the untreated. This suggests all treatments applied to the first planted seed persisted in the rhizosphere to control rice water weevil attacking the replant. Also, Dermacor X-100 applied to the first planted, but not replant seed, provided excellent control of stalk borers (primarily Mexican rice borer). All seed treatments produced higher yields than the untreated.

Results for 2014: rice water weevil populations were relatively low throughout the experiment, but data suggest all seed treatments applied to the first planted seed protected untreated replant seed from rice water weevil attack. Yields were not significantly different among treatments.

Results for 2015: barriers were not utilized in this experiment, rainfall that was abnormally high [21.4 cm (8.4 inches) from planting to emergence of the first planting] and severe blackbird damage were mitigating factors. Again, rice water weevil populations were relatively low throughout the experiment. Dermacor X-100 applied to first but not replant seed, reduced rice water weevil populations 58%. Stalk borer activity was low throughout the experiment, so data are not very meaningful. Yields were low and not significantly different among treatments. These results indicate replant seed should be treated with an insecticide to provide effective control of rice water weevil.

In conclusion, results are not clear, suggesting the experiment should be repeated another year. Very wet conditions in 2015 probably affected the results. So, we tentatively recommend farmers to treat replant seed if abnormally wet conditions occur during the first plant growth. Or, apply a preflood insecticide for rice water weevil control and perhaps follow up with a pyrethroid application(s) for stalk borer control.

Exploring Trait Mediated Interaction Units in the Pest Complex of Rice (*Oryza sativa*)

Kraus, E.C. and Stout, M.J.

Lissorhoptrus oryzophilus, the rice water weevil, is the most economically important pest of rice in the U.S. This insect has spread from its native region in North America and has become a global pest. The adults feed on foliage of plants, causing little damage. The larvae, however, feed on roots reducing tillering and shoot growth. This feeding activity overall reduces panicle densities and grain harvest weights. *Spodoptera frugiperda,* Fall armyworm, is also a pest of rice. Control for fall army worm includes managing nearby grasses, flooding, and chemical insecticides. Generally fall armyworm is an early season pest before flooding while the weevil enters after flooding and remains farther into the season. These two insects form a Trait Mediated Interaction Unit (TMIU) with the rice plant. We hypothesized that fall armyworm feeding would induce plant traits capable of decreasing plant suitability for weevils. In order to investigate we artificially infested small plots with fall armyworm larvae. Larvae were allowed to feed on plants for 7-10 days and damage was then rated. At this time plots were flooded, and weevils were allowed to naturally infest the field. Core samples taken after two weeks indicate that early season defoliation by fall armyworm significantly decreases overall larval infestation by rice water weevil. This research may contribute to biotechnological approaches to pest control in rice. The information may be incorporated into management programs to reduce the associated costs of pest control, as it may call for reconsideration of fall armyworm thresholds.

Stink Bugs in California Rice - A Developing Problem?

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

Several species of stink bugs (Hemiptera: Pentatomidae) have historically threatened crop production and hindered integrated pest management programs in the diverse, intensive agricultural systems in California. Endemic species have damaged primarily fruit and nut crops and successful IPM programs have mitigated damage. Rice has traditionally not been impacted by stink bug populations. The rice stink bug, *Oebalus pugnax*, does not occur in California. However, the expansion of endemic stink bug populations as well as recent introduction of two invasive stink bug species have the potential to destabilize rice IPM programs. Recent introductions have included the bagrada bug, *Bagrada hilaris*, and brown marmorated stink bug, *Halyomorpha halys*. The former species invaded southern California and western Arizona in 2008 and specializes on brassicas although it will feed on a wide range of plant species. The bagrada bug range has expanded to the central coast area and San Joaquin and Sacramento Valleys. The brown marmorated stink bug was first found in the western U.S. in 2004 and now populations are established in several counties in the Sacramento Valley, the key rice production area. Greenhouse studies are ongoing to determine how these pests adapt to the environmental and crop conditions in the state.

In addition, several species of endemic stink bugs appear to be inflicting a low level of damage to rice; kernel damage has been noted at harvest from several areas. The redshouldered stink bug (*Thyanta custator accerra*) and other species have been investigated in terms of this damage.

Studies with brown marmorated stink bug on developing panicles showed a pair of adults could reduce kernel weights by 46% during the milk stage of kernel development; effects on weights during the soft dough and hard dough stages were minimal. This resulted because this pest more than doubled the incidence of blank kernels during the milk stage infestations. The percentage of damaged kernels ranged from 17.4 to 31.3% across the kernel maturity stages and was actually highest on the soft dough stage. Field studies have also been conducted on rice damage by the redshouldered stink bug. Cage studies showed up to 2.75% kernel damage and 15% grain losses per stink bug, and grower field surveys have defined the incidence of this species and three other endemic species in rice fields.

Effect of Planting Date on Insect Control and Yield with Insecticide Seed Treatments

Lorenz, G., Hardke, J., Clayton, T., Chaney, M., Frizzell, D.L., Taillon, N.,
Castaneda-Gonzalez, E., Plummer, A., and Black, J.

Insecticide seed treatments were evaluated compared to a fungicide check across six planting dates. Observations included efficacy for control of grape colaspis and rice water weevil. Differences among treatments were observed between treatments for control of these major pests and subsequent yield. Nipsit Inside and Cruiser provided control of grape colaspis compared to Dermacor and the untreated check. Dermacor provided the best control of rice water weevil compared to all other treatments and the untreated check.

Control of Rice Stink Bug with Selected Insecticides in Large and Small Plot Trials in Arkansas Rice

Taillon, N., Lorenz, G., Plummer, A., Chaney, M., Black, J., and Clayton, T.

Foliar insecticide treatments were evaluated compared to an untreated check in both large block and small plot studies from 2008 through 2015. Observations included efficacy for control of rice stink bug and yield. Results indicate several options for producers that will provide control when paired with good sampling methods for detection of rice stink bugs on heading rice.

Revisiting Rice Stink Bug Thresholds in Arkansas

Hardke, J.T., Lorenz, G., Clayton, T., Lee, G., Chaney, M., Castaneda-Gonzalez, E.,
Frizzell, D.L., Taillon, N., Plummer, A., and Black, J.

Field studies were conducted in 2014-2015 to re-evaluate the current rice stink bug threshold in Arkansas. The current recommendation is to treat when five rice stink bugs per 10 sweeps are found the first 2 weeks of heading; and when 10 stink bugs per 10 sweeps are found the second weeks of heading. Rice stink bug sampling studies were conducted in 2014 to develop a baseline estimate for area sampled when scouting for rice stink bugs in the field. Based on these studies, the standard area per sweep chosen was 1.67 m in length by 0.38 m sweep net width (0.63 m^2).

Field caging studies were conducted in 2014 and 2015 to evaluate the ability of varying densities of rice stink bug to damage rice kernels. Each field cage was 1.83 m^3 and the actual area of planted rice within each cage was equivalent to approximately five sweeps. Cages were placed over plots immediately prior to heading and remained covered until harvest. Cages were infested for 7 d at each of four growth stage timings: heading, milk, soft dough, and hard dough. Rice stink bugs were infested in cages at densities of 0, 4, 8, 25, or 42 rice stink bugs per cage. These numbers are slightly elevated in order to account for low levels of stink bug mortality. In both years, no stink bug infested cages resulted in a significant increase in damaged kernels or a reduction in grain yield compared to the non-infested cages. Based on these results, further research is needed to better determine the most appropriate threshold for Arkansas. However, at this time no changes to the current threshold are justified.

Interactive Effects of Silicon Soil Amendment and Nitrogen Levels on the Rice Insect Pest Complex

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

Fertilization practices can affect insect pest population and the severities of infestations. Typically, populations of rice pests, such as the rice water weevil and stem borers, increase with increasing nitrogen rates leading to substantial yield loss. In addition, silicon, though not classified as essential plant nutrient, is considered beneficial because it enhances plant defense against pests, and amending soils with silicon can reduce pest populations. This study was conducted to evaluate the independent and interactive effects of silicon amendment and nitrogen levels on rice insect pest complex. Field experiments were conducted in Beaumont, Texas, in 2013, 2014, and 2015 with two silicon treatments (0 and 4000 kg/ha) and in Crowley, Louisiana, in 2015 with four nitrogen levels (0, 67, 101 and 135 kg/ha) and two silicon treatments (0 and 5000 kg/ha). A decrease on the incidence of stem borer damage was observed in plots treated with silicon; however, effect was not significantly different than untreated plots. Culm hardness, a physical barrier for stem boring insects, has shown to have increased in rice plants treated with silicon. In a greenhouse experiment, we found that the force required to penetrate the culm was higher in silicon-treated rice plants. In Louisiana, a slight reduction on the number of rice stink bug captured by sweep net has been observed when plots treated with nitrogen are amended with silicon. Furthermore, in another greenhouse experiment, a feeding assay using fall armyworm larvae showed lower relative growth rates in armyworms fed with silicon-treated rice plants. Rice water weevil infestations on the other hand, were not significantly affected by silicon treatment in most field experiments; although lower larval counts were observed in silicon treated plots in one experiment. In Texas, a minor increase in rice yield was observed in silicon treated plots while a greenhouse experiment in Louisiana has shown higher total filled grain weights on pots treated with silicon compared to untreated. Silicon soil amendment may be a valuable component of management practice program to combat multiple pests.

Anthraquinone-based Repellents Research for Rice Crop Protection

Werner, S.J. and Linscombe, S.D.

Blackbirds can damage newly-planted and ripening rice in the mid-South. In 2011, USDA Wildlife Services' researchers estimated that blackbird-caused economic losses to the U.S. rice industry were $23.1 million based upon the value of the rice crop in Arkansas, California, Louisiana, Mississippi, Missouri and Texas. The National Wildlife Research Center's (NWRC) research regarding blackbird impacts to rice production is presently focused to develop application strategies for non-lethal chemical repellents and provide data necessary for the registration of effective wildlife damage management techniques. NWRC recently developed a novel application strategy that exploits blackbirds' use of ultraviolet visual cues for the application of chemical repellents and the protection of agricultural crops. In collaboration with Arkion Life Sciences and the LSU AgCenter's Rice Research Station, NWRC conducted a field efficacy study in June–August 2015 to evaluate a novel formulation of an anthraquinone-based repellent (AV-4044; a.i. 9,10-anthraquinone). As predicted, red-winged blackbirds within rice enclosures treated with AV-4044 consumed more of the maintenance diet (i.e. alternative to treated rice) than those within untreated rice enclosures (n = 10 enclosures per repellent treatment). Interestingly, rice yield was greatest in blackbird enclosures treated with AV-4044 and least within untreated enclosures. Chemical residue analyses from these foliar repellent applications will supplement these field efficacy data. For the 2016 growing season, FIFRA Section 18 Emergency Exemptions are pending for the use of AV-1011 rice seed treatment (a.i. 9,10-anthraquinone) in Arkansas, Louisiana, Mississippi, Missouri and Texas. USDA's Wildlife Services program will continue to provide Federal leadership and expertise for the management and research of blackbird impacts to U.S. rice production.

Characterization of Tadpole Shrimp Injury and Its Effect on Rice Seedling Establishment

Espino, L.

Most of the rice grown in California is water-seeded, meaning that fields are flooded before the seed is broadcasted. In this system, the tadpole shrimp (*Triops longicaudatus*) is a key pest. Tadpole shrimp can feed on the germinating seeds and seedlings, uproot seedlings, and muddy water, reducing stand establishment. Management relies on pesticides. Stands can be affected if tadpole shrimp infestations are not detected and controlled timely.

The objective of this study was to determine the susceptibility of several stages of seedling development to injury caused by tadpole shrimp of different sizes. Seedling stages used were S0, when no structures have emerged from the seed; S1, when the coleoptile has emerged; S2, when the coleoptile and radicle have emerged; and S3, when the prophyll has emerged. The S3 stage was sub-divided in two stages; S3-I, when only the prophyll has emerged; and S3-II, when the first true leaf is visible but not fully unfurled. Tadpole shrimp used were classified as small, medium or large, when carapace length was smaller than a rice seed (4-6 mm); about the size of a rice seed (6-8.5 mm); or larger than a rice seed (9-13 mm). Ten seedlings of each stage were introduced in 350 ml plastic containers that had a 2- to 3-cm layer of soil and flooded to 7 to 8 cm. Each container was infested with 2 small, 1 medium, or 1 large tadpole shrimp, or left uninfested. Tadpole shrimp were allowed to feed on the seedlings for 24 h, after which they were killed using copper sulfate. A day later, seedling injury was characterized and quantified. Twelve days later, seedling establishment, root length, plant height, and leaf stage of rice were determined. The study was conducted twice in 2015, once in May and once in July.

Tadpole shrimp fed on the coleoptile and radicle, but not on the prophyll. Once the prophyll emerged and the coleoptile wilted, tadpole shrimp feed on the growing roots. They also buried S0, S1 and S2 seedlings. As tadpole shrimp size increased, the number of injured seedlings increased. On average, each small, medium, and large tadpole shrimp injured 0.9, 1.6 and 2.5 seedlings, respectively. Small, medium and large tadpole shrimp infestation reduced percentage seedling establishment by 40, 68 and 80%, respectively. The relationship between the number of injured seedlings and percentage established seedlings was not significant because not all injury prevented seedling establishment. No clear pattern was observed in the effect of tadpole shrimp infestation at each seedling stage on percentage establishment, except that the reduction of establishment was lowest when infestation occurred during the S0 stage (20-50%). Root length, plant height and leaf stage of rice were significantly affected by tadpole shrimp infestation; however, differences were small and most likely biologically irrelevant.

Tripartite Plant-Mycorrhizal-Insect Relationships may Impact Changing Rice Resistance

Bernaola, L. and Stout, M.

Rice, *Oryza sativa*, faces hardships in Louisiana from both above-ground (AG) and below-ground (BG) stressors and rice plants defend themselves against harmful insects and pathogens in many ways. Interactions between plants and herbivores and between plants and arbuscular mycorrhizal fungi (AMF) are ubiquitous in terrestrial ecosystems and may be interconnected by complex regulatory networks via a shared host plant. Arbuscular Mycorrhizal Fungi (AMF) form symbiotic associations in many plant roots and are thought to play a central role in plant nutrition, growth and fitness. Previous studies suggest that AMF colonization makes rice more susceptible to insect and pathogen attack. We hypothesize that the interaction of AMF with rice roots activates responses that change the resistance of rice to pests. Our aims are to evaluate the effects of AMF on rice water weevil (RWW) and fall armyworm (FAW) by using different soil types; investigate if AMF increases plant nutrient uptake by rice, thereby making rice plants more susceptible to pests; and investigate if AMF symbiosis affects plant signaling pathways related to plant defense by comparing the transcriptional changes triggered in rice leaves with AMF. In field and greenhouse studies, we showed that the effects of AMF colonization on the susceptibility to pests, RWW and FAW, are soil dependent. Nutritional analyses of root and shoot tissues indicated that AMF colonization does not have major effects on nutrient uptake on mycorrhizae-colonized plants, suggesting that the observed differences in plant resistance were due to changes in defense-related pathways. In addition, we showed that AMF grow in a natural way in all places sampled of rice fields. These results suggest that AMF colonization influences processes in the root system of rice, making them more susceptible to insect attack. Understanding interactions among above- and below-ground organisms may help in developing novel methods for managing pests of rice.

The Effect of Calcium Application on Reducing the Straighthead of Rice in a Field Where the Straighthead Naturally Induced

Pokharel, M., Singh, S., and Huang, B.

Straighthead is a physiological disorder of rice (*Oryza sativa* L.) which causes sterile florets and leads to reduced grain yield. Some specific characteristics of rice straighthead are upright panicles because of unfilled grains and distorted lemma and palea into a crescent or parrot-beak shape. The objectives of this study were to investigate the influence of calcium application on reducing straighthead and selecting resistant varieties and germplasm under field conditions where straighthead naturally occurred. Forty-four varieties, including 27 inbreds, 6 breeding lines, and 11 sterile lines were planted on a silt loam soil at University of Arkansas at Pine Bluff (UAPB) farm where the straighthead naturally occurred historically. There were three treatments in a randomized completely block design with three replications in each treatment. First plot was treated with Ca using lime at a rate of 2 tons/acre, second was treated with Ca using lime at a rate of 4 tons/acre and third plot was control. At Physiological maturity, straighthead severity was recorded by using a 0-9 straighthead rating scale described by Yan et al., 2005. Random sampled rice panicles were harvested and seed set rates were determined and analyzed. Results revealed that straighthead score for rice susceptible varieties was significantly reduced with lime application, for example, straighthead score of Cocodrie variety was reduced from 8 to 3. On the other hand, lime application had no significant effects on rice resistant cultivars. Similarly, seed set rate for susceptible varieties was drastically increased with lime application. Lime application might be a measure to overcome straighthead severity in rice and increase grain yield in such silt loam soil type.

Small Differences in Water Level Impacted Straighthead Ratings

Heuschele, D.J. and Pinson, S.R. M.

Straighthead (STHD) is a physiological disorder that results in sterile rice panicles that remain upright at maturity. Depending on the rice variety and its level of host plant resistance, yields can be reduced significantly. US rice varieties are screened and scored for STHD resistance by inducing STHD with MSMA soil amendment in designated field nurseries. At plant maturity, rice varieties are rated for STHD severity on a scale of 0 to 9; "0" rating indicating no signs of stress with >90% seed set and no parrot beaking or twisting of panicles, and "9" rating for plants that are stunted and do not extrude panicles.

The STHD screening nursery at the Dale Bumpers National Rice Research Center, Stuttgart, AR, has been in operation for 40 plus years. Annual MSMA amendment is needed to induce STHD in the nursery. The MSMA is sprayed at a rate of 6.72 kg per hectare then incorporated into the soil the day of planting. Multiple plots of known resistant and susceptible check varieties (usually 'Zhe733'and 'Cocodrie', respectively) are planted across each field to verify that STHD induction is consistent throughout each experiment. Anaerobic soil conditions are critical for the induction of STHD, therefore a permanent flood is applied as early as plants are tall enough (generally 2 weeks after emergence), recharged regularly, and held on the field until all plants have matured and been rated for STHD response.

During the 2015 growing season an F3 mapping population was evaluated for STHD and the parental lines were used as repeated checks in these fields. The parents were selected based on previous years of study that placed them on opposite ends of the STHD scale; 'Jefferson' rated as resistant (0-2), and 'Grassy' as highly susceptible due to severely stunted plant height, no emergence of panicles, and rated consistently "9" for STHD. Maintaining a deep flood in the STHD nursery in 2015 was particularly problematic due to short levee heights that limited the maximum flood depth at the highest point in the experimental field to approximately 7.5 cm. The 2015 fields contained even wider plot-to-plot differences in flood depth due to the development of significant soil level irregularities (low spots and high spots) since the last laser leveling. Fields were recharged multiple times a week to maintain a constant flood; flood depth fluctuated by approximately 3 cm between recharges. As much as one month before heading it was apparent that some Grassy plots were less stunted than others. To test the hypothesis that even small differences in flood depth, as found within a single experimental field, might be introducing non-genetic variability in STHD ratings, we began monitoring flood depth variation within the Grassy/Jefferson F3 research fields.

Maximum flood depths for each Grassy/Jefferson check plot location were determined at two growth stages, each time immediately after the permanent flood was recharged; with plot averages ranging each time from 7.5 to 13.5 cm maximum flood depth. Check and test plots containing segregating Grassy/Jefferson F3 progeny were rated at maturity for STHD and plants measured for height.

A positive linear relationship between water depth and STHD ratings occurred for both Grassy and Jefferson. The confounding effect of water-depth on STHD ratings was not restricted to shallow field areas, but extended linearly to the deeper water depths as well. The slope of the relationship was similar enough between the two varieties that water depth could be used as a covariate to correct STHD within experimental fields. When this covariate was tested with the Grassy/Jefferson F3 population, the non-genetic between-replication variation was reduced by18-26%, with some STHD ratings being adjusted by as much as ±1. Jefferson and Grassy are so different for STHD response that altering any single plot rating by ±1 does not shift their classification from resistant or susceptible. However, in 2015 the more commonly used susceptible check variety Cocodrie received STHD ratings ranging from 7 down to 5, a range in responses where use of water depth to correct individual plot STHD ratings would shift a rating from moderately resistant (4 or 5) to more consistently susceptible (≥6).

Because MSMA induced STHD requires an anoxic root environment, the soil may be acquiring oxygen when the flood is at its lowest level, approximately 4 cm in some of our field areas in 2015. This study demonstrates the importance of maintaining a consistent and relatively deep flood across all plots when screening for STHD resistance. If plot water depths vary, as they do in most rice fields, they can be used as a covariate to improve STHD ratings.

The Effect of Calcium and Nitrogen on Reducing Straighthead and Increasing Seed Set Rate of Rice on a Silt Loam Soil

Li, Y., Tiwari, S., Ntamatungiro, S., and Huang, B.

Four varieties (Cocodrie, PB11, PB13, and PB18) were planted in the greenhouse to test the effect of Ca and N on reducing straighthead on this Silt Loam soil. The Silt Loam soil was collected from the field where straighthead was naturally induced in the past years on the farm of University of Arkansas at Pine Bluff. Cocodrie has been normally used as a straighthead susceptible check in straighthead studies. Straighthead and seed set rate were significantly different among the treatments of Check, Nitrogen and, Calcium-I (164.25g Ca/pot) and Calcium-II (328.50g Ca/pot) for all varieties ($p<0.0001$). Nitrogen application reduced straighthead symptom by 1-2 scores for the four varieties, and Ca greatly reduced straighthead symptoms by 2-5 scores in this silt loam soil. Both N and Ca greatly increased the seed set rate for all varieties, but the seed set rate increase by Ca application was greater than that by application of N. In general, the application of additional N can reduce straighthead and increase the seed set rate, while application of Ca greatly reduces straighthead and increase the seed set rate on the Silt Loam soil in the greenhouse conditions.

Development of a User Friendly Method to Produce Massive Amounts of *Rhizoctonia solani* for Field Evaluation of Sheath Blight Resistance

Gibbons, A., Jia, Y., and Bianco, T.

The purpose of this study was to develop a relatively simple, economical, and user friendly method to produce large volumes of *Rhizoctonia solani*. Large volumes of *R. solani* are the key to testing various rice varieties for sheath blight resistance under field conditions. To produce the required amounts of sheath blight fungi, a slow growing sheath blight field isolate (RR0134) was chosen. The field isolate was grown on a potato dextrose agar (PDA) by introducing shredded mycelium-infiltrated filter paper to the culture plate. The plate was incubated at 30°C until the appearance of black-bodied sclerotia. This product was used as the initial inoculant.

To grow large amounts of *R. solani*, corn chops, whole rye grain, and water in the proportion of 2.48 Kg: 1.27 Kg: 3.5 to 3.75 liters (L), respectively were mixed and allowed to soak for 30 minutes. The mixture was then autoclaved for 1 hour at 121°C/1.0 Kg/cm ^{2}. After the media was allowed to cool overnight, it was mixed and double-bagged. The double-bagged media was loosely sealed and autoclaved an additional two cycles (1 hour/121°C/1.0 Kg/cm2). The sterilized media was then transferred into 42 cm x 20 cm x 16cm (11.4L) plastic containers and allowed to cool prior to inoculation. The corn/rye media was inoculated by cutting the PDA media containing *R. solani* into 1 to 2 cm squares. The PDA squares were transferred into the sterilized mixture and the tubs were covered with a lid and placed in a growth environment of 25-30°C and 45% relative humidity. The fungi were grown in the sterilized mixture for 3-5 days until the presence of white-bodied sclerotia were noted. The sheath blight containing media was then air dried and ground.

Ultimately, we produced a total of 87.3 Kg of inoculation media using this method. The ground media was ultimately used to inoculate trimmed leaves of susceptible rice varieties allowing us to verify pathogenicity before storage. We have successfully demonstrated that a large-scale inocula production using this method is suitable to evaluate rice sheath blight resistance in the field.

Fungicide Rate and Timing Implications for Rice Disease Control

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

Disease pressure was higher in Louisiana in 2015 than in 2013 and 2014. Even with the cold winter, blast got an early start on CL151 and Jupiter. Most of the fields with severe leaf blast lost their floods sometime after permanent flood. Fungicide use was high, with most blast-susceptible varieties treated with at least a single 50-70% heading growth stage application. It appears that most of these applications were effective in suppressing blast except in a few situations where rain occurred soon after application, the fungicide was applied too late, or a different mode of action fungicide with poor blast activity was used. Very susceptible varieties required two fungicide applications, one at boot and one at heading, to effectively control blast. Kernel smut severity was higher in some fields due to fungicides being applied at heading rather than the boot growth stage. Sheath blight did not develop to severe levels, even with the all of the rain received during the early season. Most fields were treated once with a strobilurin fungicide at the boot growth stage for sheath blight. Exceptions were in areas where a strobilurin-resistant fungicide sheath pathogen was present. In these fields, the new fungicides Sercadis and Convoy, which have a different mode of activity, were effective against the resistant fungus. The consensus is that sheath blight is becoming more of a problem on hybrid varieties, and fungicide applications have become more common.

Cercospora was present but light in most fields in 2015. Fungicide applications were not as effective as anticipated in some fields, and higher rates and multiple applications of propiconazole-containing fungicides were needed. Fungicide timing for Cercospora should also be adjusted with earlier applications, the later rice is planted. Cercospora was severe in the second crop. Unfortunately, propiconazole is not that effective in controlling Cercospora in the second crop nor is it labeled. Stubble management, including rolling, mowing, and stubble removal, were effective at reducing Cercospora in the ratoon crop.

Rice disease control is becoming more difficult using a single fungicide application due to fungal resistance to fungicides, multiple diseases requiring different timings for effective control, and higher multiple applications being warranted. Rice producers are encouraged to use full labeled rates, rotate modes of actions, and use multiple fungicide applications, when justified, to effectively and economically manage rice diseases.

Abstracts of Posters on Plant Protection
Panel Chair: Xin-Gen Zhou

Analysis of Rice Blast Avirulence Genes in Field Blast Isolates in the Southern USA from 1950 to 2015

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

The avirulence genes in *Magnaporthe oryzae* determine the efficacies of resistance (R) genes in rice. Understanding the dynamics of AVR genes is useful in determining the stability of the effective resistance genes in rice cultivars. A total of 859 rice blast field isolates collected from the southern USA from 1959 to 2015 were investigated. The presence and/or absence of AVR genes were verified using PCR with gene specific DNA primers. The percentages for AVR-Pib, AVR-Pi9, ACE1(AVR-Pi33), AVR-Pizt, AVR-Pita1, and AVR-Pik were 97%, 96%, 92%, 87%, 87%, and 38%, respectively. These findings suggest that Pib, Pi9, Pi33, Piz, and Pi-ta are stable R genes to protect against rice blast disease in the southern USA. The reliability of this prediction will be validated with IRRI monogenic lines carrying corresponding R genes and our progress will be reported.

Screening of Rice Varieties for Resistance to Rice Blast in Turkey

Unan, R., Seidi, M., and Zhou, X.G.

Rice blast is one of the most destructive diseases of rice in Turkey. Screening rice varieties for resistance is essential to the development of blast-resistant varieties under local environments. In this study, we evaluated the reactions of 10 varieties to leaf blast in artificially inoculated research plots and in a naturally infected field in 2015. The experiments were conducted as a randomized complete block design with three replicates. Ten different isolates collected from the Thrace and Anatolia region of Turkey were used for pathogen inoculation. Disease reactions were rated on a scale of 0 to 5 at 20, 40 and 60 days after inoculation. Both evaluations demonstrated significant difference in resistance to rice blast among the varieties. In the inoculated research plots, two varieties (Balaban, Siyah-1) showed to be resistant, five varieties (Karadeniz, Osmancik-97, Mevlutbey, Sumnu, and Cakmak) moderately resistant, and three varieties (Karacadag, Kiziltan, Sariceltik) susceptible. In the naturally-infected field, leaf blast symptoms developed only on the three varieties, Karacadag, Kiziltan, and Sariceltik, but not on other varieties. The two resistant varieties identified in this study may provide the source to develop rice varieties with a broad spectrum of resistance to rice blast. This is the first report of the reactions of rice varieties to rice blast under artificially inoculated field conditions in Turkey.

Development of Sheath Blight-Resistant Lines for Louisiana

Galam, D., Sanabria, Y., Groth, D., and Oard, J.

Sheath blight disease, caused by the fungus *Rhizoctonia solani* Kuhn, is considered a chronic problem for rice producers in Louisiana. The disease greatly affects both grain yield and quality. Fungicides are commonly used to control the disease, but this approach is not always sustainable, cost effective, or environmentally-friendly. The long term goal of this project is to develop sheath blight-resistant germplasm by using conventional breeding approaches coupled with DNA marker technology. During the summer of 2013, 50 moderately susceptible to moderately resistant lines were selected from 700 F_4-F_5 families evaluated at the Rice Research Station, Crowley. In 2014 a total of 129 lines were identified in inoculated plots at Crowley that showed substantially higher levels of resistance than commercial cultivars. A total of 41 resistant advanced lines with desirable height were identified during the 2015 field season. Seven of the 41 lines also exhibited maturity and panicle traits similar to the Louisiana commercial varieties Catahoula, Cocodrie, and CL111. This material will be used in 2016 as pollen donors to create elite backcross and pure line populations adapted to Louisiana conditions. Advanced lines will be also identified using a combination of field evaluation and DNA marker technology.

In Vitro Evaluation of Fungicides for Rice Kernel Smut

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

Kernel smut of rice is more prevalent during rainy years in fields receiving excessive rates of nitrogen fertilizer. Long grain rice including hybrids are more prone to disease than short and medium grain varieties. Although cultural practices are the primary means of managing kernel smut, protective fungicides are often applied in Arkansas to suppress the disease in fields having a history and planted with susceptible varieties. However, in recent years, desired levels of suppression from fungicides containing propiconazole appeared to decrease in efficacy for commercial fields. An *in vitro* study was initiated to evaluate the sensitivity of the kernel smut fungus to new and existing fungicides with an outcome of relating the data to current field practices of fungicide application to suppress disease. Fungicides containing a triazole (propiconazole, difenoconazole, cyproconazole and tetraconazole) individually or in combination with azoxystrobin were included in the test. A fungicide containing azoxystrobin only was included as a control to the pre-mixed fungicides. To compare across treatments, untreated plates were included. The experiment was run at two rates, six replications and repeated four times. Data indicated significant differences in colony counts between the untreated and treated plates. Fungal colonies for each treatment were counted following standard procedure. Colony numbers in untreated plates were estimated due to overcrowding. Differences of 81 to 94 percent were observed among the tested fungicides in suppressing growth of kernel smut on PDA amended agar. Although, azoxystrobin individually was inconsistent in suppressing the growth of the kernel smut fungus, it appeared to complement propiconazole or difenoconazole. Overall, the full rates rendered up to 20 percent suppression compared to the half rates. This study showed the kernel smut fungus is still sensitive to existing and new triazoles but nothing totally suppressed the growth of kernel smut fungus on culture medium. This study suggests further field investigations to relate rates of application, timing, and spray coverage with cultural practices to better manage the disease with existing or new triazole fungicides.

First Record of *Tagosodes orizicolus* Attacking Ratoon Rice in Texas

Way, M., Vyavhare, S., Mock, C., Mock, W., Metz, K., McKamey, S., and Porter, P.

In the fall of 2015, farmers reported an unknown pest attacking ratoon rice west and southwest of Houston. We visited a suspect ratoon rice field in Brazoria County and found large populations (nymphs and adults) of a planthopper attacking rice. Damage was widespread through the field---not limited to specific areas of the field (e.g. margins). However, "hot spots" were observed in this field where rice was dying and brown. In other less affected areas, rice was yellow or bronze, while in other areas with slight damage, rice was still green. Rice was heading to hard dough in this field at the time of these observations. Copious honeydew and sooty mold fungus were also evident.

We collected samples of the planthopper from the above field and sent them off for identification by USDA APHIS. They were identified as *Tagosodes orizicolus* (Muir) – a planthopper native to Central America. Further observations and collections were made in other ratoon rice fields. We found this planthopper in abundant numbers in ratoon rice fields in Fort Bend, Colorado and Wharton Counties, as well as Brazoria County.

We will continue to monitor this invasive pest during the winter of 2015 and the 2016 growing season. We are in the process of developing a research/extension program to manage this pest if it becomes problematic in the future.

Developing a Small UAV Platform to Detect Sheath Blight of Rice

Zhang, J., Zhang, D.Y., Zhou, X.G., and Zhang, G.Z.

Small UAVs (Unmanned Aerial Vehicles) have high potential to be used to detect and manage the diseases of various crops because they are low cost and user-friendly. The objective of this study was to develop a UAV platform to detect sheath blight in rice in the field. A quadrotor drone equipped with high-resolution RGB-/multispectral camera was developed and images from these sensors were collected over research plots of different rice varieties with different levels of sheath blight. The ground truth-NDVIs (Normalized Difference Vegetation Indexes) of these rice varieties were also collected. Through comparison and analysis, there appeared to have a good correlation between the ground truth-NDVIs values collected and the NDVI values extracting from the UAV images. The multispectral images even provide higher accuracy to differentiate different levels of sheath blight. These results indicate that small UAV platform can provide a useful tool to detect the development of sheath blight in rice.

Mexican Rice Borer Distribution and Impact in Louisiana

Wilson, B.E., Beuzelin, J.M., Reagan, T.E., and Stout, M.J.

The Mexican rice borer, *Eoreuma loftini*, is an invasive stemborer (Lepidoptera: Crambidae) which is a major pest of rice, sugarcane, and corn in Texas that has been advancing eastward along the Gulf Coast since the 1980s. Since it was first detected in Louisiana in 2008, ongoing pheromone trap monitoring has tracked eastward expansion of the Mexican rice borer into Louisiana. Pheromone traps and larval scouting documented the first infestations of this pest in rice in southwest Louisiana. Pheromone trap captures and larval infestations throughout the growing season were compared between fields planted with chlorantraniliprole treated seed and those with untreated seed in Calcasieu Parish. Additionally, GIS spatial analysis was applied to pheromone trap data to map population distribution throughout the rice production area of southwest Louisiana from 2013–2015.

This program has now documented occurrence of the Mexican rice borer in 9 Louisiana Parishes: Calcasieu, Cameron, Jefferson Davis, Beauregard, Allen, Acadia, Evangeline, Vermilion, and St. Landry. The invasive pest has become established as an economic pest of rice in Calcasieu, Jefferson Davis, and Acadia Parishes. Pheromone trap monitoring indicates the species is expanding its range eastward at a rate of approximately 22 km per year. Surveys of Mexican rice borer populations in rice revealed damaging infestations levels in fields which did not receive insecticidal seed treatments in Calcasieu Parish in 2012 and 2013. Mexican rice borer damage caused an estimated 4–28% yield reduction in untreated rice in 2013. Chlorantraniliprole seed treatments successfully reduced stem borer injury to <1% of tillers with whiteheads in both years of the survey. Continued monitoring of Mexican rice borer range expansion into Louisiana is needed as the rate of expansion is anticipated to increase in future years as increasing amounts of infested sugarcane are shipped to sugar mills further east.

Comparison of Media and Bait Technique to Detect *Burkholderia glumae* from Soil

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

Bacterial panicle blight (BPB) is among the major diseases of economic importance in Arkansas where nearly 50 percent of the U.S. rice is produced. Although more than one species of *Burkholderia* are known to cause BPB, *Burkholderia glumae* has been frequently isolated on semi-selective agar medium (CCNT) from BPB symptomatic rice florets in the past five seasons. Molecular identification of samples from 2015 also confirmed *B. glumae* as the major causal agent for BPB in Arkansas. Although *B. glumae* is thought to be mainly seedborne, the question arises whether it could also survive in soil. With continuous rice cultivation in some fields of Arkansas, information on the bacteria's survival would be useful for developing control strategies. *B. glumae* was recovered from artificially inoculated sterile and natural soil in preliminary tests with the plating of serial diluted soil suspensions on CCNT. However, detection failed as the bacterial population in the soil declined over time and with further serial dilutions. The objective of this test was to study different agar media and bait technique to detect *B. glumae* from soil containing population levels below the detection level of CCNT. Agar media CPG and SMART were selected based on literature. Yellow onion, carrot, and celery were included for bait comparison. CCNT was included as a control. Natural soil was obtained from a field at the Rice Research and Extension Center near Stuttgart and autoclaved to create sterile soil. The field area was known to have no rice planted in the last five years and tested negative for *B. glumae* before treatment started. Thirty ml of *B. glumae* suspension containing approx. 1.8×10^7 colony forming units (cfu) per ml was added and mixed with 100 g of soil thereby inoculating and establishing non-sterile and sterile soil batches. Serial dilutions were made separately for each soil beginning with 1 gm of soil per 10 ml water and plated onto media following the standard procedure. Media plates were incubated for at least 48 h at 39 ^{o} C. Approx. 1 mm thick layer of onion and about 2.5 cm cross sectioned pieces of celery and carrot were scratched with sterile tools (i.e. pipette tips, needles, etc.) to create a wound prior to inoculation with 10 µl of the respective soil dilutions. Vegetable pieces were kept in a petri dish with moistened filter paper and incubated for at least 4 days at 30^{o} C. Results after 48 h on media indicated the detection level of CPG was similar to CCNT recovering $1x10^6$ cfu/ml soil suspension. However, CPG allowed more contaminates to grow especially at the lower dilutions compared to CCNT. SMART medium did not show as many colonies as expected in 48 h when compared to CCNT or CPG at any of the dilutions. With longer incubation time, SMART media produced distinctive blue colonies ideal for single colony isolation and purification of *B. glumae*. Although yellow onion, carrot and celery were able to detect *B. glumae* at levels tested with CCNT, more refinement in technique with all methodologies was needed to recover this bacterium at even lower populations in the soil.

Characterizing the Role of Gibberellic Acid (GA) in Rice Defense against Fall Armyworm (*Spodoptera frugiperda* Smith) Feeding

Bernaola, L. and Stout, M.

Plants respond to insect herbivory through changes in signaling pathways of defense response, which result in production of secondary metabolites and other resistance-related traits that can reduce insect fitness. Hormonal regulation of these responses has been previously studied and the gibberellin (GAs) and jasmonate (JAs) pathways are two key pathways modulating antagonistically these responses. Gibberellic acid (GA) is a hormone involved in plant growth and development that has not been extensively studied in plant defense against insects, whereas JA is known to be implicated in plant defense responses. In this study, the effect of GA on resistance to fall armyworm was compared in a commercial cultivar of rice *Oryza sativa* (L.) cv 'Cocodrie' and a GA mutant of the Shiokari rice cultivar 'Super Dwarf' deficient in GA production. To explore the effect of GA responses on the negative GA-JA interactions, a greenhouse experiment was conducted in plants treated with or without GA_3 to determine resistance to FAW by measuring the weight gains of larvae and pupae weight of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (FAW) (Lepidoptera: Noctuidae). Treatment with GA_3 resulted in a dose-dependent reduction in growth of FAW on the mutant line but no concentration effect was observed on the commercial line. Larval weight gain showed that GA_3 induced resistance to fall armyworm in the 'Super Dwarf' line. These findings provide evidence to suggest that GA may play a role in plant defense via signaling pathways in response to FAW feeding and suggest further studies of the role of the GA signaling in plant defense are needed.

Baseline Sensitivity to Propiconazole, Azoxystrobin and Fluxapyroxad and Resistance Monitoring in *Cercospora janseana*

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

Narrow brown leaf spot (NBLS) caused by *Cercospora janseana* has become one of the major foliar diseases of rice in southern United States. Cultivar resistance, an effective option for management of this disease, can be lost after a few years of release of a new cultivar because of the development of new races of *C. janseana*. Fungicides have been used for control for this disease for many years. Ineffectiveness of applications of fungicides has been reported recently. The objective of this study was to develop baseline sensitivities to common fungicides to evaluate fungicide efficacy and to monitor potential development of fungicide resistance in *C. janseana* in Texas.

Field isolates of *C. janseana* were used to determine the baseline sensitivities to azoxystrobin [quinone outside inhibitor (QoI)], propiconazole [demethylation inhibitors (DMI)] and fluxapyroxad [succinate dehydrogenase inhibitors (SDHI)]. A total of 50 isolates collected from growers' fields and rice research plots in Texas were evaluated for baseline sensitivities. Each fungicide was tested at various concentrations ranging from 0 to 10 ppm. Actively growing 1-week old mycelium of *C. janseana* isolates was plated at the center of Petri plates containing fungicide-amended media and incubated at 28 ºC under the 12/12h (light/darkness) cycle. Radial growth was measured at 10 days after incubation and baseline sensitivities and EC50 values were determined. Responses to these fungicides differed among the isolates evaluated. The SDHI fungicide fluxapyroxad and the DMI fungicide propiconazole presented a greater inhibition in mycelium growth compared to the QoI fungicide azoxystrobin.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Muthukumar Bagavathiannan

Update on Weed Control in Mississippi Rice

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

Interference from weeds is a primary source of yield loss in Mississippi rice (*Oryza sativa*). Rice yield losses from weed interferences result mainly from poor control of barnyardgrass (*Echinochloa crus-galli*), Palmer amaranth (*Amaranthus palmeri*), *Leptochloa* spp., hemp sesbania (*Sesbania herbacea*), and *Ipomoea* spp. The 2016 Mississippi State University Rice Planning Budget allocates $125 to $150 per acre for herbicides, making weed control one of the single greatest expenses in rice production.

Reports of poor herbicide efficacy and rice injury were common in Mississippi rice during 2014 and 2015. The majority of these problems were directly or indirectly caused by poor environmental conditions during April and May both years. Although it did not affect large acreage in Mississippi, one problem observed both years was injury from imazethapyr on the Clearfield rice hybrid 'CL XL745'. In most cases, injury appeared when applications were completed shortly before or after extreme rainfall events. Stress from the poor growing environment likely reduced the hybrid's ability to metabolize the herbicide; therefore, an unusual level of injury was observed.

Approximately 95% of rice in Mississippi is grown in a 1:1 or 1:2 rotation with soybean (*Glycine max*). Although crop rotation is a primary method to manage herbicide resistance, this issue is a growing problem for Mississippi rice growers. One barnyardgrass population from Sunflower County exhibits multiple resistance to herbicide Groups 1 [acetyl CoA carboxylase (ACCase)], 2 [acetolactate synthase (ALS)], 4 (synthetic auxin), and 7 (photosystem II inhibitors). Other populations exhibit resistance or multiple resistance to different combinations of herbicides in these groups. Resistance to ALS herbicides in rice flatsedge (*Cyperus iria*) has become a widespread problem in Mississippi rice, and ALS herbicides are no longer recommended for application on this species. Lastly, ALS resistance in red rice (*Oryza sativa*) from Mississippi was confirmed through genetic testing in 2015.

Off-target herbicide movement is a perennial problem for rice growers. Mississippi State University Extension Service recommendations suggest application of the non-selective herbicide paraquat mixed with a residual herbicide to control glyphosate-resistant weeds prior to planting corn (*Zea mays*), cotton (*Gossypium hirsutum*), or soybean. Rice is often grown in close proximity to these crops, and cases of off-target movement of paraquat to rice have increased in Mississippi in recent years. Research at the Mississippi State University Delta Research and Extension Center in 2015 showed that injury following exposure to paraquat at 10% of the labeled rate was least with applications at panicle differentiation. However, rice exposed to paraquat at panicle differentiation never matured. Therefore, the full extent of paraquat injury occurring at midseason may not be apparent until later in the growing season.

The Weed Management Research Program at the Mississippi State University Delta Research and Extension Center annually evaluates experimental herbicides and new premixes of older herbicides for their potential in rice. One currently under evaluation is a new herbicide-resistant technology from BASF that will be marketed as Provisia. The Provisia technology is a non-GMO herbicide resistance trait similar to the Clearfield technology. It allows postemergence application of an ACCase herbicide not previously labeled in rice. The herbicide currently under evaluation is quizalofop.

Two applications of quizalofop at 0.115 kg ai/ha provided complete control of red rice and volunteer hybrid rice in 2015. In 2014, red rice control 14 d after early-postemergence applications was reduced when quinclorac, propanil plus thiobencarb, or halosulfuron plus thifensulfuron were added to quizalofop. However, red rice control was similar among all herbicide treatments 14 d after early-postemergence applications in 2015. Tank mixtures with quizalofop will likely be restricted with fewer options than currently available in a Clearfield rice weed control system.

Emerging Weed Issues in Texas Rice

Bagavathiannan, M., Zhou, X.G., Liu, R., Samford, J., Vawter, J., and Bradshaw, G.

Weed management is a growing challenge in Texas rice production, but region-wide information on problem weed issues and weed management research needs is currently lacking. Field and stakeholder surveys were conducted to better understand the prevalence of herbicide-resistant weeds as well as other problem weed issues across the major rice producing counties in Texas. A semi-stratified survey methodology was implemented to document weed escapes in rice fields during late summer. Seed samples were also collected during the survey to test them for resistance to some commonly used rice herbicides such as clomazone, propanil, quinclorac, fenoxaprop and imazethapyr. Additionally, a paper-based survey was also conducted to understand the perspectives of growers and crop consultants on weed management issues and research needs in Texas rice. Surveys revealed that barnyardgrass, weedy rice, Nealley's sprangletop and hemp sesbania are the dominant weed issues in this region. Preliminary evaluations have also revealed that herbicide-resistant weeds are emerging to be a significant concern.

Evaluation of Alternate Wetting and Drying Water Management on Barnyardgrass (*Echinochloa crus-galli*) Control for Conventional and Clearfield® Herbicide Programs in Rice (*Oryza sativa* L.)

Atwill, R.L., Krutz, L.J., Bond, J.A., and Golden, B.R.

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 hectare meters per year and has done so for approximately 30 years. Recently, efforts have been made to reduce the amount of irrigation water used for rice production. While alternate irrigation strategies are a viable option to reduce aquifer withdrawals, changes in current weed control practices must be addressed prior to widespread adoption of water-saving irrigation regimes in the mid-south. An experiment was conducted at the Delta Research and Extension Center in Stoneville, MS to evaluate the control of barnyardgrass for conventional and Clearfield herbicide programs in an alternate wetting and drying (AWD) irrigation regime as compared to a continuous flood. Experimental plots were over-seeded with barnyardgrass and evaluated for barnyardgrass control. Control of barnyardgrass and rice grain yield in experimental plots were not different for rice grown under continuous flood compared to AWD (20 cm below soil surface). Barnyardgrass control for Clearfield® herbicide program was 93% pooled over all herbicide treatments, and was not different for continuous and AWD irrigation. For conventional rice, barnyardgrass control (pooled over all herbicide treatments) for continuous irrigation averaged 74% control, while AWD irrigation averaged 82% control. Water management practices that reduce groundwater withdrawals are a viable option for rice producers in the mid-south. In addition, barnyardgrass control in AWD irrigation is maintained compared to a continuously flooded system using current herbicide programs for conventional and Clearfield® rice production systems.

Germination and Growth of Prominent Rice Weeds as Influenced by Flooding

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

Flooding is an important tool for weed management in rice production. Whether or not weeds can emerge under flooded conditions and how flooding at different stages of weed growth can impact their growth and development are not well understood. This study investigated the germination and growth characteristics under flooding of various weeds present in Texas rice culture. Twelve common weed species were chosen based on their presence in rice culture, including weedy rice (*Oryza sativa f. spontanea*), broadleaf signalgrass (*Brachiaria platyphylla*), hemp sesbania (*Sesbania herbacea*), barnyardgrass (*Echinochloa crus-galli*), amazon sprangletop (*Leptochloa panicoides*), Palmer amaranth (*Amaranthus palmeri*), waterhemp (*Amaranthus rudis*), Johnsongrass (*Sorghum halepense*), Neally's sprangletop (*Leptochloa nealleyi Vasey*), northern jointvetch (*Aeschynomene virginica*), yellow nutsedge (*Cyperus esculentus*) and yellow foxtail (*Setaria pumila*). Two separate experiments were conducted. 1) seedling emergence: one hundred seeds of each species were planted in plastic containers under three flooding treatments (periodic flushing, 2.5 cm and 6.5 cm flooding levels) and three replications. Emergence was recorded every three days, indicative of germination potential. 2) growth and development: weed seedlings were grown in plastic cups (17 cm tall x 11 cm diameter) and were exposed to 6.5 cm of standing water at different growth stages (just emerged, 2 cm, 5 cm and 10 cm tall). Plant growth characteristics such as plant height, biomass, seed number and root volume were recorded. Weedy rice and hemp sesbania showed an excellent ability to germinate under both levels of flooding, while the germination levels of barnyardgrass and amazon sprangletop were reduced by flooding. Palmer amaranth, waterhemp, johnsongrass, yellow nutsedge and broadleaf signalgrass did not germinate under both levels of flooding. Except for weedy rice, all other species could not continue to survive when flooding occurred prior to the 2 cm seedling stage. Results of this study will be helpful in developing an effective irrigation management strategy for weed control in rice.

Field Evaluation of Potential Weed-Suppressive Traits in an Indica x Tropical Japonica Mapping Population

Gealy, D., Pinson, S.R. M., Jia, Y., and Zhang, F.

The *indica* rice accession, PI 312777 (a.k.a. WC 4644), is highly productive and can suppress barnyardgrass (*Echinochloa crus-galli*) in reduced-input systems, but the genetic control of this weed suppression is unknown. A set of 330 recombinant inbred lines (RILs) was developed using single seed descent from a cross between ‘Katy’ (non-weed-suppressive tropical *japonica* [TRJ]) and PI 312777 (weed-suppressive, allelopathic) for the purpose of identifying the genetic bases of weed suppression. The objective of this study was to evaluate potential weed suppressive traits with which to select a subset of F_8 RILs exhibiting extreme contrasting phenotypes for further evaluation in field, greenhouse, and laboratory experiments, to identify QTLs for these traits, and to further evaluate the role of each gene and trait in weed suppression and allelochemical exudation. At Stuttgart, AR in 2015, three replicate plots each of 330 RILs (F_8 seed) were drill-seeded at a rate of ~320-330 seeds/plot in 2.13 m long plots consisting of two rows 30.5 cm apart. Nitrogen fertilizer was broadcast at a rate of 110 kg ha^{-1} as urea before application of the permanent flood, and plots were maintained weed free using commercially available herbicides and hand-weeding. Transgressive variation was observed among most phenotypic traits, many of which have been shown to be associated with weed suppression. These included leaf area development, seedling growth rate, plant height, tiller number, and grain yield. Leaf area per plant (estimated as total leaf number per plant x average length of 5 leaves x average width of 5 leaves at the midpoint) at 3 weeks after emergence (WAE) ranged from 3 to 221 cm^2, averaging 73 cm^2, compared with 79 and 55 cm^2 for the *indica* and TRJ parents, respectively. Seedling growth rate from emergence to 2 weeks after permanent flood (WAF) ranged from 0.9 to 2 cm/day, averaging 1.4 cm/day, which was the same as both parents. At 2 WAF plant heights ranged from 35 to 85 cm, averaging 56 cm, compared with 56 and 57 cm for the *indica* and TRJ parents, respectively. Plant growth rate from 2 WAF to maturity ranged from 0.27 to 3 cm/day, averaging 1.1 cm/day, compared with 0.9 and 1.2 cm/day for the *indica* and TRJ parents, respectively. Tiller number at 2 WAF ranged from a rating of 1 to 6 (based on a relative scale in which the *indica* parent was defined as 5 and the TRJ parent was defined as 1), averaging ~3. Days to heading ranged from 58 to 130 days after emergence (DAE), averaging 86 DAE, compared with 85 DAE for both parents. Mature plant heights ranged from 62 to 164 cm, averaging 109 cm, compared with 101 and 115 cm for the *indica* and TRJ parents, respectively. Grain yields ranged from to 2160 kg ha^{-1} to 11000 kg ha^{-1}, compared with ~11030 kg ha^{-1} and 8390 kg ha^{-1} for the *indica* and TRJ parents, respectively. A replicated greenhouse study was conducted with F_9 plants to evaluate tiller and panicle development over time. Tiller number at 5 WAP ranged from 1.8 to 5.0 tillers/plant, averaging 3.2, compared with 4.1 and 2.9 tillers/plant for the *indica* and TRJ parents, respectively. Panicle number at maturity ranged from 1.9 to 8.0 panicles/plant, averaging 3.2, compared with 4.3 and 2.6 panicles/plant for the *indica* and TRJ parents, respectively. Panicle number was moderately correlated with tiller number at 5 WAP (r=0.44) and more highly correlated with tiller number at 11 WAP (r=0.72). Overall, several RILs were taller, had greater growth rates, and produced more leaf area than either parent, suggesting that they might be well-suited for weed suppression, however few RILs consistently produced more tillers or yield than the *indica* parent in the field. A subset of these RILs, based on contrasting phenotypes, is being selected for mapping studies. These results will be used to identify rice genotypes that optimize both weed suppression and crop productivity for reduced-input systems.

Nealley's Sprangletop (*Leptochloa nealleyi*) Control in Louisiana Rice Production

Bergeron, E.A., Webster, E.P., McKnight, B.M., and Rustom, S.Y.

A study was conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA in 2014 and 2015 and a grower location near Estherwood, LA in 2015 to evaluate herbicide timing for Nealley's sprangletop (*Leptochloa nealleyi* Vasey) control. The study was a randomized complete block design with four replications. In 2014, Clearfield 'CL 151' rice was drill-seeded at 90 kg/ha and Clearfield 'CL 111' rice was planted at the same rate in 2015. Previous research indicated quinclorac plus halosulfuron had no control of Nealley's sprangletop; therefore, quinclorac at 420 g ai/ha plus halosulfuron at 53 g ai/ha was applied delayed preemergence (DPRE) to control grasses, sedges, and broadleaf weeds in the plot area. Herbicide treatments consisted of fenoxaprop at 122 g ai/ha at 1, 2, 3, 4, 5, and 6 weeks after emergence (WAE) in order to determine when control measures should be initialized to maximize Nealley's sprangletop control and rough rice yield. A weed-free plot was also added by employing herbicide application and hand-weeding for a comparison to treatment.

At harvest, rice treated with fenoxaprop 1 WAE compared with the nontreated yielded 6790 and 5349 kg/ha, respectively. By delaying the initial application of fenoxaprop, a sizeable reduction in rice yield was observed. Comparing rice yields of 1 WAE to 6 WAE applications resulted in a 1276 kg/ha decrease; which is a loss of 36.4 kg/ha per day by delaying treatment. At current rice market price that results in an $8.00 loss per day for every day the herbicide application is delayed.

A study was established in a glasshouse on the Louisiana State University campus in Baton Rouge, Louisiana in 2014, 2015, and 2016. The objectives were to evaluate herbicides for control of Nealley's sprangletop. The study was a completely randomized design with nine replications. Nealley's sprangletop seed was planted in plastic planting flats with 60, 2.5 by 2.5 cm cells filled with Jiffy potting mix until reaching one- to two-leaf growth stage. After reaching the appropriate size, the Nealley's sprangletop was transplanted into 6- by 10-cm cone containers filled with Jiffy potting mix and placed into racks. The racks were placed in plastic containers, 41cm by 41cm by 47 cm, and filled with 67 L of water for subsurface irrigation for the length of the study. Urea fertilizer, 46-0-0, was added to the water at 280 kg/ha at the three- to four-leaf stage.

Nealley's sprangletop had one- to two-tillers with a height of 20- to 30-cm at herbicide application. Herbicides applied were: propanil at 4480 g ai/ha, propanil plus thiobencarb at 6720 g ai/ha, quinclorac at 420 g/ha, thiobencarb at 4480 g ai/ha, bispyribac at 28 g ai/ha, imazethapyr at 105 g ai/ha, imazamox at 44 g ai/ha, penoxsulam at 40 g ai/ha, clethodim at 150 g ai/ha, cyhalofop at 314 g ai/ha, fenoxaprop at 122 g ai/ha, quizalofop at 120 g ai/ha and 185 g ai/ha, glufosinate at 450 g ai/ha, glyphosate at 840 g ai/ha, EXP-001 at 118 g ai/ha. Nealley's sprangletop control, leaf number, tiller number, and height were evaluated at 0, 5, 10, 14, 21 and 28 days after treatment (DAT). Fresh plant biomass was obtained at 28 DAT.

At 21 DAT, control and height reductions occurred with propanil, propanil plus thiobencarb, cyhalofop, quizalofop, clethodim, glyphosate, glufosinate, fenoxaprop, imazethapyr, imazamox, thiobencarb, and EXP-001, compared with the nontreated. Applications of fenoxaprop and quizalofop at both rates on Nealley's sprangletop had no leaves or tillers 21 DAT. Nealley's sprangletop treated with fenoxaprop, and quizalofop was controlled 95 to 98%. Penoxsulam, bispyribac, and quinclorac had little to no activity on Nealley's sprangletop with control 0 to 10%. Imazethapyr and imazamox reduced overall height of Nealley's sprangletop, but caused excessive tillering and achieved less than 20% control. From a burndown standpoint, glyphosate controlled Nealley's sprangletop 94% and glufosinate 50%.

Nealley's sprangletop may not be highly competitive with rice, however it is a prolific seed producer with high seed viability. Fenoxaprop, quizalofop, propanil, and clethodim are more active when applied to young actively growing Nealley's sprangletop, and should be applied in a timely manner to optimize control and maximize yield. It is important to correctly identify this weed in order to select the appropriate weed management program. Currently, the best herbicide option for Nealley's sprangletop control is fenoxaprop applied at 122 g ai/ha. With the development of Provisia rice, a new rice cultivar resistant to quizalofop, quizalofop will also be a useful tool in Nealley's sprangletop management.

Evaluation of Late Season Salvage Options for Barnyardgrass and Amazon Sprangletop in Midsouth Rice

McCown, M.S., Barber, L.T., Norsworthy, J.K., Hill, Z.T., and Doherty, R.

Late season weed emergence is a continuing problem in Midsouth rice production. Weed emergence in the later part of the season can be due to improper herbicide application timing, herbicide coverage, or poor water management. Unfortunately, these circumstances can lead to salvage situations where the grass species begin growing rapidly, infests the rice crop, and eventually can overtake the crop. In particular, two of the most troublesome grass weeds in rice are barnyardgrass (*Echinochloa crus-gali*) and Amazon sprangletop (*Leptochloa panicoides*). In 2015, an experiment was conducted at the Southeast Extension and Research Center in Rowher, Arkansas to evaluate control options for late-season grass escapes and to evaluate crop tolerance of CL111 cultivar. Nine commonly used rice herbicides were evaluated alone and in combination. Various combinations of the following herbicides were evaluated: saflufenacil at 0.025 kg ai/ha (1 oz/A) (Sharpen), cyhalofop at 0.31 kg ai/ha (15 oz/A) (Clincher), quinclorac at 0.28 and 0.42 kg ai/ha (21.3 and 32 oz/A) (Facet L), fenoxaprop at 0.122 kg ai/ha (24 oz/A) (Ricestar HT), and quizalofop at 0.09 kg ai/ha (13 oz/A) (Targa). Herbicide treatments were applied at 4- to 5-leaf grass (MPOST), 14 days after first application (PREFLD), and after flood (POSTFLD). The MPOST application was applied a 26 days after the crop was planted. At the PREFLD application, greatest control was observed with Ricestar HT at 97% control of both barnyardgrass and Amazon sprangletop. Comparable control was observed with the addition of Sharpen or Facet L at 0.42 kg ai/ha (32 oz/A) with Ricestar HT. However, a significant difference in injury was observed between these treatments. Injury was 43% with Ricestar HT+Sharpen, 25% with Ricestar HT alone, and <5% with Ricestar HT+Facet L. Treatments including Targa caused severe crop injury, eventually leading to plant death; however, provided excellent control of the weed species evaluated. At 21 days after the MPOST application, rice in all other plots had out-grown most injury symptoms. At 16 days after the POSTFLD application, the addition of the low rate (21.3 oz/A) of Facet L to any tank mixture caused slight antagonist effect on the control of Amazon sprangletop. At the end of the season, greater than 94% control of barnyardgrass was observed across all treatments; however, improved control was observed in plots with sequential herbicide applications. Amazon sprangletop control of >97% was observed with treatments including: Ricestar HT fb Ricestar HT PREFLD, Clincher fb Clincher POSTFLD, and Ricestar HT+Facet L at 0.42 kg ai/ha (32 oz/A) fb Clincher POSTFLD. From these results we can conclude that sequential applications are needed to control late season grass escapes, particularly barnyardgrass and Amazon sprangletop.

Evaluation of Command Plus Obey Programs for Control of Barnyardgrass and Amazon Sprangletop in Rice

Rose, J., Barber, L.T., Norsworthy, J.K., and Doherty, R.

Barnyardgrass and Amazon sprangletop are two of the most troublesome grass weeds in rice production in Arkansas. With resistance to propanil and quinclorac becoming more prevalent in barnyardgrass, other herbicides with different mechanisms of action will have to be used. Clomazone, commonly known as Command 3 ME, was introduced into rice production in 2001. Though Command can cause some injury to rice, it has quickly become the foundation for the management of propanil- and quinclorac-resistant barnyardgrass in Arkansas. In late planted rice, the use of Command alone or in a tank mix with quinclorac could increase the control of barnyardgrass and Amazon sprangletop when incorporated into a herbicide program. In 2015, a trial was conducted to investigate the use of Command alone or premixed with quinclorac, commonly known as Obey, to control barnyardgrass and Amazon sprangletop in rice. This trial was conducted on a Sharkey clay soil at the Southeast Research and Extension Center located in Rohwer, Arkansas. Herbicide programs included Command at 449 or 897 g ai/ha applied preemergence (PRE), Obey at 897 g ai/ha PRE, Prowl H2O (pendimethalin) at 1065 g ai/ha applied delayed PRE (DPRE), and Ricebeaux (propanil + thiobencarb) at 5.04 kg ai/ha applied postemergence (POST). At 16 days after PRE applications, greatest control was observed with treatments including the high rate of Command. At 55 days after initial application, Command at 897 g ai/ha followed by (fb) Prowl + Ricebeaux POST continued to provide >95% control of both species. However, control was comparable to other programs that include Obey PRE fb Command at 449 g ai/ha + Ricebeaux POST and Obey PRE fb Prowl DPRE fb Ricebeaux POST. At 70 days all three of these programs provided >90% of control of both species, suggesting that applying a PRE application of Command or Obey at 897 g ai/ha is needed. Based on this research, using Command at 897 g ai/ha PRE fb Prowl + Ricebeaux POST, Obey PRE fb Prowl DPRE fb Ricebeaux POST, and Obey PRE fb Command at 449 g ai/ha + Ricebeaux POST all provided ≥90% control of barnyardgrass and Amazon sprangletop throughout the course of the season.

Comparison of Rebel EX and Grasp Extra in Rice

Steppig, N.R., Norsworthy, J.K., and Barber, L.T.

With a little less than 1.214 million ha planted in 2015, rice is an important crop both in the Midsouth and in California. An integral part of a successful crop, no matter what region it is grown in, is weed control. Weed interference with rice can result in almost complete crop failure in the absence of effective control options. Fortunately, a variety of effective chemical control options exists for control of barnyardgrass (*Echinochloa crus-galli*) and other weeds common to rice production systems. Two particular products, Rebel EX® and Grasp® Xtra (Dow AgroSciences, Indianapolis, IN) provide multiple modes of action for controlling grass and broadleaf weeds in rice systems. A field trial was conducted in 2014 at the Southeast Research and Extension Center in Rohwer, Arkansas, and in 2015 at the University of Arkansas Rice Research and Extension Center near Stuttgart, Arkansas to evaluate the effectiveness of both products in a weed control program. Tests in 2014 examined the utility of Rebel EX® and Grasp® Xtra as part of weed control programs in combination with labeled rates and application timings of herbicides common in Arkansas rice production. Results from the 2014 field trial showed that programs containing both herbicides provide excellent control of two particularly troublesome weeds - barnyardgrass and hemp sesbania (*Sesbania herbacea*). In 2015, the trial focused on control directly resulting from two different application timings (pre-flood and post-flood) of Rebel EX® and Grasp® Xtra. Results from this field trial indicate that both herbicides provide excellent season-long northern jointvetch (*Aeschynomene virginica*) control and at least one month of adequate barnyardgrass control following application; however, delaying application timing resulted in larger barnyardgrass plants at treatment and regrowth of the noncontrolled plants. Based on the results of both trials, Rebel EX® and Grasp® Xtra will provide control of several of the most problematic weeds of rice when applied in a timely manner; thus, these products should be integrated into programs that rely on a multiple effective herbicides for providing season-long weed control in rice.

Tolerance of Rice to Warrant

Jones, G.T., Norsworthy, J.K., Godwin, J.A., Rose, J., and Scott, R.C.

Herbicide resistance is a continuing problem that an increasing number of growers face each year. Proactive approaches to resistance are needed to ensure the sustainability of weed control in agriculture. Currently, there are no group 15 herbicides labeled for in crop use in rice. Warrant, a group 15 herbicide, is an encapsulated form of acetochlor marketed by Monsanto for use in corn, cotton, grain sorghum, and soybean. Warrant offers residual control of several problematic weeds in rice such as barnyardgrass (*Echinochloa crus-galli*), red rice (*Oryza sativa*), broadleaf signalgrass (*Urochloa plattyphylla*), and Palmer amaranth (*Amaranthus palmeri*). A field study was conducted in Stuttgart, AR at the Arkansas Rice Research and Extension Center in 2015 to examine the effect of Warrant application timing and rate on injury to rice (*Oryza sativa*). Warrant was applied at rates of 0.63 kg/ha (1.5 pt/A) and 1.04 kg/ha (2.5 pt/A). Timings were delayed PRE (DPRE), spiking, 1-leaf to 2-leaf rice, and 3-leaf to 4-leaf rice. Stands were not reduced by any treatment. Injury was observed at all timings; however, it was minor and disappeared in all treatments except DPRE (5%) by 21 days after treatment (DAT). Injury was not apparent at any point past 21 DAT. Yields were not significantly reduced for any treatment. As this study documented, the addition of Warrant to rice weed control programs could result in minimal injury and not affect rice yields while offering excellent control of several problematic small-seeded grasses and broadleaves.

How Important is the Selection of Adjuvants When Applying Sharpen in Rice?

Hale, R.R., Norsworthy, J.K., Young, M.L., Lancaster, Z.D., and Scott, R.C.

Sharpen is a contact herbicide that can be used for broadleaf weed control in rice. It is beneficial to include an adjuvant in combination with Sharpen to achieve optimum weed control. Currently, Sharpen at 73.1 ml/ha (1 fl oz/A) + methylated seed oil (MSO) at 1169 ml/ha (1 pt/A) is recommended as a burndown application prior to planting. Sharpen at 73.1 ml/ha (1 fl oz/A)+ 1% v/v crop oil concentrate (COC) can be applied from the 2-lf stage through panicle initiation. Current recommendations do not include the use of MSO nor the use of COC at 2338 ml/ha (1 qt/A). However, this additional adjuvant may aid in weed control which would be beneficial. A field study was conducted at the Pine Tree Research Station near Colt, AR to evaluate the tolerance of rice to Sharpen with COC and MSO at 1169 ml/ha (1 pt/A) and 2338 ml/ha (1 qt/A), and when tank-mixed with Facet L at 3142 ml/ha (43 fl oz/A). All applications were made using a CO_2-pressurized backpack sprayer calibrated to 140.3L/ha (15 GPA). Treatments were applied at different growth stages including: 1-lf rice, 3-lf rice, 1.27 cm (0.5-inch) internode elongation, and 7.6-10.2 cm (3 to 4 inch) joint. Only main effects of adjuvant, Facet use, and application timing were significant for rice yield. In general, the addition of MSO to Sharpen increased rice injury over the addition of COC to Sharpen; however, this increase in injury did not translate into a reduction in yield. Plots receiving applications containing Sharpen plus COC at 1169 ml/ha (1 pt/A) had yields of 8221 kg/ha while rice yielded 7818 kg/ha when Sharpen was applied with MSO at 1169 ml/ha (1 pt/A). The 2338 ml/ha (1 qt/A) rate of MSO and COC resulted in rice yields comparable to the lower use rate for each adjuvant. Treatments applied at the 1.27 cm (0.5-inch) internode elongation stage or earlier showed no differences in rice yield which was 900-1035 kg/ha (20 to 23 bu/A) greater than when Sharpen was applied at the 7.6-10.2 cm (3 to 4 inch) joint stage. Based on these results, yield loss can be observed when Sharpen is applied beyond the 1.27 cm (0.5-inch) internode elongation growth stage, and while MSO may increase rice injury this does not translate to reductions in yield.

Rice Performance Following Exposure to Low Rates of Residual Herbicides

Lawrence, B.H., Edwards, H.M., Hydrick, H.T., Bond, J.A., Golden, B.R., Phillips, T.L., and Peeples, J.D.

In Mississippi, rice (*Oryza sativa*) is produced within the Mississippi and Yazoo river alluvial floodplains, and it is commonly grown adjacent to corn (*Zea mays*), cotton (*Gossypium hirsutum*), and soybean (*Glycine max*). Glyphosate-resistant weeds, primarily glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), are the principal weed control issue facing row crop growers in Mississippi. Residual herbicide applications prior to planting for glyphosate-resistant weed control have been widely adopted in cotton, corn, and soybean; however, these applications often include paraquat, and off-target movement to rice from these applications is common. Injury symptoms can be complex because multiple modes of action are represented. Therefore, research was conducted to characterize the rice response to exposure to a sublethal rate of Gramoxone SL applied in mixtures with different residual herbicides.

Research was conducted in 2015 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate the effect on rice growth and development of applications of sublethal rates of Gramoxone SL mixed with residual herbicides. The experimental design was a randomized block with four replications. Herbicide treatments were applied at 10% of the rates recommended for application in Mississippi. They included Gramoxone SL at 0.0834 kg ai/ha alone and in mixtures with Authority MTZ at 0.0556 kg ai/ha, Boundary at 0.2256 kg ai/ha, Canopy at 0.0052 kg ai/ha, Corvus at 0.0127 kg ai/ha, Cotoran at 0.1112 kg ai/ha, Envive 0.0114 at kg ai/ha, Fierce at 0.0198 kg ai/ha, Lexar EZ at 0.2859 kg ai/ha, Prefix 0.3089 at kg ai/ha, and Sonic 0.0313 kg ai/ha. A nontreated control was included for comparison. Treatments were applied to rice in the two- to three-leaf growth stage. 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, and rice lodging severity was visually estimated at maturity. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

At 7, 14, and 28 DAT, the greatest rice injury was observed following Gramoxone SL plus Lexar EZ. Gramoxone SL plus Authority MTZ, Boundary, or Cotoran caused less injury than Gramoxone SL plus Lexar EZ 7 DAT; however, injury was still ≥ 51% with these treatments. Injury was 41% with Gramoxone SL alone 14 DAT, and this level of injury was similar to that from mixtures of Gramoxone SL with Canopy, Fierce, or Prefix. All other herbicide mixtures except Gramoxone SL plus Lexar EZ injured rice 50 to 54% 14 DAT. Gramoxone SL plus Corvus injured rice 76% 28 DAT, but this was less than injury observed with Gramoxone SL plus Lexar EZ. Injury to rice with mixtures of Gramoxone SL plus Prefix or Fierce was comparable to Gramoxone SL alone 28 DAT. All treatments delayed maturity ≥ 11 d; however, Gramoxone SL plus Lexar EZ delayed maturity 15 d compared with the nontreated control. Rice height and lodging severity estimations were similar following application of all herbicide mixtures.

Injury was greatest when Gramoxone SL was mixed with residual herbicides representing Group 27 compared with herbicides in other groups. Injury was ≥ 53% 28 DAT and maturity was delayed ≥ 11 d with all treatments; therefore, applications of Gramoxone SL plus residual herbicides to fields in proximity to rice should be avoided if conditions are conducive for off-target movement.

Sensitivity of Grass Crops to Drift Rates of Quizalofop

Palhano, M.G., Norsworthy, J.K., Lancaster, Z.D., Steppig, N.R., Green, J.K., and Scott, R.C.

As the evolution of herbicide resistance continues, new technologies are required to properly achieve control of herbicide-resistant weeds. BASF is currently developing a new non-GMO rice called Provisia that will be resistant to quizalofop, an ACCase-inhibiting herbicide. Along with the benefits brought with this new technology, there is also concern about potential off-target movement on to common Arkansas grass crops. Hence, three field experiments were conducted in 2014 and 2015 at the University of Arkansas Northeast Research and Extension Center in Keiser to evaluate the sensitivity of corn (*Zea max*), grain sorghum (*Sorghum bicolor*), and conventional rice (*Oryza sativa*) to drift rates of quizalofop. The experiment was set up as a 2 factor factorial, randomized complete block design, with factor A being drift rate of quizalofop and factor B being growth stage at application. Drift rates used in the studies were 1/10x, 1/25x, 1/75x, 1/100x, and 1/200x of a proposed labeled rate of 0.14 lb ai/A. All drift rates were applied at three growth stages of corn and grain sorghum and two growth stages of rice. Applications were made using a CO_2-pressurized backpack sprayer at 15 GPA. Results demonstrated that grain sorghum and corn are fairly tolerant to drift rates of quizalofop. However, plots where the 1/10X rate were at the 2- to 3-leaf or boot stage seemed to be the most injurious to grain sorghum with 27 and 36% injury, respectively. Corn was highly sensitive to the higher drift rate of quizalofop when applied at the 2- to 3-leaf stage. Visual injury averaged 40%, and corn yield was reduced by 61% from the 1/10X rate at 2- to 3-leaf stage relative to the nontreated control. Rice did not exhibit any negative effects at the quizalofop drift rates tested at any of the application timings.

Will an Insecticide Seed Treatment on Rice Reduce Injury from Drift Rates of Glyphosate and Imazethapyr?

Martin, S., Norsworthy, J., Scott, R., Lorenz, G., Hardke, J., and Lancaster, Z.

Every year there are multiple reports of drift occurrences in rice. With a large percentage of crops being glyphosate-resistant and approximately 50% of Arkansas rice being non-Clearfield (imidazolinone-resistant), the majority of drift complaints in rice are from Newpath (imazethapyr) or Roundup (glyphosate). In 2014 and 2015, a field experiment was conducted at the Rice Research and Extension Center in Stuttgart, Arkansas and at the University of Arkansas Pine Bluff farm in Lonoke, Arkansas to evaluate whether or not insecticide seed treatments could reduce injury from Roundup or Newpath drift or decrease the recovery time of the rice. 'Roy J' rice was planted and simulated drift events of a 1/10 rate of Newpath or Roundup was applied to each plot. Each plot had either a seed treatment of CruiserMaxx Rice, NipsIt INSIDE, Dermacor X-100, or a fungicide-only seed treatment. The simulated drift event was applied at the 2- to 3-leaf growth stage. Crop injury was assessed 2 and 5 weeks after treatment (WAT). Rice water weevil samples were taken 3 weeks after flood for the 2015 locations. All seed treatments provided increased rice water weevil control over the nontreated insecticide plots in the event of herbicide drift. CruiserMaxx Rice and NipsIt INSIDE provided reduced injury over the fungicide-only treatments at both 2 and 5 WAT. Dermacor X-100 was equal to the fungicide-only treatment at both ratings. CruiserMaxx Rice and NipsIt INSIDE provided increased yields over the fungicide-only treatment with Dermacor X-100 yielding equivalent to the fungicide-only treatment. Based on these results, CruiserMaxx Rice and NipsIt INSIDE have potential to provide some safening against Newpath and Roundup drift whereas Dermacor X-100 will provide marginal or no safening to these herbicides.

Are Rice Insecticide Seed Treatments Safening Rice from POST Herbicides?

Meyer, C.J., Norsworthy, J.K., Martin, S.M., Scott, R.C., Lorenz, G., and Hardke, J.T.

Recent evidence and observation suggests that insecticide seed treatments may have a greater impact on crop performance beyond controlling the insects they are intended for, such as protecting rice and aiding in crop recovery from various herbicide applications. A field experiment designed as a randomized complete block factorial was conducted at the Rice Research and Extension Center near Stuttgart, AR in 2014 and 2015 to determine if an insecticide seed treatment could reduce rice injury to common rice herbicides. The objective of these experiments was to evaluate if CruiserMaxx Rice seed treatment could potentially safen against high rates and multiple applications of common rice POST herbicides compared to a standard fungicide-only seed treatment control. The factorial treatment structure consisted of 8 herbicides applied to both insecticide/fungicide treated and fungicide-only treated seed.

Nonherbicide controls were included for both seed treatments. Various rates and either single or multiple applications of propanil, saflufenacil, and carfentrazone were applied to rice POST and evaluated for crop injury, canopy height, and yield. For crop injury, assessed two weeks after the final herbicide application, and canopy height, no "herbicide*seed treatment" interaction was observed (p=0.5257, 0.9449, respectively). Averaged across both years and all herbicides, the seed treatment main effect showed that CruiserMaxx Rice reduced injury by 8% compared to the standard. The greatest injury to the crop was observed when carfentrazone (0.56 kg ai ha^{-1}) was applied alone or with propanil (4.5 kg ai ha^{-1}). When canopy heights were collected at 1 cm internode elongation, the height of CruiserMaxx Rice treatments were 3 cm taller than the standard, averaged across all herbicides (p=0.0056). Averaged across all herbicide treatments, the insecticide seed treatment improved yield by 303 kg ha^{-1}. This research shows that CruiserMaxx Rice is positively influencing rice recovery from POST herbicides, providing a competitive advantage to rice beyond controlling insects, and ultimately improving rice yield.

Influence of Environmental Conditions on the Efficacy of Quizalofop on Junglerice and Weedy Rice

Rouse, C.E., Burgos, N.R., and Harden, J.

In recent years, an increased value has been placed on improved herbicide efficacy not just for weed control but as a necessity for reducing the incidence of resistance evolution to herbicides. A number of factors, including environmental conditions, play a role in how the herbicide will interact with the plant from the time of application to the inhibition of target proteins. A greenhouse study was conducted to evaluate the effects the environment, at or around the time of application, has on the efficacy of quizalofop for control of weedy rice (*Oryza sativa*) and junglerice (*Echinochloa colona*). Three environmental conditions were evaluated: shade (to simulate cloud cover), dry down prior to herbicide application, and simulated rainfall following application. Shade treatments included shading for 2 days before application (DBA), 2 days after application (DAA), and no shade. Three dry down treatments were included commencing at 10 DBA, 5 DBA, and a control in which field capacity was maintained up to application. Following the herbicide application, simulated rainfall events occurred 1 hour after application (HAA), 5 DAA, and 10 DAA. The fourth factor was weed, including susceptible- and graminicide-tolerant populations of weedy rice and junglerice. Quizalofop (60 g ha^{-1}) was applied over the top to pots with 5 plants at the 2-leaf growth stage. The plants were evaluated for visual injury and biomass 3 weeks after application. For analysis, each shade treatment with all of the subfactors was analyzed separately; dry down was a random effect; and a factorial arrangement of simulated rainfall by species was evaluated using ANOVA procedure. Shading played a role in herbicide response; shading prior to herbicide application resulted in greater weed injury (88%) than all other shade treatments. Simulated rainfall following application had negative impacts as well, reducing herbicide efficacy by as much as 25%. In this test, shoot biomass was impacted more by water availability than the herbicide application. These results indicated that cloudy or rainy conditions, which are often encountered around planting season, may result in increased crop injury following quizalofop applications. It appears that light plays a greater role in weed/crop response to herbicide than the soil moisture conditions around application time.

Provisia Rice Production System Efficacy and Stewardship

Guice, J., Youmans, C., Rhodes, A., Schultz, J., and Harden, J.

The Provisia™ Rice System, a new non-GM herbicide tolerant system under development by BASF, will complement the Clearfield® Rice System by providing growers another effective tool for weed control and resistance management in rice. The system will be a combination of Provisia traited rice treated with Provisia™ Herbicide. In field trials conducted from 2013 through 2015, Provisia rice exhibited excellent tolerance to single and sequential applications of Provisia Herbicide. Provisia Herbicide will provide postemergence control of non-Provisia rice [red rice, volunteer conventional rice (*Oryza sativa*), hybrid rice, and Clearfield rice types] and other common annual and perennial grasses, including barnyardgrass (*Echinochloa crus-galli*). Our research shows the most consistent and optimal programs utilize sequential applications with the first of the sequence being applied early post-emergence (2-3 leaf growth stage), followed by a second application mid to late post-emergence. Research indicates that Provisia herbicide, when tankmixed with other rice herbicides, provided control of broadleaf and annual grass weeds. The Provisia Rice System used in conjunction with the Clearfield Rice System and a soybean rotation (3 year system) will offer growers a sustainable management program for red and volunteer rice types. Provisia Herbicide registration is anticipated in 2016 with a limited commercial introduction in 2017.

Herbicide Options in a Provisia Rice Production System

Rustom, S.Y., Webster, E.P., McKnight, B.M., and Bergeron, E.A.

A current problem for rice growers is the management of weedy rice species such as F_2 hybrids and red rice outcrosses. ‘Provisia’ rice is a herbicide resistant rice cultivar currently under development by BASF, the herbicide targeted for use is quizalofop. Quizalofop, an ACCase herbicide activity is often antagonized when mixed with herbicides with broadleaf and/or sedge activity. In 2015, studies were conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA and the Northeast Research Station (NERS) near St. Joseph, LA to evaluate potential antagonism of quizalofop when mixed with herbicides with broadleaf and/or sedge activity. All herbicide applications were made at the three- to four- leaf stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha.

The first study was conducted at the RRS to evaluate potential herbicide interactions of quizalofop mixed with ALS inhibiting herbicides. Plot size was 1.5 by 2.2 m consisting of eight-19.5 cm rows. Each plot included 4 rows of ‘Provisia’ and 1 row of ‘CL 111’, ‘CLXL 745’, ‘Mermentau’, and red rice. Percent control was recorded for each rice cultivar and barnyardgrass at 14, 28, and 52 days after treatment (DAT). The experimental design was a randomized complete block with a two-factor factorial arrangement of treatments with four replications. Factor A was no qiuzalofop or quizalofop at 120 g ai/ha. Factor B consisted of penoxsulam at 40 g ai/ha, penoxsulam plus triclopyr at 352 g ai/ha, halosulfuron at 53 g ai/ha, bispyribac at 34 g ai/ha, orthosulafamuron plus halosulfuron at 94 g ai/ha, orthosulfamuron plus quinclorac at 491 g ai/ha, imazosulfuron at 211 g ai/ha, and bensulfuron at 43 g ai/ha.

At 14 DAT, a single application of quizalofop controlled barnyardgrass 88% and all rice cultivars 88 to 90%. Quizalofop activity was reduced with the addition of penoxsulam. Barnyardgrass control was reduced to 78% and control of rice cultivars was 76 to 84%. The addition of penoxsulam plus triclopyr to quizalofop was similar to penoxsulam for barnyardgrass control; however, control of rice cultivars appeared to be more antagonistic, with CLXL 745 reduced from 84 to 75%. The addition of bispyribac to quizalofop resulted in similar control observed with penoxsulam plus triclopyr.

At 28 DAT, a single application of quizalofop controlled barnyardgrass and all rice cultivars 95%. Quizalofop activity was reduced with the addition of penoxsulam, penoxsulam plus triclopyr, or bispyribac with control of rice barnyardgrass and rice cultivars below 50%. A second application of quizalofop at 120 g/ha was applied to all treatments following the 28 DAT rating. At 52 DAT, the follow-up single application of quizalofop controlled barnyardgrass and all rice cultivars to acceptable levels.

The second study was conducted at the NERS to evaluate potential interactions of quizalofop when mixed with various herbicides and two water sources. Plot size was the same as previously mentioned. Plots included 4 rows of Provisia and 2 rows of CL 111 and CLXL 745. Percent control was recorded for the above cultivars and barnyardgrass at 14, 21, and 42 DAT. The experimental design was a randomized complete block with a three-factor factorial arrangement of treatments replicated four times. Factor A consisted of two different water sources as carriers: Crowley, LA, and St. Joseph, LA. Factor B was no quizalofop or quizalofop at 120 g ai/ha. Factor C was halosulfuron at 53 g ai/ha, propanil plus thiobencarb at 6,720 g ai/ha, penoxsulam plus triclopyr at 352 g ai/ha, bentazon at 1,053 g ai/ha, or no mixture.

At 42 DAT, activity of quizalofop applied alone was similar for both carriers, with 90 to 98% control for all species. The addition of propanil plus thiobencarb to quizalofop with Crowley water reduced the activity of quizalofop on barnyardgrass to 23%, and CL 111 and CLXL 745 to 74 and 69%, respectively. The same mixture with St. Joseph water appeared to be less antagonistic on barnyardgrass with 65% control; however, more antagonistic on CL 111 with 61% control. The addition of penoxsulam plus triclopyr to quizalofop resulted in similar barnyardgrass activity with both carriers with 64 to 66% control; however, the same mixture with St. Joseph water appeared to be more antagonistic than Crowley water on CL 111 and CLXL 745, reducing control from 91% to 76% and 89% to 70%, respectively. The addition of halosulfuron or bentazon to quizalofop resulted in similar activity on barnyardgrass and rice cultivars as a single application of quizalofop.

In conclusion, caution should be taken when mixing quizalofop with penoxsulam, penoxsulam plus triclopyr, bispyribac, and propanil plus thiobencarb. In addition, the water source could also impact quizalofop plus other herbicide mixtures. Halosulfuron or Bentazon may be options when mixing with quizalofop for broadleaf and/or sedge control.

Evaluation of Provisia™ Rice for Mid-South Rice Production Systems

Lancaster, Z.D., Norsworthy, J.K., Martin, S.M., Young, M.L., Hale, R.R., and Scott, R.C.

With the stress that herbicide-resistant weeds put on our current rice production systems, new technologies are needed to control these weeds. BASF is currently developing a new non-GMO rice trait that will be resistant to quizalofop, an acetyl coenzyme A carboxylase (ACCase)-inhibiting herbicide. The Provisia™ rice system will provide an additional herbicide trait to be used in rice production systems. Multiple studies have been conducted to evaluate the best use of this technology in Arkansas. The first study was conducted in the summer of 2014 and 2015 at the University of Arkansas Rice Research and Extension Center in Stuttgart, Arkansas to determine the best rate structure for sequential applications of quizalofop when the first application is made at either the 2-leaf or 6-leaf stage of grasses. The experiment was set up as a two factor, randomized complete block design with factor-A being the growth stage at first application and factor-B being the rate structure of quizalofop. This experiment was evaluated for two different growth stages of initial herbicide application of 2-leaf and 6-leaf grass. Herbicide rate structures were 80, 120, or 160 g ai/ha followed by 80, 120, or 160 g ai/ha sequential application 14 days after the initial application. The highest total amount of quizalofop applied in a rate structure was 240 g ai/ha total. In 2014 the greatest control of both barnyardgrass and broadleaf signalgrass was recorded with the 120/120 g ai/ha treatment with 99 and 98% control, respectively. The 80/80 g ai/ha treatment had the least control of both barnyardgrass and broadleaf signalgrass with 89 and 90% control, respectively, with no significant difference in herbicide rates found in 2015. Control for barnyardgrass and broadleaf signalgrass was reduced by making the first application on 6-leaf grass compared to 2-leaf grass for 2014, and had the same effect for red rice in 2015. The results of this experiment suggest that the most likely recommended rate structure for quizalofop will be 120 g ai/ha on 2-leaf grasses followed by a subsequent application at approximately 14 days after the initial application. A second experiment was conducted in the fall of 2015 at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, Arkansas to compare postemergence activity of quizalofop on barnyardgass, Amazon sprangletop, fall panicum, and broadleaf signalgrass to current ACCase-inhibiting herbicides labeled for use in rice. The experiment was conducted in the greenhouse as a two factor, randomized complete block design with factor-A being growth stage of grass weeds and factor-B being herbicide treatments. The experiment was evaluated at three different growth stages of application of 3-leaf, 6-leaf, and 12-leaf grass growth stage. Herbicides evaluated were quizalofop at a low (80 g ai/ha), medium (120 g ai/ha), or high (160 g ai/ha) rate compared to cyhalofop (312 g ai/ha) and fenoxaprop (122 g ai/ha). For all grass weeds evaluated, a significant herbicide by growth stage interaction was found. The highest overall control was found at the smaller grass growth stages, with control decreasing with increasing size. Quizalofop at all 3 rates had the highest level of control for all grass weeds when compared to fenoxaprop and cyhalofop. The results from this experiment suggest that quizalofop has overall higher levels of control on grass weeds when compared with fenoxaprop or cyhalofop, and that applications of any of the herbicides should be made to smaller grasses for best results.

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 USA. The herbicide is characterized by excellent safety to both *japonica* and *indica* cultivars, has a favorable toxicological and eco-toxicological profile and offers broad spectrum control of grasses, sedges and broadleaves at rates of 200 – 300 g ai/ha. Benzobicyclon is a slow releaser of the active triketone metabolite that functions as an inhibitor of *p*-hydroxyphenylpyruvate dioxygenase (HPPD). Benzobicyclon will be labeled as a post-flood herbicide for U.S. rice production. The molecule is currently under review by the USEPA and registration is expected in the next few years.

Determining the Efficacy of Benzobicyclon on Weedy Rice

Young, M.L., Norsworthy, J.K., Sandoski, C., McCown, M.S., Godwin, J.A., and Miller, M.R.

Due to the repetitive use of the same herbicide modes of action in rice, many weeds have evolved herbicide resistance. With increasing stress on our current chemistries, a new mode of action is needed in rice production. Gowan Company is developing benzobicyclon, a new post-flood rice herbicide. Benzobicyclon a Group 27 herbicide will control a broad-spectrum of grasses, aquatics, broadleaves, and sedges, including those currently resistant to Group 2 herbicides. Benzobicyclon will most likely be premixed with halosulfuron and marketed under the tradename Rogue. This will be the first 4-hydroxyphenylpyruvate dioxygenase (HPPD) herbicide commercially available in U.S. rice production. In 2015, an unexpected observation was made from a field study conducted at the Rice Research and Extension Center in Stuttgart and at the Pine Tree Research Station in Colt, Arkansas. At both locations, bays treated post-flood with benzobicyclon at 247 or 494 g ai/ha had a high level of weedy rice control relative to bays not containing benzobicyclon. This observation prompted a greenhouse evaluation of the efficacy of benzobicyclon on weedy rice accessions collected across Arkansas, Mississippi, and Southeast Missouri. Grain from these weedy rice accessions had a tremendous amount of variability in awn presence, hull color, grain shape, and grain color. More than 120 accessions are currently being evaluated for resistance to imazethapyr and sensitivity to benzobicyclon. Although the screening results are not yet complete, it appears that benzobicyclon at 371 g ai/ha will provide control of many of the weedy rice accessions included in this study. Efforts are currently underway to better understand morphological characteristics that correlate with sensitivity of weedy rice to benzobicyclon and tolerance of rice varieties to this herbicide.

Benzobicyclon Weed Control in Louisiana Water-Seeded Rice Production Systems

McKnight, B.M., Webster, E.P., Bergeron, E.A., and Rustom, S.Y.

Benzobicyclon is a HPPD inhibitor that is registered for use in Japan. Benzobicyclon must be applied in flood water to be active and is primarily taken up by plants through root and shoot tissue. Field studies were initiated to evaluate the timing and application rate of benzobicyclon on common weeds in Mid-South rice. A field study was established to evaluate benzobicyclon activity when applied at different rates. This study was conducted in 2015 at the H. Rouse Caffey Rice Research Station (RRS) on a Crowley silt loam soil, and on a Midland silt loam soil. The same study was also conducted at the Northeast Research Station (NERS) near St. Joseph, Louisiana in the 2015 growing season on a Sharkey clay soil. Following seedbed preparation, a permanent flood was established and a natural infestation of weeds emerged. No rice was planted in the area in order to encourage weed pressure without competition. Prior to flooding, 90-cm diameter by 30-cm tall galvanized metal rings were installed into individual plots to contain benzobicyclon and prevent herbicide dilution. The application timing at all locations occurred when ducksalad [*Heteranthera limosa* (Sw.) Willd.] had reached the expanded leaf growth stage, or spoon stage. Other weeds present at the Crowley and St. Joseph location included Indian jointvetch (*Aeschynomene indica* L.), yellow nutsedge (*Cyperus esculentus* L.), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], purple ammania (*Ammannia coccinea* Rottb.), Indian toothcup [*Rotala ramosior* (L.) Koehne], and *Lindernia* spp. Benzobicyclon was applied at 10 different rates: 0, 31, 62, 123, 185, 246, 493, 739, 986 and 1232 g ai ha^{-1}. Applications were made using a CO_2-pressurized backpack sprayer calibrated to deliver 140-L ha^{-1}. The design was a randomized complete block with four replications. At the study conclusion in all locations weeds were hand-harvested, separated by species, and fresh weights were recorded.

Yellow nutsedge control with benzobicyclon on the Crowley silt loam was 39 to 53% with rates of 739 g ai ha^{-1} and higher at the conclusion of the study, 42 DAT. The highest level of barnyardgrass control was 34 and 35% with the 986 and 1232 g ai ha^{-1} rates, respectively. Ducksalad control was 93 to 97% with 739 g ai ha^{-1} and higher rates, and was superior in control to any lower rates applied. Total weed biomass fresh weight inside a containment ring at the conclusion of the study was 6347 grams in the nontreated to 3 grams of total biomass with 986 g ai ha^{-1} benzobicyclon. Ducksalad and purple ammania control 42 DAT on the Midland silt loam was 95 to 99% and 89 to 97%, respectively, with rates 185 g ai ha^{-1} and higher. Total weed biomass fresh weight at 42 DAT was 5683 grams in the nontreated to 3 grams in the ring receiving 1232 g ai ha^{-1} benzobicyclon. At the St. Joseph location, total weed biomass fresh weight at the conclusion of the study was 1429 grams in the nontreated compared with 358 grams in the rings receiving 986 g ai ha^{-1} benzobicyclon.

A separate field study was initiated in 2013 and 2014 at the RRS to evaluate the activity of benzobicyclon when applied at different timings in water-seeded rice production utilizing a pinpoint flood. Following seedbed preparation and establishment of a seeding flood, pre-germinated 'CL 111' was hand-broadcast into individual plots. The seeding flood was removed 24 hours later to allow for seedling establishment. Approximately 5 to 7 days after seeding, rice plants reached the pegging growth stage and the pinpoint flood was introduced and maintained throughout the growing season. Benzobicyclon treatments consisted of a single rate of 246 g ai ha^{-1} applied with 1% COC v/v at seven different timings: preplant, in the seeding flood, 24-h following draining of the seeding flood, on pegging rice, 24-h following establishment of the pinpoint flood, at the 2- to 3-leaf stage, and the 4- to 5-leaf stage.

In 2013, at the time of the last weed control rating, 49 DAT, benzobicyclon applied on pegging rice and 24-h after the pinpoint flood establishment controlled barnyardgrass 98 and 99%, respectively. The same pegging and pinpoint flood timings controlled yellow nutsedge 97 and 96%, respectively, 49 DAT. Ducksalad control did not differ among any application timing with 84 to 99% control. In the 2014 study, barnyardgrass control at 49 DAT did not differ among any of the application timings and control was 93 to 99%. Yellow nutsedge control at 49 DAT did not differ among any of the application timings and control was 97 to 99%. Ducksalad control was 93 to 99% and did not differ among any application timing. No differences were observed with rice yield regardless of application timing.

Control of *Cyperus difformis* and *Leptochloa fusca* in Europe with Benzobicyclon

Cornette, L., Holmes, K., and Martin-Andres, M.

Benzobicyclon is a novel mode of action herbicide for European rice with activity against a broad range of grasses, sedges and broad-leaved weeds and selective to paddy rice. It functions by inhibiting the activity of the *p*-hydroxyphenylpyruvate dioxygenase enzyme system and thus is classified as an HRAC F2 herbicide (HPPD-inhibitors). It is absorbed by the young stems, buds and roots of weeds and provokes a bleaching effect by inhibiting the biosynthesis of carotenoids, thus preventing photosynthesis.

Weed resistance to ALS-inhibitor herbicides is becoming a serious issue in the rice producing areas of Europe and a number of species have become difficult to control with the currently available commercial products. Several key active ingredients have been lost in recent years due to the EU regulatory process and new alternatives are desperately needed.

Benzobicyclon has been tested in Europe for four years in France, Greece, Italy, Portugal and Spain on several rice varieties. In total, more than 60 trials have been performed by several Contract Research Organizations (CROs) on behalf of the companies Gowan and SDS Biotech K.K. This paper summarizes the results of 25 trials carried out against two commercially significant weed species: *Cyperus difformis L.* and *Leptochloa fusca* (L.) Kunth subsp. *fascicularis* (Lam.) N. Snow.

All trials were performed according to a Random Complete Block design with three to four replications. Plot size was greater than 20 sq m and sowing rate was between 180-250 kg/ha. Water management of each plot was independent. Herbicides were sprayed in water volumes of 200 to 350 L/ha. References were VIPER® (Penoxsulam 2.04% OD at 2 L/ha) and RONSTAR® (Oxadiazon 250 g/l EC at 1.5 L/ha) and were used at their registered rates and timing of application.

Benzobicyclon showed excellent activity (consistently > 90% control) at application rates of 200 to 300 g a.i./ha when applied at weed pre-emergence vs *Cyperus difformis* as well as vs *Heteranthera reniformis* in all trials. Applications just after flooding or around the sowing date proved particularly efficient. Benzobicyclon controlled *Leptochloa fusca* in Spain but the level of control in Italy was less consistent. It also showed interesting but more variable efficacy against *Echinochloa* spp, *Alisma plantago-aquatica, Schoenoplectus supinus, Leersia orizoides* and *Scirpus maritimus*. There was a positive correlation between efficacy and dose rate and the efficacy was generally better with earlier applications. Benzobicyclon also controlled ALS-resistant *Cyperus* sp biotypes.

Rinskor™ Active: A New Herbicide for Mid-South U.S. Rice

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

Rinskor™ active is a new postemergence herbicide being developed by Dow AgroSciences for use in U.S. direct- and water-seeded rice. Rinskor is a member of the new arylpicolinate class of herbicides that exhibits broad-spectrum herbicidal activity on select grass, sedge, and broadleaf weed species. Mid-South U.S. rice weeds susceptible to Rinskor include but are not limited to: *Echinochloa crus-galli, Echinochloa colona, Urochloa platyphylla, Cyperus iria, Cyperus esculentus, Sesbania herbacea, Aeschynomene* spp., *Conyza* spp., *Amaranthus* spp., *Ambrosia* spp., *Alternanthera philoxeroides, Eclipta prostrata, Heteranthera* spp. *and Sagittaria* spp. In greenhouse studies, Rinskor controlled numerous *E. crus-galli* populations, including ALS-, propanil-, and quinclorac-resistant biotypes. Grass and sedge weeds treated with Rinskor exhibit swelling and necrosis of the crown while broadleaf weeds treated with Rinskor exhibit an epinastic response followed by plant death. Rinskor displays excellent safety to both medium-grain and long-grain rice varieties, and hybrids within conventional and Clearfield® rice systems. The U.S. registration of Rinskor is expected in 2017 or 2018.

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Environmental Fate of Rinskor™ Active: Evaluation of Carryover on Subsequent Crops

Miller, M.R., Norsworthy, J.K., Perry, H., and Huang, R.

New technologies are needed as a result of the stress that barnyardgrass (*Echinochloa crus-galli*) and other weeds continue to place on current rice production systems. Recently, Dow AgroSciences announced a new herbicide, Rinskor™ Active, which is the second herbicide in a new structural class of synthetic auxins that provides an alternative mode of action for rice. This new herbicide has broad-spectrum postemergence activity on broadleaf, grass, and sedge species at low use rates. Multiple experiments were designed to determine the carryover potential of Rinskor onto subsequent crops. The first experiment was designed as a randomized complete block with four replications. Treatments included Rinskor applied at 40 followed by (fb) 40 g ai ha^{-1}, 80 fb 80 g ai ha^{-1}, and a non-treated check. In 2014, herbicides were applied and fields remained fallow.The following year corn, cotton, soybean, grain sorghum, and sunflower were planted within the previously treated area. Stand counts, crop heights, and visual injury assessments were taken for each crop following planting and aboveground (dry) biomass was collected 28 days after planting. No significant differences were observed among the treatments for any of the assessment data highlighting the rotational flexibility of common row crops one year following a Rinskor application. A second experiment was conducted during 2014 and 2015 to evaluate potential plant-back restrictions to soybean following an application of Rinskor. The experiment was designed as a randomized complete block with four replications. Treatments included a two factor factorial treatment structure comprised of two rates of Rinskor: 30 and 60 g ai ha^{-1} applied at four timings: 56, 28, 14, and 0 days prior to planting soybean. Visual estimates of soybean injury were highest 21 days after planting when 30 or 60 g ai ha^{-1} of Rinskor was applied 0 days before planting. Soybean injury remained throughout the season as a result of overall stand loss. Soybean yield was similar to the non-treated control when 30 or 60 g ai ha^{-1} of Rinskor was applied 56 or 28 days prior to planting whereas all other treatments had significantly lower yield. The results found in this study indicated a short replant interval for soybean relative to other herbicides commonly applied in rice, and there is unlikely to be any rotational restrictions for soybean or other commonly grown row crops the year following a Rinskor application in rice.

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Integration of Very-Long-Chain Fatty Acid Inhibiting Herbicides in Rice Production

Godwin, J.A., Norsworthy, J.K., Young, M.L., Palhano, M.G., Hale, R.R., and Scott, R.C.

Very-long chain fatty acid inhibiting herbicides (group 15) are commonly used in U.S. corn, cotton, and soybean production along with Asian rice production. Due to the vast evolution of resistance to common weeds in U.S. rice such as barnyardgrass (*Echinochloa crus-galli*) and red rice (*Oryza sativa*), it is essential that new herbicide modes of action be integrated into current production systems. It is believed that several group 15 herbicides will have a potential fit in U.S. rice if appropriate crop tolerance can be established. Group 15 herbicides including pethoxamid, acetochlor, pyroxasulfone, and *S*-metolachlor were evaluated for rice tolerance at different application timings. Herbicide rates were as follows: acetochlor at 1.05 kg ai/ha (Warrant), pyroxasulfone at 0.149 kg ai/ha (Zidua), *S*-metolachlor 1.07 kg ai/ha (Dual II Magnum), and pethoxamid at 0.841 kg ai/ha. Each herbicide was applied at three different timings including: delayed preeemergence (DPRE), spiking, and 1- to 2-leaf rice. The data evaluated included rice stand counts, crop heights, rice injury, percent heading, and rough rice yield. Based on these data, rice had the greatest tolerance to pethoxamid and acetochlor. The rice showed no significant reduction in yield, stand count, heading percentages, or heights when compared to the nontreated check. Also, the rice injury from acetochlor and pethoxamid dissipated throughout the growing season. In contrast, it was found that the rice showed significantly less tolerance to pyroxasulfone and *S*-metolachlor. Rice injury of up to 70% from pyroxasulfone applications and 30% from *S*-metolachlor applications was observed, regardless of application timing. This injury caused a significant decrease in yield when compared to the nontreated check. A significant reduction in rice tolerance was also seen in relation to application timing. Less injury was observed as herbicides application timing was delayed. Based on this research, there appears to be sufficient rice tolerance to acetochlor and pethoxamid to demand further investigation of these herbicides in U.S. rice.

Development and Registration Status of BUTTE Herbicide in California

Holmes, K., Brazzle, J., and Takahashi, A.

BUTTE® herbicide is a granular formulation containing 3% benzobicyclon plus 0.64% halosulfuron that is being developed by Gowan for use on California rice. Benzobicyclon is a novel HPPD inhibitor that was invented by SDS Biotech and has been used in Asian rice for over a decade. Halosulfuron was invented by Nissan and has been used in rice around the world for over two decades. The combination of these two active ingredients has been in development for use in California rice since 2009.

BUTTE has been evaluated in numerous trials in the Sacramento Valley over the last six years and has been shown to control a broad range of sedge, grass and broadleaf weeds in water seeded rice. BUTTE has performed best when applied early in the season, before the rice crop reaches a 2 – 3 true leaf stage. The product is very well tolerated by rice and its crop safety appears to be unaffected by soil type, water or soil temperature or variety.

BUTTE was submitted to the USEPA and the state of California as a concurrent submission in December, 2014. The active ingredient benzobicyclon and the end use product BUTTE were granted reduced risk status by the USEPA in May 2015. The Section 3 registration for BUTTE is expected in August 2016 and the product should be launched in California for use in the 2017 season.

Development of Rice Lines Resistant to Aryloxyphenoxy-propionate Herbicides through Induced Mutation with Gamma Rays

Andrade, A., Noldin, J.A., Oliveira Neto, A.M., Schiocchet, M.A., Tcacenco, F.A., Pereira, A., Marschalek, R., Eberhardt, D.S., and Tulmann, N.A.

Weedy-rice (*Oryza sativa* L.) is currently considered to be one of the most noxious weed in paddy rice, due mainly to the taxonomical similarity with cultivated rice species. Nowadays the use of imidazolinone-resistant rice cultivars (Clearfield®) is considered the best control system for weedy-rice. On the other hand, the selection of weedy-rice plants resistant to imidazolinones threatens the Clearfield® technology. The development of herbicide-resistant rice cultivars with mechanism of action different from ALS is a strategic alternative for managing weedy-rice resistant populations.

Through induced mutation with gamma rays targeting seeds, Epagri (Santa Catarina State Agricultural Research and Rural Extension Agency, Brazil) developed two rice lines resistant to aryloxyphenoxy-propionate herbicides. Both lines carry a mutation in the carboxyl-transferase gene domain, which encodes acetyl-coenzyme A carboxylase (ACCase) (EC 6.4.1.2).

Under field and greenhouse conditions, rice seedlings at the stage V_1-V_3, showed resistance to the herbicides quizalofop-p-ethyl (75 g a.i. ha^{-1}) and haloxyfop-p-methyl (60 g a.i. ha^{-1}). The use of aryloxyphenoxy-propionate-resistant rice lines represents an innovative and promising alternative for weedy-rice management in paddy rice.

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Abstracts of Posters on Weed Control and Growth Regulation
Panel Chair: Muthukumar Bagavathiannan

Do Insecticide Seed Treatments Reduce ALS Herbicide Injury to Clearfield Rice?

Martin, S., Norsworthy, J., Scott, R., Lorenz, G., Hardke, J., and Young, M.

Increased use of insecticide seed treatments in rice have brought up many questions about the potential benefits of these products. In 2014 and 2015, a field experiment was conducted at the Rice Research and Extension Center in Stuttgart, Arkansas and at the University of Arkansas Pine Bluff Farm in Lonoke, Arkansas to evaluate whether an insecticide seed treatment could possibly lessen injury from acetolactate synthase (ALS)-inhibiting herbicides in Clearfield® rice. Two varieties were tested (CLXL745 and CL152) with and without an insecticide seed treatment (CruiserMaxx® Rice). Four different herbicide combinations were evaluated (a non-treated check, two applications of Regiment®, two applications of Newpath®, and two applications of Newpath® plus Regiment®). The first herbicide application was early postemergence (1- to 2-leaf rice) and the second application was prior to establishing the permanent flood (preflood). Crop injury was assessed at 2, 4, and 6 weeks after final herbicide application. At 6 WAT, the rice treated with CruiserMaxx Rice and had two applications of Newpath plus Regiment showed less injury than the rice treated with the fungicide-only seed treatment with the same herbicide program. Overall, CLXL745 rice showed less tolerance to ALS-inhibiting herbicides than CL152. Even with this severe level of injury, the rice plants recovered by the end of the growing season and yields within a variety were similar with and without a seed treatment across all herbicide treatments. Rough rice yields averaged over seed treatments and herbicides were 8700 kg/ha (160 bu/A) for CL152 and 10,125 kg/ha (225 bu/A) for CLXL745. These results show that repeated applications of ALS-inhibiting herbicides can cause severe injury to Clearfield® rice, especially CLXL745, but rice is able to recover from this injury without an adverse effect on yield.

Crop Rotation: An Important Practice for Weedy Rice Management

Rustom, S.Y., Webster, E.P., McKnight, B.M., and Bergeron, E.A.

Hybrid rice seed has a history of dormancy, and it can become a weedy plant if allowed to establish the following growing season as an F_2. Clearfield F_2 plants can vary in phenotype and are often resistant to imazethapyr and imazomox. These resistant F2 plants can become a tremendous weed problem when Clearfield hybrid rice is grown in consecutive years. Another problem with the Clearfield rice technology is outcrossing with red rice (*Oryza sativa* L.). The outcrosses and the F_2 rice plants coupled with red rice form a complex of rice weeds that will be referred to as weedy rice.

A producer location was identified near Esterwood, Louisiana with a history of 3 consecutive growing seasons of Clearfield hybrid rice production. This location was determined to have a complex weedy rice infestation. In 2013, a four year study was established consisting of five different rotations and utilizes the use of Provisia Rice which contains a non-genetically modified trait allowing for the use of quizalofop. The study also added Liberty Link soybean which allows the use of glufosinate. The utilization of these two herbicides in conjunction with the other herbicides further expands the flexibility of active ingredient and differing mode of action rotation. The rotations used were: Rotation 1) Roundup Ready soybean (2013)/Provisia Rice (2014)/Roundup Ready soybean (2015)/Clearfield Hybrid Rice (2016); Rotation 2) Fallow (2013)/Provisia Rice (2014)/Roundup Ready soybean (2015)/Clearfield Hybrid Rice (2016); Rotation 3) Clearfield Hybrid Rice (2013)/Liberty Link soybean (2014)/Provisia Rice (2015)/Clearfield Hybrid Rice (2016); Rotation 4) Roundup Ready soybean (2013)/Liberty Link soybean (2014)/Roundup Ready soybean (2015)/Clearfield Hybrid Rice (2016); Rotation 5) Roundup Ready soybean (2013)/Clearfield Hybrid Rice (2014)/Roundup Ready soybean (2015)/Clearfield Hybrid Rice (2016). Herbicide programs and cultural practices were consistent across a given rotation.

In 2013, each 0.2 ha block followed the rotations listed above, and herbicide programs employed for each year are listed below. The Clearfield 'CLXL 745' was treated with clomazone at 336 g ai/ha plus imazethapyr at 105 g ai/ha on one- to two-leaf rice, followed by (fb) imazethapyr at 105 g ai/ha on three- to four-leaf rice fb a panicle initiation (PI) application of imazamox at 44 g ai/ha. RR soybean was treated with glyphosate at 1120 g ai/ha plus dimethenamid at 945 g ai/ha at the first trifoliate leaf. A second application of glyphosate at 1120 g ai/ha was applied at 21 days later. Rotation 4 was treated with pyroxasulfone 150 g ai/ha added to first application of glyphosate plus dimethenamid. The fallow area, Rotation 2, was treated with glyphosate at 1120 g ai/ha at the same time the soybeans were treated with glyphosate. A tillage operation occurred in the fallow area 2 weeks after the second glyphosate application. A third glyphosate application occurred 4 weeks later in the fallow area. Prior to rice harvest weedy rice plant counts were determined. In 2013, weedy rice plants for each rotation were: Rotation 1 - 17.2 plants/m^2; Rotation 2 - 25.1 plants/m^2; Rotation 3 - 0.3 plants/m^2; Rotation 4 - 5.2 plants/m^2; Rotation 5 - 7.8 plants/m^2. In 2014, weedy rice weedy rice plants for each rotation were: Rotation 1 - 0.005 plants/m^2; Rotation 2 - 0.004 plants/m^2; Rotation 3 - 2.6 plants/m^2; Rotation 4 - 3.1 plants/m^2; Rotation 5 - 39.6 plants/m^2.

In 2015, rotations 1, 2, 4, and 5 were planted with Roundup Ready soybean and each rotation contained 0 weedy rice plants/m^2 at the end of the 2015 growing season. Rotation 3 was planted with Provisia Rice and contained 0.25 weedy rice plants/m^2 at the end of the 2015 growing season. The utilization of Roundup Ready and Provisia technology vastly improved rotational flexibility in 2015 and will serve as excellent rotational tools in conjunction with Clearfield technology for weedy rice management. This research indicates that long term crop rotation, herbicide active ingredient rotation, and employing different production practices can be used to manage weedy rice and reduce the weedy rice population in future growing seasons.

Surveying Herbicide Resistance and Problem Weed Issues in Texas

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

Weeds present an important constraint to rice production and profitability. A thorough understanding of dominant weed species and the prevalence of herbicide resistance will help prioritize research and outreach activities for addressing critical issues in a timely manner. A late season survey was conducted in eight major rice producing counties in Texas, including Colorado, Wharton, Lavaca, Jackson, Waller, Fort Bend, Liberty and Chambers. A semi-stratified survey methodology was followed. In each survey field, GPS location, dominant weed species and level of infestation were documented. Seed samples were also collected to screen for resistance to important rice herbicides such as clomazone, propanil, quinclorac, fenoxaprop and imazethapyr. Barnyardgrass (*Echinochloa cras-galli*), Nealley's sprangletop (*Leptochloa nealleyi* Vasey), weedy rice (*Oryza* sativa f. *spontanea*) and hemp sesbania (*Sesbania herbacea*) were frequently found in Texas rice. Mass screening for herbicide resistance is on the way, but a preliminary evaluation of limited weedy rice samples revealed the presence of resistance to imazethapyr.

Amelioration of Environmental Stresses in Rice Production

Mohammed, A.R. and Tarpley, L.

Rice production along the Gulf Coast experiences various stresses such as drought, high night temperature (HNT), high ultraviolet-B (UV-B), cool soil temperatures during planting and nutrient imbalance. Limited water supply has reduced rice acreage in Texas, whereas the HNT and UV-B radiation threatens the sustainability of rice production. Recent meteorological data indicated faster increases in night temperatures, drought and UV-B radiation across the rice production areas of the world. The Texas A&M AgriLife Research Rice Physiology Project has been studying the effects of various stresses in rice production and trying to mitigate the environmental and nutrient stresses. Rice plants were exposed to water stress [flooded rice vs. aerobic rice (alternate wetting and drying- procedure from International Rice Research Institute)], heat stress [HNT (30 ºC) vs. ambient night temperature (ANT; 25 ºC)], UV-B radiation stress [high UV-B (10 kJ m^{-2} d^{-1}) vs. ambient UV-B (5 kJ m^{-2} d^{-1})], nitrogen stress [normal vs. low (40% less than normal N)] and cool soil temperature stress [normal vs. low (10 ºC)]. Rice plants exposed to the above mentioned stresses showed decreased rice yield or growth through effects on rice physiology. Increase in night temperature from 25 to 30 ºC decreased rice yield by 11%, whereas an increase in UV-B radiation from 5kJ to 10 kJ decreased rice yield by 22%. Decrease in nitrogen fertility by 40% decreased rice yield by 23%.

Models indicate that rice production will be subject to increase in a variety of environmental stresses affecting crop production, namely heat, drought, salinity, and relative humidity, hence rice farming will have to be better adapted to a range of abiotic and biotic stresses. A long-term approach to negate the effects of abiotic stress is to develop stress-tolerant cultivars. The short-term approach includes the use of agrochemicals, especially those with plant growth regulator (PGR) capabilities, for the prevention and/or amelioration of various environmental stresses. Screening for tolerance is the first step in developing stress-tolerant cultivars. We have screened and identified high UV-B tolerant cultivars, HNT-tolerant cultivars and drought-tolerant cultivars. We have also developed a set of PGRs to mitigate HNT stress and UV-B stress. The PGRs include 1-methylcyclopropene (1-MCP), alpha-tocopherol, abscisic acid (ABA), aminoethoxyvinylglycine (AVG), glycine betaine and salicylic acid. Application of 1-MCP increased rice yield (10%) under HNT, compared to untreated plants under HNT. On an average, plants treated with alpha-tocopherol, glycine betaine or salicylic acid showed 20% increase in rice yield compared to untreated, under elevated UV-B radiation. We appreciate the partial funding provided by AgroFresh Inc., Philadelphia, PA, USA, and Valent BioSciences Corporation, Libertyville, IL, USA.

Sensitivity of Conventional, STS and Bolt Soybean to Rice Herbicides

Steppig, N.R., Norsworthy, J.K., and Barber, L.T.

In the southern United States, rice and soybean fields are often grown in close proximity to one another. As such, the potential for herbicide drift from rice fields onto soybean acreage exists, and can pose a significant threat to soybean yields. A number of herbicide tolerance traits exist in soybean, including sulfonylurea tolerance (STS) and the emerging Bolt™ technology that increase crop tolerance to the acetolactate synthase (ALS)-inhibiting class of herbicides. A field trial was conducted at the Lon Mann Cotton Research Center at Marianna, Arkansas in 2015 to assess conventional, STS, and Bolt™ soybean sensitivity to a number of ALS-inhibiting herbicides commonly used in rice and other crops (halosulfuron, primisulfuron, imazosulfuron, orthosulfamuron, rimsulfuron, nicosulfuron, bensulfuron, penoxsulam, bisypribac). This field trial utilized a Randomized Complete Block design with nine herbicides applied at labeled rates. Results from the experiment indicate that STS and Bolt™ soybean show significantly lower injury to most herbicides compared to a conventional variety. Bolt™ varieties were injured but did survive and recover from full rates of bispyribac, penoxsulam, and primisulfuron, whereas these herbicides caused almost complete death of conventional and STS soybean. Since herbicide applications in this study were made at full rates for rice production or other registered crops, it can be assumed that crop tolerance to drift rates will be substantially higher, thus signifying that planting of STS or Bolt soybean varieties adjacent to rice fields can greatly reduce the risk for soybean injury from off-target movement of the evaluated herbicides.

How Do Soybean Cultivars with BOLT™ Technology Respond to Rice Herbicides?

Edwards, H.M., Peeples, J.D., Lawrence, B.H., Hydrick, H.T., Phillips, T.L., and Bond, J.A.

Acetolactate synthase (ALS)-inhibiting herbicides are commonly utilized in both soybean (*Glycine max*) and rice (*Oryza sativa*) in the southern U.S., but none of the ALS herbicides used in conventional rice are labeled for soybean. Soybean are susceptible to drift of sulfonylurea (SU) herbicides from rice fields because these crops are often grown in close proximity. The BOLT™ technology from DuPont Pioneer was released in 2015 and enhances soybean tolerance to SU herbicides and possibly to other ALS herbicides. If injury to BOLT cultivars from ALS herbicides used in rice was less than that on soybean cultivars without the BOLT technology, the new cultivars could be utilized adjacent to rice fields to mitigate the effect of spray drift from rice herbicide applications. Therefore, research was conducted to compare the response of Roundup Ready, sulfonylurea tolerant (STS), and BOLT soybean cultivars to low rates of ALS herbicides common in southern U.S. rice production. Research was conducted in 2015 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS. The experimental design was a split block with three replications. Whole plots were ALS herbicides common in southern U.S. rice applied at 12.5% of the labeled application rate to simulate an off-target drift event. Herbicide treatments included imazosulfuron (League) at 0.021 kg ai/ha, a prepackaged mixture of halosulfuron plus thifensulfuron (Permit Plus) at 0.0049 kg ai/ha, bispyribac (Regiment) at 0.0047 kg ai/ha, and a prepackaged mixture of orthosulfamuron plus halosulfuron (Strada Pro) at 0.012 kg ai/ha. A nontreated check was included for comparison. Sub plots were soybean cultivars and included 'Pioneer P49T09BR' and 'Pioneer P50T15R" (BOLT cultivars), 'Asgrow AG4632' (STS cultivar) and 'Pioneer P95Y10' (Roundup Ready cultivar). Herbicide treatments were applied when the majority of soybean plants in each plot had one to two fully expanded trifoliate leaves. Soybean injury was visually estimated at 7, 14, and 28 d after application (DAT). Data were subjected to ANOVA and estimates of the least square means were used for mean separation.

Pioneer 95Y10 was injured more than BOLT cultivars with each herbicide 7, 14, and 28 DAT. Although the magnitude was >40%, halosulfuron plus thifensulfuron injured Pioneer 95Y10 less than other herbicides 14 and 28 DAT. Injury to Pioneer 95Y10 and Asgrow 4632 was similar with bispyribac 7, 14, and 28 DAT, and the level of injury was greater than that exhibited by the BOLT cultivars. Bispyribac injured Asgrow 4632 and both BOLT cultivars more than other herbicides at all evaluations. Asgrow 4632 was injured more than the BOLT cultivars with orthosulfamuron plus halosulfuron 7 DAT; however, the response of Asgrow 4632 to imazosulfuron, halosulfuron plus thifensulfuron, and orthosulfamuron plus halosulfuron was similar to Pioneer 50T15R 14 and 28 DAT. Injury to Pioneer 49T09BR was greater than that for Asgrow 4632 and Pioneer 50T15BR with orthosulfamuron plus halosulfuron 14 DAT. Problematically, the response to some of the herbicides evaluated in the current research varied between the BOLT cultivars. Injury to Pioneer 49T09BR with bispyribac was greater than that for Pioneer 50T15R at all evaluations. The same trend was observed with orthosulfamuron plus halosulfuron 14 DAT.

Roundup Ready, STS, and BOLT soybean cultivars responded differently to ALS herbicides used in southern U.S. rice. The STS cultivar Asgrow 4632 was as tolerant as the BOLT cultivar Pioneer 50T15R following applications imazosulfuron, halosulfuron plus thifensulfuron, and orthosulfamuron plus halosulfuron applied at 12.5% of labeled rates. Among the four cultivars evaluated, response to bispyribac was most variable with injury ranging from 23 to 85% 28 DAT. Although it was not completely tolerant to all herbicides evaluated, Pioneer 50T15R could be planted adjacent to rice fields to lessen the potential effects of drift of ALS herbicides.

Residual Activity of Quizalofop Compared to Common Rice Graminicides

Lancaster, Z.D., Norsworthy, J.K., Martin, S.M., Godwin, J.A., Palhano, M.G., and Scott, R.C.

With the evolution of weeds that have resistance to multiple herbicide modes of action, a new technology is needed to control many of these troublesome weeds. BASF is currently developing a new rice that will be resistant to the herbicide quizalofop. A field experiment was conducted in the summer of 2014 and 2015 at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, Arkansas to evaluate the residual activity of quizalofop relative to other graminicides for crop injury and grass weed control. The experiment was set up as a split-split plot design assigning overhead-irrigation activation as the whole plot factor, with plant-back date as the sub-plot, and herbicide treatments as the sub-subplot. This experiment was evaluated for four different crops (conventional rice, quizalofop-resistant rice, grain sorghum, and corn). Herbicide treatments were varying rates of quizalofop (Targa), fenoxaprop (Ricestar HT), cyhalofop (Clincher), fluazifop (Fusilade DX), clethodim (SelectMax), and sethoxydim (Poast). The irrigation event was applied with a traveling gun sprinkler system, and the plant-backs were made at 0, 7, and 14 days after treatment. On all crops, injury increased with herbicide activation over no activation. At 14 to 21 days after treatment, corn and grain sorghum both had the greatest injury of 19 and 20%, respectively, from the high rate of sethoxydim. Conventional rice and quizalofop-resistant rice had the greatest injury of 13 and 4%, respectively, from fluazifop. Herbicides effectively controlled emerged grasses at the time of application, but provided little residual grass control. Barnyardgrass (*Echinochloa crus-galli*) and broadleaf signalgrass (*Urochloa platyphylla*) were best controlled with the high rate of fluazifop at 98 and 96%, respectively, 14 days after treatment. The results of this experiment suggest that caution will need to be taken for the plant-back period for susceptible crops, depending on herbicide applied and environmental factors.

Can PGR Seed Treatments Alleviate Herbicide Injury Caused by Volunteer Rice Control Herbicides?

Rouse, C.E., Penka, T.M., Burgos, N.R., Schmidt, L., Hardke, J.T., and Scott, R.C.

Management of volunteer rice populations in rice production is difficult as there are few options for selective control. Novel approaches using our understanding of crop physiology and alternative herbicides may provide additional alternatives. Group 15 herbicides, or root and shoot inhibitors, may reduce volunteer rice infestation, but may also cause significant crop injury. For this type of herbicides to be viable, different strategies are needed. Plant growth hormones, which regulate plant development and stress responses, may be beneficial in reducing crop injury. A study was conducted at the Southeast Research and Extension Center, Rohwer and the Rice Research and Extension Center, Stuttgart, Arkansas to determine if PGR seed treatments can reduce rice injury caused by acetochlor and pyroxasulfone. This study included three factors: plant growth hormone seed treatments (Ascend, Falgro, Ascend + Falgro), herbicide (acetochlor and pyroxasulfone), and herbicide timing (preemergence and V2); a no-herbicide control and a commercial standard seed treatment (no-PGR) were also included as reference. Crop injury was evaluated visually throughout the season. Plant population (0.75 m^2) and height (cm) were recorded at 3, 6, and 9 weeks after planting (WAP). Prior to harvest, panicle and stalk numbers (0.5 m^2) and height (4 plants per plot) were measured; rough rice yield was recorded. Data were analyzed as a RCBD with a three-factor factorial treatment structure using an ANOVA; significant means were separated using Fisher's protected LSD ($\alpha = 0.05$). Location by treatment interactions were not significant; thus, the data were pooled across locations. In general, the PGR seed treatments did not reduce crop injury regardless of the herbicide used or the application timing. Injury 6 WAP was significantly higher for the PRE application (81%), with pyroxasulfone causing more injury (62%) than acetochlor (37%). By 9 WAP, rice treated with pyroxasulfone PRE had the greatest injury (77%); all other herbicide treatments caused less than 32% injury. Generally, acetochlor treatments resulted in the highest yields within any PGR seed treatments (7919-8625 kg/ha. The pyroxasulfone treatment significantly reduced yields within all of the seed treatments (5548-6759 kg/ha). When pyroxasulfone was applied, seed treatment with a mixture of Ascend and Falgro resulted in better yield (>1009 kg/ha) compared with Ascend or Falgro alone. The PGR mixture appeared to reduce the yield impact from pyroxasulfone injury; however, this yield increase is not enough to warrant recommending pyroxasulfone. Acetochlor is less injurious to rice and could potentially be integrated into rice production systems with less risk for injury.

Barnyardgrass Control: The Addition of Sharpen to Rice Herbicides

Hale, R.R., Norsworthy, J.K., Godwin, J.A., Steppig, N., Meyer, C.J., and Scott, R.C.

Provisia™ rice is a new technology being developed by BASF that will allow for the use of quizalofop, an ACCase-inhibiting herbicide, for control of grass weeds. Barnyardgrass [*Echinochloa crus-galli*] is one of the most problematic weeds in Midsouth rice production. The physiological and biochemical capability of barnyardgrass to quickly evolve resistance continues to limit herbicide options for control. Sharpen is a contact herbicide labeled for broadleaf weed control in rice. When tank-mixing systemic herbicides with contact herbicides, antagonism or a reduction in efficacy is often observed. Hence, a field study was conducted at the Pine Tree Research Station near Colt, AR to evaluate Provisia™ rice tolerance and the interaction of herbicide combinations with Sharpen for barnyardgrass control. This experiment was arranged in a randomized complete block design with three common rice herbicides applied at the 1/2X and 1X rate with and without a 1/2X and 1X rate of Sharpen. All applications were made using a CO_2-pressurized backpack sprayer at 142 L/ha. Treatments were applied when barnyardgrass reached the 3- to 4-leaf growth stage, and all treatments contained crop oil concentrate (COC) at 1% (v/v). Treatments contained a 1/2X and 1X rate that included Sharpen at 12.5 g/ha and 25 g/ha, Clincher at 157 g/ha and 314 g/ha, Ricestar HT at 61.5 g/ha and 123 g/ha, and Provisia at 80 g/ha and 160 g/ha, respectively, along with a nontreated check. The addition of Sharpen resulted in an additive response for barnyardgrass control at 7 days after treatment (DAT) for all combinations, except for the 1/2X rates of Clincher + Sharpen, based on Colby's method for assessing interactions. By 14 DAT, the 1/2X rates of Clincher + Sharpen, and 1X rates of Ricestar HT + Sharpen was deemed antagonistic. Overall, main effects of herbicide and the addition of Sharpen were significant at 7 DAT and a main effect of herbicide was significant at 14 DAT. From these results, Sharpen + Clincher and Sharpen + Ricestar HT may not be good options when both broadleaf and grass weed species are present in the field.

Herbicide Control Options for Nealley's Sprangletop (*Leptochloa nealleyi*)

Bergeron, E.A., Webster, E.P., McKnight, B.M., and Rustom, S.Y.

A study was established at the LSU AgCenter H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA in 2014 and 2015 and a grower location near Estherwood, LA in 2015. This study evaluated Nealley's sprangletop (*Leptochloa nealleyi* Vasey) control when treated with imazethapyr plus propanil applied at different rates. The experimental design was a randomized complete block with a factorial arrangement of treatments with four replications. Factor A was imazethapyr at 0 or 70 g ai/ha and Factor B was an emulsifiable concentrate propanil at 0, 2240, 3360, or 4480 g ai/ha. In April 2014, Clearfield 'CL 151' rice was drill-seeded at 90 kg/ha and Clearfield 'CL 111' rice was planted at the same rate in March 2015. All herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha. All treatments were applied mid-postemergence (MPOST) to three- to four-leaf rice. A crop oil concentrate at 1% v/v was added to imazethapyr when applied alone, and no adjuvant was added to any mixture containing propanil.

At 49 DAT, a single application of imazethapyr controlled Nealley's sprangletop 75% while the imazethapyr plus propanil at 2240, 3360, or 4480 g/ha controlled Nealley's sprangletop 92, 89, and 81%, respectively. Rice treated with a single application of imazethapyr yielded 4960 kg/ha compared with rice treated with imazethapyr plus propanil at 2240, 3360, or 4480 g/ha yielded 7490, 6290, and 7018 kg/ha, respectively.

In 2014 and 2015, a study was initiated to evaluate Nealley's sprangletop control when treated with a single application of cyhalofop or fenoxaprop or a sequential application of either herbicide. This study was established at the RRS in 2014 and 2015 and a grower location near Estherwood, LA in 2015. The initial application was applied to rice in the two- to three-leaf stage or early-POST (EPOST), or an EPOST application followed by an application 2 weeks after on four- to five-leaf rice, or late-POST (LPOST). Cyhalofop rates were 208, 314, or 417 g ai/ha. Fenoxaprop rates were 66, 86, or 122 g ai/ha. Previous research indicated quinclorac plus halosulfuron had no control of Nealley's sprangletop; therefore, quinclorac at 420 g ai/ha plus halosulfuron at 53 g ai/ha was applied delayed preemergence (DPRE) to control grass, sedge, and broadleaf weeds in the plot area. Herbicide treatments were applied as previously described.

At 21 DAT, the Nealley's sprangletop treated with fenoxaprop at 66, 86, or 122 g ai/ha, applied EPOST, was controlled 80 to 85%, compared with the cyhalofop applied EPOST at 208, 314, or 417 g ai/ha treated Nealley's sprangletop with 64 to 76% control. At 36 DAT, all Nealley's sprangletop treated with an EPOST fb LPOST application of fenoxaprop or cyhalofop was controlled 92%. The lowest control of Nealley's sprangletop, 64%, was at 21 DAT, with the application of cyhalofop at 208 g ai/ha at EPOST. Although at 51 DAT the control was similar from both herbicides, the higher control observed at 21 DAT with fenoxaprop at 122 g ai/ha yielded 8090 kg/ha compared with rice treated with cyhalofop at 208 and 314 g ai/ha with a rice yield at 6520 and 7180 kg/ha, respectively. Rice treated with an off label rate of cyhalofop at 417 g ai/ha resulted in a yield similar to rice treated with fenoxoprop at 122 g ai/ha. Rice treated with fenoxaprop at 66, 86, or 122 g ai/ha or cyhalofop at 208, 314, or 417 g ai/ha yielded 970 to 1020 kg/ha higher than the nontreated.

Nealley's sprangletop is a prolific seed producer with high seed viability. It is important to correctly identify this weed in order to select the appropriate weed management program. Imazethapyr alone will not control Nealley's sprangletop and may be the reason this weed has spread in Louisiana. A postemergence application of fenoxaprop applied at 122 g ai/ha should be used on small actively growing Nealley's sprangletop when it is present in rice.

Sharpen Tank-Mix Options for Control of Rice Flatsedge in Midsouth Rice

Jones, G.T., Norsworthy, J.K., Hale, R.R., McCown, M.S., Young, M.L., and Barber, L.T.

Repetitive use of ALS-inhibiting herbicides in Midsouth rice production has led to occurrences of sulfonylurea-resistant rice flatsedge (*Cyperus iria*). Additional modes of action (MOA) must be used to slow the spread of such herbicide-resistant weeds. Sharpen (saflufenacil) herbicide was labeled for use in rice in 2014 for preplant, preemergence, or postemergence applications to help control problem weeds. Sharpen exhibits good control of rice flatsedge when plants are less than 8 cm in height. However, the addition of a graminicide or other herbicide with grass activity will be needed to control grasses that are likely present within the same field. An experiment was conducted in 2015 to examine the influence of application timing on the control of rice flatsedge by various tank-mixes including Sharpen at the Pine Tree Research Station in Colt, AR. Application timings included pre-flood (PREFLD), 2 week post-flood (2WK POSTFLD), and 4 week post-flood (4WK POSTFLD) treatments. Sharpen, Facet L (quinclorac), Clincher (cyhalofop), SuperWHAM! (propanil), and Ricestar HT (fenoxaprop) were included in the study. Herbicides were evaluated for efficacy alone and in combination to allow evaluation with Colby's method to reveal any antagonistic or synergistic affects present. Injury ratings were taken at 7 and 14 days after treatment (DAT) and yields were adjusted to 13% moisture. Injury was greatest in treatments applied POSTFLD that included Sharpen. Yields were reduced by the Sharpen alone treatment; however, the addition of other herbicides did not decrease yield further. Control of rice flatsedge was greater than 95% in all treatments involving Sharpen. As expected, no control was seen from group 1 herbicides (Clincher, Ricestar). SuperWHAM! and Facet L exhibited greater than 95% control when applied alone. No synergistic or antagonistic relationships were documented through Colby's method. Therefore, based on the documented results in this experiment, Facet L, Clincher, SuperWHAM!, or Ricestar HT may be tank-mixed with Sharpen for additional control of problem weeds.

Activity and Control of Common Mid-South Rice Weeds with Benzobicyclon

McKnight, B.M., Webster, E.P., Bergeron, E.A., and Rustom, S.Y.

Benzobicyclon herbicide is a HPPD inhibiting herbicide that has been used in Japanese rice production since 2001. Benzobicyclon is absorbed primarily through root and shoot tissue and past research has suggested that the herbicide must be applied in flood water to be active on susceptible plant species. No past research has been conducted evaluating the role flood depth has on benzobicyclon activity on common Mid-South weed species. A greenhouse trial was established in 2013 on the Louisiana State University campus in Baton Rouge, Louisiana to evaluate benzobicyclon applied at several different rates in 2 flood depths.

Yellow nutsedge (*Cyperus esculentus* L.) tubers were planted into potting mix in 50-cell planting flats and watered to induce germination. Following germination, 5 nutsedge plants at the 3- to 6-leaf growth stage were transplanted into containers that were designed to hold a specific flood depth. The plants were allowed to establish in the containers for 7 days before a flood was established and benzobicyclon treatments were applied. This study was a randomized complete block with a factorial arrangement of treatments. Factor A was two flood depths: 5- and 10-cm. Factor B consisted of benzobicyclon at 0, 246, 492, 984, 1476, and 1968 g ai ha^{-1}. Herbicide treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} and 1% v/v COC was added to all benzobicyclon treatments. Visual injury ratings were taken 14, 21, and 28 days after treatment (DAT). At the conclusion of the study, 28 DAT, nutsedge height and leaf number were recorded for all plants and total fresh weight and tuber number were determined.

At the conclusion of the study the most consistent control, 79%, was observed with the 984 g rate in the 10-cm flood. Phytotoxicity ratings from all herbicide treatments applied in the 5-cm flood were 45 to 60%, and 43 to 79% in the 10-cm flood. The tallest plants in either flood depth treatment were in nontreated containers. Plants receiving any rate of benzobicyclon in both flood depths had a reduced plant height compared with nontreated plants. Nontreated yellow nutsedge plants in a 5- or 10-cm flood depth had more leaves per plant than plants receiving any rate of benzobicyclon in the 5- or 10-cm flood, 28 DAT. Mean tuber count was 6 and 5.4 for nontreated plants in the 5- and 10-cm flood, respectively. All plants treated with benzobicyclon had fewer tuber numbers regardless of the flood depth treatment. Whole-plant fresh weight was higher with nontreated plants over plants receiving herbicide treatment in the 5- and 10-cm flood.

While complete control of yellow nutsedge with benzobicyclon did not occur within 28 days of herbicide treatment, the reduction of plant tubers could offer benefits for rice producers by impacting potential future populations of this weed. Reduction in yellow nutsedge biomass and height may also reduce competition with rice plants. Because this product must be applied in flood water for herbicide activity to occur, benzobicyclon has a fit in water-seeded rice production which is a common planting practice in Louisiana.

Evaluation of a Benzobicyclon plus Halosulfuron Premix for Weed Control in Arkansas Rice

Young, M.L., Norsworthy, J.K., Sandoski, C., Scott, R.C., Miller, M.R., and Steppig, N.

Rogue Plus™, a new rice herbicide, is being developed by Gowan Company for post-flood control of problematic weeds. Rogue Plus will contain a mixture of halosulfuron (Group 2) and benzobicyclon (Group 27) herbicides and will control a broad-spectrum of grasses, aquatics, broadleaves, and sedges, including those currently resistant to Group 2 herbicides. If labeled as expected, this will be the first 4-hydroxyphenylpyruvate dioxygenase (HPPD) herbicide commercially available in U.S. rice production. This new mode of action in rice will enable producers to control a variety of weed species that become increasingly more problematic as the season progresses. A field study was conducted in 2014 and 2015 at the Rice Research and Extension Center in Stuttgart, AR to understand if the addition of halosulfuron (Permit) to benzobicyclon would increase the level of weed control compared to benzobicyclon alone for barnyardgrass, Amazon sprangletop, ducksalad, California arrowhead, hemp sesbania, northern jointvetch, yellow nutsedge, and smallflower umbrella sedge. Treatments in 2014 included: benzobicyclon at 247 and 371 g ai/ha, and a mixture of both rates of benzobicyclon plus halosulfuron at 35.2 and 52.5 g ai/ha, and a control. In 2015, there were two additional treatments added to the treatment structure of halosulfuron at 35.2 and 52.5 g ai/ha applied alone for a total of seven treatments. Benzobicyclon alone was effective in controlling Amazon sprangletop, ducksalad, California arrowhead, and smallflower umbrella sedge. The addition of halosulfuron to benzobicyclon generally improved control of those weeds that were marginally controlled by benzobicyclon alone. The low rate combination of benzobicyclon plus halosulfuron was often as effective as the high rate of benzobicyclon alone. The results of this study suggest that benzobicyclon premixed with halosulfuron has potential for control of problematic weeds in Arkansas rice and could be used as an additional weed management tool for control of herbicide-resistant weeds.

Benzobicyclon, a New Rice Herbicide for the Control of Sedges in Central America and the Caribbean

Calibeo, D., Zuniga, T., and Holmes, K.

The efficacy and selectivity of a novel mode of action herbicide, benzobicyclon, for pre-emergence control of grasses and sedges was evaluated in the irrigated rice cultivation area of Bagaces, Guanacaste, Costa Rica. A 400g/L SC (AVANZA® 400SC) formulation of benzobicyclon was evaluated at rates of 0.3, 0.6, 0.9, and 1.2 L/ha, against Command (clomazone) 48 EC at a rate of 1 L/ha and an untreated control. The control rate, coverage and density of weeds, and crop phytotoxicity were measured 7, 14 and 21 days after treatment application. The main weeds in the experimental area were: *Echinochloa colona, Cyperus iria, Heteranthera limosa, and Rottboellia cochinchinensis.* Benzobicyclon provided excellent control of *E. colona* and *H. limosa* at the 3 highest rates through 21 days. All four rates provided excellent control of *C. iria*. It did not provide adequate control of *R. cochinchinensis.* Compared to benzobicyclon, Command provided excellent control of *E. colona*, very poor control of *C. iria* and moderate control of *H. limosa*. Soil type, land preparation, and water management practices during and after application, may impact the efficacy of benzobicyclon. All rates of benzobicyclon demonstrated excellent selectivity on rice. Benzobicyclon at rates of 0.6 – 1.2 L/ha, applied pre-emergence exhibits control of a number of economically important weed species in Costa Rican rice production. As a new MOA herbicide, benzobicyclon may be an excellent addition to a herbicide resistance management program for rice.

Evaluation of Tank-mix Options for Provisia in Provisia Herbicide in Provisia Rice

McCown, M.S., Barber, L.T., Norsworthy, J.K., Lancaster, Z.D., Green, J.K., and Miller, M.R.

Barnyardgrass control in rice is becoming increasingly difficult as a result of increased resistance to common herbicides. BASF is currently developing a new non-GMO rice trait that will provide rice tolerance to quizalofop, an acetyl coenzyme A carboxylase (ACCase)-inhibiting herbicide. Along with this new trait BASF will be marketing the herbicide quizalofop under the tradename Provisia. An experiment was conducted in 2015 at the Southeast Research and Extension Center in Rowher, AR (SEREC) and at the Rice Research and Extension Center (RREC) near Stuttgart, AR to evaluate early postemergence (EPOST) tank mixtures containing Provisia herbicide in Provisia rice. In this study, nine common rice herbicides were evaluated in combination with Provisia herbicide for weed control and crop tolerance. Tank mixture candidates included: quinclorac at 0.042 kg ai/ha (32 oz/A) (Facet), pendimethalin at 1.12 kg ai/ha (46.5 oz/A) (Prowl 3.3), saflufenacil at 0.0187 kg ai/ha (0.75 oz/A) (Sharpen), carfentrazone at 0.056 kg ai/ha (0.75 oz/A) (Aim), penoxsulam at 0.042 lb ai/A (2.4 oz/A) (Grasp), bispyribac at 0.052 kg ai/ha (0.93 oz/A) (Regiment), halosulfuron at 0.052 kg ai/ha (1 oz/A) (Permit), propanil+bensulfuron at 3.0+0.0233 kg ai/ha (96 oz/A) (Duet), and propanil+thiobencarb at 2.25+2.25 kg ai/ha (96 oz/A) (Ricebeaux). All treatments were applied at the 1- to 3-leaf stage of rice (EPOST) and followed by (fb) quizalofop at 0.120 kg ai/ha (15.5 oz/A) (Provisia) applied 21 days after and prior to flooding (MPOST). As a result of some tank mixes (Aim or Sharpen), slight injury was observed on Provisia rice at both locations; however, no more than 10% injury was observed with any tank mixture. At both locations, weed control was evaluated on barnyardgrass and red rice. In addition, Amazon sprangletop and some off-type rice cultivars were evaluated at Rowher location. At 22 days after the EPOST application, the greatest barnyardgrass control was seen in those tank mixes that contained more than one mode of action, such as the addition of halosulfuron, at both locations, however these differences were no longer present 10 days following a MPOST application. There was a similar story with the control of Amazon sprangletop where increased control was seen when a tank mix was made with Provisia. At the Rohwer, location there was some possible antagonism seen when propanil+bensulfuron was mixed with Provisia with ≤ 60% control of barnyardgrass or Amazon sprangletop being observed. There was some variation in red rice control seen between locations at the Rohwer location, >89% red rice control was observed with all tank mixtures and Provisia alone after the first application and 99% control after the second application timing. Whereas in Stuttgart, only 75-90% control of red rice was seen after the first application and similar results after the second application timing. After the two application timings, 99% control was seen of all off-type rice cultivars. From these results, we conclude that having a tank mixing partner, with Provisia is beneficial in controlling weedy grasses and off-type rice cultivars, including red rice.

Modification of Application Volume, Rate, and Adjuvant Use for Enhancement of Rinskor™ Active

Miller, M.R., Norsworthy, J.K., Weimer, M., and Perry, H.

In rice, several major weed species have evolved herbicide resistance making effective control difficult to achieve. Barnyardgrass (*Echinochloa crus-galli*), broadleaf signalgrass (*Urochloa platyphylla*), hemp sesbania (*Sesbania herbacea*), and yellow nutsedge (*Cyperus esculentus*) continue to be some of the most troublesome weeds in rice today. As the evolution of herbicide resistance continues, the commercialization of new technologies is needed. Rinskor™ Active, a new arylpicolinate herbicide from Dow AgroSciences, provides an alternative mode of action for use in rice that exhibits broad-spectrum postemergence activity of broadleaf, grass, and sedge species. Two field studies were conducted in 2014 and 2015 to evaluate the efficacy of Rinskor as influenced by application volume, formulation, rate, and adjuvant rate. Both experiments utilized a randomized complete block design with four replications. In the first experiment two formulations of Rinskor were evaluated, an SC formulation containing no preloaded adjuvant and a NeoEC™ formulation. Both Rinskor formulations were applied at 15 and 30 g ai ha^{-1} with MSO at 0, 0.7, 1.4, 2.1, 2.8, and 3.5 L ha^{-1} at an application volume of 141 L ha^{-1}. Weeds evaluated included barnyardgrass, broadleaf signalgrass, hemp sesbania, yellow nutsedge, and Palmer amaranth (*Amaranthus palmeri*) planted in a non-flooded dryland setting. Efficacy of both formulations improved with increasing Rinskor and MSO rates. In the second experiment, the SC formulation of Rinskor was applied at 15 and 30 g ai ha^{-1} at three application volumes: 47, 94, and 187 L ha^{-1} across four MSO rates 0, 1.2, 2.3, and 3.5 L ha^{-1}. Results indicated overall weed control was greater with 30 g ai ha^{-1} than 15 g ai ha^{-1}, regardless of application volume or MSO rate, and control with 30 g ai ha^{-1} improved as application volume and MSO rate increased. Results from these studies indicate the potential for effective weed control with both the SC and NeoEC formulations. Additionally, the unique auxin chemistry of Rinskor will introduce an alternative mode of action in rice weed control and a resistance management tool.

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Assessment of Pethoxamid when Applied Alone and in Tank Mixes with Common Herbicide Regimes in Arkansas Rice

Godwin, J.G., Norsworthy, J.K., McCown, M.S., Martin, S.M., Lancaster, Z.D., and Scott, R.C.

Pethoxamid is a very-long chain fatty acid-inhibiting herbicide (Group 15) belonging to the chloroacetamide family. Currently, there are no Group 15 herbicides registered for use in U.S. rice; however, due to the success of Group 15 herbicides in Asian rice culture, it is believed that herbicides such as pethoxamid may have a potential fit in Arkansas rice production. Due to the strong evolution of resistance to several of the most commonly used herbicide modes of action in rice, it is important that new modes of action be integrated into rice production whenever possible. Pethoxamid has been found to be very effective in controlling grasses such as barnyardgrass (*Echinochloa crus-galli*) and red rice (*Oryza sativa*) along with small-seeded broadleaves. If crop tolerance can be established, pethoxamid may be used in Arkansas rice to combat resistance. Pethoxamid was applied alone and in combination with several commonly used herbicides in Arkansas rice including clomazone, quinclorac, propanil, imazethapyr, and carfentrazone. In each herbicide regime, pethoxamid was applied at 560 g ai/ha. Data were taken on visual crop injury, crop stand, crop height, percent heading, and rough rice yield. Injury of no more than 3% was observed when pethoxamid was applied alone. Yields from all treatments were statistically similar to that of the untreated control. Based on these results, pethoxamid should be further evaluated in drill-seeded rice culture.

Evaluation of Fluridone for Crop Safety and Weed Control in Rice

Meyer, C.J., Norsworthy, J.K., and Scott, R.C.

Fluridone is a currently registered herbicide for use in aquatic systems and received an emergency exemption label for use in cotton in 2012. Fluridone is a phytoene desaturase inhibitor (WSSA Group 12) and currently no Group 12 herbicides are labeled for use in rice. Prior research suggests rice may have an inherent tolerance to fluridone residues in the soil; thus, rice tolerance to various rates of fluridone applied PRE was evaluated in an Arkansas rice system. Fluridone was applied at 112, 168, 224, and 282 g ai ha^{-1} to plots established at the Rice Research and Extension Center near Stuttgart, AR. Additionally, fluridone at 112 g ai ha^{-1} was applied in mixture with clomazone (336 g ai ha^{-1}) and clomazone alone at the same rate was included for comparison. Crop injury was evaluated 3 weeks after application and all treatments containing fluridone had $\leq$ 6% injury. The most injury occurred from fluridone + clomazone (6% injury) and was not different from the clomazone-alone treatment. Prior to the application of a permanent flood (7 weeks after planting) the treated plots had no injury. However, after the application of a permanent flood, bleaching of rice tissue in all treatments containing fluridone was observed. The rice in fluridone-treated plots showed increasing injury each week and did not produce yield. Fluridone has a high persistence in the soil and is highly water soluble; thus, the establishment of a permanent flood likely dissolved the fluridone remaining in the soil from the PRE application. The result was severe herbicide injury, rapid deterioration of the crop, and crop loss. Weed control was also evaluated in this trial, and although fluridone may not be used in a rice system, this research suggests fluridone will provide suppression of barnyardgrass, broadleaf signalgrass, and will provide control of hemp sesbania. The results from this research demonstrate the importance of evaluating rice crop tolerance to new herbicides in a season-long production system.

Evaluation of Rinskor™ in Full-season Rice Weed Control Programs

Palhano, M.G., Norsworthy, J.K., Miller, M.R., and Scott, R.C.

Rinskor™ Active is a new arylpicolinate herbicide being developed by Dow AgroSciences for postemergence weed control in rice. This new active ingredient is a synthetic auxin, member of the unique arylpicolinate chemical family, which exhibits broad-spectrum activity on select grass, sedge, and broadleaf weed species. As the evolution of herbicide resistance continues, the introduction of Rinskor™ brings a new, valuable weed control tool that has an alternative mode of action for control of ALS-, ACCase-, propanil-, and quinclorac-resistant weed species in rice. A study was conducted during the summer of 2015 at the Rice Research and Extension Center in Stuttgart, Arkansas that evaluated the efficacy of Rinskor in herbicide programs commonly used in Arkansas rice production. The experiment was organized as a randomized complete block with four replications comparing 13 different herbicide programs. Herbicide applications were made at four application timings: pre-emergence; early post-emergence; 3-5 days post-flood; and 7-10 days post-flood. Overall, the utilization of Rinskor in herbicide programs enhanced barnyardgrass (*Echinochloa crus-galli*) control. Contrast analysis revealed treatments that contained Rinskor were significantly better in controlling barnyardgrass than treatments without Rinskor. Additionally, treatments that contained Rinskor and/or Permit (halosulfuron) performed significantly better than treatments without these herbicides in controlling yellow nutsedge (*Cyperus esculentus*). Rinskor is highly efficacious when utilized within rice weed control programs. Rinskor has demonstrated value as an alternative herbicide mode of action in rice and potential to be a very valuable tool for growers to control herbicide-resistant weeds in Midsouth rice production. ™Trademark of the Dow Chemical Company ("Dow") or an affiliated company of Dow. Rinskor™ is not registered with the US EPA at the time of this presentation. The information presented is intended to provide technical information only.

Seaweed Extracts and Other Secret Sauces: Do They Work?

Espino, L.

Various foliar fertilizers and biostimulants are used in California rice, including seaweed-derived products. These products are usually recommended after the application of herbicides, to reduce phytotoxicity to rice and aid in rice plant recovery; when plant growth seems stunted due to cool air or water temperatures or suspected nutrient deficiencies; to improve resistance to diseases; or to promote growth and yield. Registration of these products with regulatory agencies does not require performance data. Growers and pest control advisers rely on information developed by technical, sales and marketing representatives of the industry selling the products. In the past few years, several pest control advisors and rice growers have expressed interest in using these products. However, the question of their value under our rice production system lacks scientific evaluation.

The objective of this study was to evaluate the effect of foliar fertilizers and seaweed-derived products in the growth and yield of rice when an herbicide with the potential to cause injury is used. For this, a bispiribac-sodium application was made early in the development of the crop (4 leaf stage of rice) at the highest label rate (60 ml/ha). Small plot (3x6 m) trials were conducted in 2014 and 2015. In 2014, treatments included two formulations of a nitrogen-based foliar fertilizer, three commercial seaweed-derived products (based on the species *Ascophyllum nodosum* or *Ecklonia maxima*), and a combination of nitrogen and seaweed. All treatments were applied at mid-tillering following the recommended label rate. In 2015, treatments consisted of four commercial seaweed-derived products applied at early tillering, mid-tillering, and panicle initiation following the recommended label rate. Parameters evaluated in both years were panicles per 0.09 m^2, weight of grain per panicle, plant height before harvest, and plot yield. The trials were established in a split-plot design, with main plots bispiribac-sodium and no bispiribac-sodium application, and sub-plots foliar fertilizer or seaweed treatment.

In both years, the bispiribac-sodium application did not have a negative effect on any of the parameters evaluated. In 2014, the treatments had a significant effect on some parameters, but in 2015 they did not. In 2014, treatments slightly increased the number of panicles per 0.09 m^2. When compared to the untreated (66 panicles/0.09 m^2), P-values of the other treatments were low and in the case of one *Ascophyllum nodosum* treatment (Acadian), well below the threshold for significance (80 panicles/0.09 m^2, $P = 0.017$). Increased number of panicles per square foot may be the result of increased tillering. The treatments had no effect on the number (85.41) or weight (2.48 g) of filled grains per panicle. There was no effect of the treatmetns on yield, with yields ranging from 10,266 to 10,684 kg/ha. However, when compared to the untreated, yields from plots treated with Symspray (*Ascophyllum nodosum*), Acadian, and Kelpak (*Ecklonia maxima*) had low P-values (0.396, 0.254, and 0.208, respectively), indicating a tendency to higher yields.

A Review of Fertilizer-Nitrogen Additives and Their Utility for Preflood-N Management

Slaton, N.A., Norman, R.J., Roberts, T.L., Golden, B.R., and Hardke, J.T.

Urease-inhibiting compounds including N-(n-butyl) thiophosphoric triamide (NBPT) have been researched in the USA for more than 40 years. Products containing the active ingredient NBPT are routinely applied to urea before flooding (preflood) rice (*Oryza sativa* L.) grown in the mid-South USA. Research initiated in 2002 led to the adoption of NBPT as a recommended N additive in 2004 by the University of Arkansas Division of Agriculture with the NBPT-containing product marketed as Agrotain (Agrotain International, St Louis, MO). The objective of this presentation is to review the existing knowledge of how NBPT-containing compounds can enhance urea-N recovery by rice and identify issues that require additional research.

Selected field experiments that have used semi-open, static chambers to capture NH_3 show the percentage of applied urea-N lost as NH_3 often ranges from 2 to 12% for NBPT-treated urea and 7 to 33% for urea. The mean yield difference between N sources for these same trials ranges from 0 to 26% with four of the seven sites having yield advantages >5% when NBPT-treated urea was applied. The chambers clearly show whether products claiming to be a urease inhibitor reduce NH_3 loss but the loss from inside the chamber does not represent the actual loss that occurs in the field environment.

Across 39 field trials the average rice grain yield produced with urea (7479 kg/ha or 148 bu/acre) was 505 kg/ha lower than that the yield of rice fertilized with NBPT-treated urea (158 bu/acre) suggesting an overall numerical yield benefit from its use. Thirteen mean comparisons from trials performed on dry (at time of application) clayey soils showed yields of rice fertilized with NBPT-treated urea, as compared with urea-fertilized rice, were 3-4% greater when flooded 1 to 3 days after application and 8% greater when flooded 7 to 9 days after application. Ninety-three mean yield comparisons from trials conducted on dry silt loams showed rice fertilized with NBPT-treated urea yielded -2, 3, 8, 3, and 6% greater than urea-fertilized rice when the flood was applied 1, 3-4, 5-6, 7-9, and ≥10 days after application. Of the 93 mean comparisons, 47 had yield differences <252 kg/ha (5 bu/acre) and 32 had yield differences >450 kg/ha (10 bu/acre) suggesting the yield benefit from the use of NBPT-containing urease inhibitors is not always present when preflood urea-N is applied to a dry soil. In contrast, 23 mean yield comparisons from trials conducted on moist, loamy soils showed a 15% yield benefit (1071 kg/ha) from NBPT-treated urea. The yield benefit from NBPT-treated urea applied to moist, loamy soils was >505 kg/ha in 19 of the 23 mean comparisons indicating the benefit was relatively large and consistent.

The database showed a limited number of trials that describe the efficacy or duration of benefit as affected by NBPT-application rate, trials conducted on clayey soils, and whether the rice grain yield response to N rate curve changes between NBPT-treated urea and urea. Three trials conducted under moist or dry soil conditions suggest that yield response curves for the urea and NBPT-treated urea were parallel meaning the N rate needed to produce maximal yield does not change, but the overall yield produced is shifted upwards when NBPT-urea is used as the preflood N source. Finally, there are no studies in rice that evaluate how the use of NBPT-treated urea may influence potential N losses from runoff or how long floodwater N content remains elevated following flooding.

Evaluation of Volatilization Potential of Multiple N Sources on Six Common Rice Soils in a Controlled Environment

Harrell, D.L., Kongchum, M., Schwab, G., Adotey, N., Li, J., Leonards, J., and Fluitt, J.

Trials were initiated at the LSU AgCenter's H. Rouse Caffey Rice Research Station in Crowley, Louisiana, to investigate the volatility potential of multiple fertilizer nitrogen (N) sources on several soils common in the rice production area of the Mid-Southern United States. Soils included a Mowata silt loam (pH 5.8), Alligator clay (pH 7.2), Calloway silt loam (pH 7.1), Kinder silt loam (pH 6.6), and two Crowley silt loams. Crowley1 had a pH of 6.6 while Crowley2 had a pH of 7.4. Fertilizer N sources included Agrotain Ultra treated urea (AU-U; 26.7% NBPT), manufactured Agrotain urea (MAU; NBPT concentration unknown), Agrotain Advanced treated urea (AA-U; 30% NBPT), and urea. Ammonia volatility potential was determined in a controlled environment in the laboratory using a customized system. The laboratory system included 4 temperature controlled cabinets. Six glass containers within each cabinet were used to hold 500 g of air-dried soil. Soils were adjusted to a moisture content of two-thirds FC. The lids were placed on the containers and the containers were then placed into the cabinets for 24-hours to allow the soil temperature to equilibrate with the set cabinet temperature of 26^{o}C. Fertilizers were then sieved, weighed and surface broadcast on the soils inside the containers at a rate of 48 mg N kg^{-1} soil. The lids were placed back on the containers and humidified air (approximately 100% relative humidity) was passed through the container at a rate of 1 L min^{-1}. The mean head space above the soils (at 2/3 FC) within the containers varied slightly with each soil sample evaluated and ranged from 533 – 582 cm^{-3}. Based on the head space and flow rate, the volume of air within the chamber was exchanged between 1.7 and 1.9 times per minute. Air flow ended in an acid trap containing 100 ml of 0.02 M phosphoric acid which was used to capture ammonia in the air stream and convert it to NH_4-N. NH_4-N was measured in the acid traps colorimetrically using Lachat flow-injection Analyzer equipped with an auto-dilutor. Concentration of NH_4-N was adjusted based on the final volume (weight) of the acid trap. Acid traps were changed 24, 48, 72, 96, 120, 144, 168, 216, 264, 312, and 336 h after fertilizer application.

Cumulative NH_3-N loss was 17.0, 12.2, 9.6, and 9.5 mg kg^{-1} for urea, MAU, AU, and AA, respectively, over the 14 d evaluation for Crowley1. Cumulative NH_3-N loss was 7.4, 3.7, 2.8, and 2.7 mg kg^{-1} for urea, MAU, AA, and AU, respectively, over the 14 d evaluation for Crowley2. Cumulative NH_3-N loss was 7.6, 5.4, 5.5, and 3.8 mg kg^{-1} for urea, MAU, AA, and AU, respectively, over the 14 d evaluation for Alligator. Cumulative NH_3-N loss was 4.0, 2.3, 2.0, and 1.2 mg kg^{-1} for urea, MAU, AA, and AU, respectively, over the 14 d evaluation for Mowata. Cumulative NH_3-N loss was 12.9, 6.8, 5.5, and 4.9 mg kg^{-1} for urea, MAU, AA, and AU, respectively, over the 14 d evaluation for Calloway. Cumulative NH_3-N loss was 12.6, 10.3, 7.9, and 6.1 mg kg^{-1} for urea, MAU, AA, and AU, respectively, over the 14 d evaluation for Kinder. The rate and extent of volatile N loss varied across soil types due to a combination of chemical and physical properties. Across all soils MAU, AA, and AU reduced N volatilization losses as compared to untreated urea.

Effect of Delaying the Flood and Preflood Nitrogen Application on Rice Nitrogen Uptake and Yield

Richmond, T.L., Slaton, N.A., Hardke, J.T., Roberts, T.L., and Norman, R.J.

Urea-N fertilizer is typically applied at the five-leaf stage of rice (*Oryza sativa* L.) grown in a dry-seeded, delayed-flood cultural system in Arkansas. Application of urea to a dry soil is needed to maximize rice N recovery efficiency and grain yield potential. How long the preflood-N can be delayed before yield loss occurs is poorly understood and requires additional research. Our objective was to determine the effects of delaying preflood-N fertilizer application and flooding past the five-leaf stage on growth and grain yield of rice grown on silt loam soils. Trials were established at two locations during 2015 using 'RoyJ' and selected other cultivars or hybrids including 'Jupiter', 'LaKast', 'CL111', and 'XL753'. The focus of this presentation will be on the response of RoyJ rice to flood time at Pine Tree and Stuttgart locations. Urea-N fertilizer was applied at 0, 45, 90, 135, and 180 kg/ha on five or six different dates spanning 5 or 6 weeks (230 - 911 DD10 or 453 - 1640 DD50 units), depending on the research site, after the 3-5 leaf stage. Tiller number per plant and aboveground-N content at early heading were measured for RoyJ and grain yield was measured for all cultivars and hybrids. Regression analysis was performed to examine how each growth variable was affected by time expressed as growing degree units after emergence (e.g., DD10 or DD50).

Stem number was a negative, linear function of preflood-N application time (DD10 units), regardless of urea-N rate. Stem number usually increased as urea-N rate increased and followed the general order of 180 ≥ 135 = 90 ≥ 45 > 0 kg urea-N/ha. Aboveground-N content was a quadratic function of time with only the intercept depending on preflood urea-N rate. The predicted aboveground N content of rice peaked when preflood-N was applied 896 (1635 DD50) and 377 (775 DD50) DD10 units after rice emergence at Pine Tree and Stuttgart, respectively. Grain yield responded slightly differently to preflood-N application time at the two sites. At Pine Tree, grain yield was a quadratic response to fertilization time and was characterized by a uniform quadratic coefficient with each urea-N rate having a unique intercept and linear slope coefficient. At Stuttgart, grain yield was a quadratic function of preflood-N application time described by common linear and quadratic coefficients but different intercept terms among the five urea-N rates. Maximal yield was produced when 180 kg urea-N/ha was applied 555 DD10 units (995 DD50) after emergence at Pine Tree and 434 DD10 units (889 DD50) after emergence at Stuttgart. Rice fertilized with 180 kg urea-N/ha produced yields within 5% of the maximum predicted yield when urea-N was applied between 284-616 (512-1109 DD50) and 253-620 (527-1264 DD50) cumulative DD10 units at Pine Tree and Stuttgart, respectively. At Pine Tree, the optimal cumulative DD10 units for preflood-N application increased as the urea-N rate decreased. At Pine Tree, the aboveground-N content of rice that received no fertilizer-N increased as cumulative DD10 units increased. Delaying preflood-N and flooding may decrease rice tiller formation (or retention), but the panicle-bearing stems compensate by producing a greater number of seeds per panicle. Plant development and maturity were also delayed by delaying urea-N application and flood time.

Impact of Delayed Nitrogen Applications into Flooded Rice

Frizzell, D.L., Hardke, J.T., Norman, R.J., Roberts, T.L., Slaton, N.A., Casteneda, E., Clayton, T., and Lee, G.

Approximately 96% of Arkansas rice is grown using the dry-seeded, delayed-flood system. In this system, nitrogen (N) fertilizer is applied to the crop as a single preflood (SPF) or two-way split (2WS) application. The large preflood N application is made around the 4- to 6-leaf growth stage and the second application, if needed, is applied during early reproductive growth. The decision of which option to use in a particular field is based on a number of conditions, including irrigation pumping capacity, field size, and timeliness of flood establishment. However, the preflood N application of each option should be made onto dry soil and incorporated with the floodwater to obtain maximum uptake of the preflood N fertilizer. Rainy conditions in recent years have made the application of preflood N fertilizer onto dry soil at the optimum growth stage unlikely on many fields in Arkansas. As a result, questions have emerged concerning the best management strategy for these fields to preserve grain yield potential. Therefore, studies were initiated comparing possible N fertilizer application timing options in the floodwater to the recommended practice of N fertilizer application to dry soil followed by water incorporation.

Studies were conducted at the University of Arkansas System Division of Agriculture Rice Research and Extension Center near Stuttgart, AR on a DeWitt silt loam soil using NBPT-coated urea as the N source. Rice cultivars evaluated included Roy J and CLXL745 in 2014 and LaKast and XL753 in 2015. The studies were arranged as a 2 (cultivar) x 2 (N timing) factorial. Plots received either a SPF N application to dry soil or a series of five N applications into the floodwater beginning 1 day postflood at 7 day intervals. Statistical analysis were conducted with SAS 9.4 and means were separated using Fisher's protected LSD with α=0.05. During 2014 and 2015, there was no cultivar x N timing interaction and grain yield was optimized using a SPF N application applied to dry soil and water-incorporated.

An additional study was initiated during 2015 utilizing eight N fertilizer treatments applied to LaKast rice. The study was arranged as a randomized complete block and means were separated using Fisher's protected LSD with α=0.05. Treatments consisted of the recommended SPF and 2WS options with the preflood N applied to dry soil, variations of sequential fertilizer applications into the floodwater, and a no N fertilizer check. Treatments were initiated based on dates noted from a DD50 report generated for this study. The SPF N fertilizer application resulted in significantly higher grain yield than the 2WS treatment. Both of these options produced grain yields significantly higher than any of the treatments made only into the floodwater.

Grain yield was optimized in all three studies using a single preflood N application onto dry soil and water-incorporated. Nitrogen fertilizer application into the floodwater resulted in yield reductions of 10-37% depending on cultivar within each study.

Effect of Soil Moisture on the Efficiency of Pre-flood N Applications in Rice

Harrell, D.L., Kongchum, M., Schwab, G., Adotey, N., Li, J., Leonards, J., and Fluitt, J.

Soil moisture at the time of fertilizer nitrogen (N) application can play a large role in N use efficiency (NUE) of preflood applications in rice production. Losses of N can occur from ammonia volatilization and from nitrification/denitrification. The objectives of this study were to: 1) evaluate NUE and grain yield response when preflood fertilizer N is applied on a dry, moist and flooded rice soil; and 2) quantify N volatilization losses of preflood fertilizer N when applications are made on a dry, moist and flooded rice soil. Two field yield and two field volatilization trials were conducted at the H. Rouse Caffey Rice Research Station in Crowley, Louisiana, in 2014 and 2015. Field yield trials consisted of three soil moisture conditions at fertilization: 1) dry, 2) moist, and 3) flooded. Fertilizer N treatments included urea, Agrotain Ultra-treated urea (AU-U; 26.7% NBPT), manufactured Agrotain urea (MAU; NBPT concentration unknown), and SuperU (NBPT + DCD incorporated urea). Volatilization was measured in the field over a 15-d period of time after fertilization using semi-open volatilization chambers and an acid trap.

When urea was the fertilizer source, cumulative volatilization losses over the 15-day period of the study were 23.6, 25.2, and 5.9% when applied on a dry, moist, or flooded soil, respectively, in 2015 and were 23.0, 19.8, and 4.5% when applied on a dry, moist, or flooded soil, respectively, in 2014. In both years, significantly higher volatile N losses were observed from urea when N was applied on a dry or moist soil as compared to applications into a standing flood, regardless of fertilizer source. When the fertilizer source was AU-U, MAU or SuperU, applications on a dry or moist soil were significantly reduced as compared to untreated urea; however, applications into a standing flood resulted in volatilization losses similar to untreated urea.

In 2015, when urea was the fertilizer N source, rice yield was highest when applied on a dry soil (7,992 kg ha^{-1}), was reduced when applied on a moist soil (4,353 kg ha^{-1}), and reduced further when applied into a standing flood (2,477 kg ha^{-1}). Rice grain yields, when enhanced efficiency fertilizer sources were used, were superior to urea when applied onto dry or moist soil. Rice yields were significantly less when N fertilizer was applied into a standing flood as compared to applications onto dry ground, regardless of N source. NUE of rice, when fertilizer N was applied into a standing flood, was 6% or less regardless of N fertilizer source used, highlighting the inefficiency of N applications that are applied into standing water when rice is at the 4- to 5-leaf stage of development.

Increased nitrification/denitrification and volatilization losses will occur when fertilizer applications are made onto moist soils or into flooded rice fields, as compared to applications on dry ground, when rice is at the 4- to 5-leaf stage of development. Preflood fertilizer applications should always be applied on a dry soil.

Comparison of Rice Grain Yield Response Curves to Preflood Urea-N with and without a Urease Inhibitor

Cox, D.D., Slaton, N.A., Roberts, T.L., Norman, R.J., and Delong, R.E.

Treating urea with an N-(n-butyl) thiophosphoric triamide (NBPT) containing urease inhibitor is a standard practice for preflood urea-N management for rice (*Oryza sativa* L.) in the mid-South USA. The use of an effective urease inhibitor can reduce ammonia (NH_3) loss and increase rice recovery of preflood-applied urea-N. Provided that excessive fertilizer-N is not applied, reducing NH_3 loss should lower the amount of N required to maximize rice yield. Our objective was to evaluate yield response curves of rice fertilized with urea and NBPT-treated urea to determine the optimal N rate with each N source.

A total of three trials were established in 2013 (A, B) and 2014 (C) in fields having an alkaline silt loam soil (Calhoun series). Urea-N, urea treated with Agrotain Ultra (Koch Agronomic Services, LLC., Wichita, KS) and urea treated with Factor (Rosen's Inc., Liberty, MO) were applied at rates of 0, 34, 68, 102, 136 and 170 kg N/ha (30-150 lb N/acre). Agrotain Ultra and factor were applied at labeled rates resulting in 0.088% NBPT on urea. The N treatments were applied to a dry soil in trials A and C and a moist soil in trial B. The flood was established 7 (B), 8 (A), or 10 (C) days after fertilizer-N application. Each trial was a randomized complete block, 3 (N source) by 5 factorial (N rate) plus one no fertilizer-N control in each replicate (n=4). Yield was regressed across N rates (34-168 kg N/ha) allowing for linear and quadratic N rate terms and the interaction with N source. The model was simplified by removing the most complex non-significant term until the simplest, significant model was derived. Regression was performed by site since inclusion of site-year in the model resulted in significant complex interactions among site-years.

For trial 'A', grain yield was a linear function of N rate and was not influenced by fertilizer-N source (i.e., same intercept). At sites 'B' and 'C', grain yield was a quadratic function of N rate that depended on fertilizer-N source with rice fertilized with the two urease-treated sources producing equal yields that were greater ($p < 0.15$) than the yield of rice fertilized with urea. The yield advantage of rice fertilized with urease-treated urea was 202 - 303 kg/ha (4-6 bu/acre) in trial 'C' and 650 – 700 kg/ha (13-14 bu/acre) in trial 'B'. The different responses to urea-N source and N rate are likely due to different field conditions from the time of fertilizer-N application until flood establishment. In trial 'A', fertilizer-N was applied to a dry soil and substantial rainfall occurred within 60 hours, which together may have limited NH_3 loss from all N sources, but accentuated nitrification and eventually denitrification upon flooding. As compared to Trial 'C', the greater yield benefit from the urease inhibitor in trial 'B' was likely due to fertilizer-N application onto a moist soil. The results of these three trials show a yield benefit from treating urea with the NBPT-urease inhibitor is dependent upon having conditions conducive to NH_3 loss. When such conditions are present, significant yield benefits are obtained from the use of an effective urease inhibitor. The results also indicate that the yield benefit from the urease inhibitor was not affected by N rate, which suggests that other N loss mechanisms may have been present and affected the N sources differently since NH_3 loss is usually negligible with low urea-N rates and increases as urea-N rate increases. Finally, the same linear and/or quadratic slopes suggest that maximum yields occurred at the same total-N rate but the peak yield was greater when the urease inhibitor was used at two of three sites.

The Validation of N-STaR for Rice on Clay Soils in Arkansas

Davidson, J.T., Roberts, T.L., Hardke, J.T., Slaton, N.A., and Greub, C.E.

Accurate N fertilization is vital to obtain high rice yields in Arkansas. The Nitrogen-Soil Test for Rice (N-STaR) was recently developed to estimate the N mineralization potential of a soil and provide site-specific N fertilizer recommendations. The N-STaR program was validated on silt loam soils in Arkansas in 2013, but lacks validation on clay soils. Validation is an essential component in ensuring the accuracy of the N-STaR calibration curves across a wide range of production settings.

A total of 13 sites across Arkansas were selected on clay soils of varying native-N availability. Soil samples were taken at each location to the required 30 cm depth for clay soils, and N-STaR analysis was completed to determine the N rate using the 100 and 95% relative grain yield (RGY) curves. Six treatments were compared in the validation trial; a control (0 kg N ha^{-1}), the N-STaR 95 and 100% RGY N rates applied in a standard two-way split application (2-WS), the N-STaR 95 and 100% RGY N rates applied in a single pre-flood application (SPF), and the Standard N Recommendation (SNR) based on cultivar, soil texture, and the previous crop.

Season-total N rates using N-STaR resulted in N rate changes from -224 to 0 kg N ha^{-1} when compared to the SNR. Nine of 13 locations had no statistical yield differences ($\alpha = 0.05$) between the N treatments. At three locations (Sites 3, 4, and 9), the N-STaR 95% RGY SPF was significantly different from the SNR with yield differences ranging from -1162 to -2144 kg rough rice ha^{-1}. The N-STaR 95% RGY 2-WS yielded statistically lower than the SNR at Site 3, but was statistically similar to the SNR at Sites 4 and 9. Furthermore, there were no yield differences between the N-STaR 100% RGY 2-WS and SPF treatments and the SNR at Sites 3, 4, and 9. For Site 12, the N recommendation across all N-STaR treatments was 0 kg N ha^{-1} and is contrasted by the SNR of 224 kg N ha^{-1}, based on the cultivar and previous crop. In this case, the N-STaR N recommendation yielded significantly higher than the SNR at a magnitude of 3668 kg rough rice ha^{-1}.

Overall, the N-STaR 100% RGY 2-WS and SPF applications and the N-STaR 95% RGY 2-WS application appear to accurately predict the N needs of rice in Arkansas, but the N-STaR 95% RGY SPF N rate may require an adjustment in order to limit yield loss. Further research is needed concerning SPF N applications on clay soils and what minimum N fertilizer rate thresholds may need to be set in order to prevent yield losses when using the N-STaR program in high native N fertility areas.

Evaluation of Optical Sensor-based Nitrogen Recommendation for Mid-southern U.S. Rice Production Systems

Tubana, B., Harrell, D., Walker, T., and Phillips, S.

There has been a continued research effort in refining nitrogen (N) fertilizer management in crop production. In rice (*Oryza sativa*) production systems in mid-southern U.S., N rate recommendation is established from response trials that are continuously conducted year after year at multiple locations using different rice cultivars. The use of optical sensing technology in determining mid-season N rate requirement in rice was recently pursued in the region as a mean to improve N fertilizer management. The optical sensor-based N decision tool (SBN) utilizes normalized difference vegetation index (NDVI) readings to determine mid-season N application rate based on two components: (1) yield potential which gives an estimate of N demand and (2) N response index which gives an estimate of available N in the soil. Unlike other N recommendation approach, SBN takes into account the variability of environmental factors both in space and time which highly influence plant growth and development, and N transformation in the soil system. This study was conducted to evaluate the performance of SBN and common split N application (fixed split N) in rice using grain yield, N use efficiency, and net return as metrics. Trials were established at different rice producing areas in Louisiana and Mississippi using different rice cultivars (CL152, CL162, and CL261) from 2009 to 2011. Two fixed split N rate combinations were included: (a) 85 kg N ha^{-1} preplant + 50 kg N ha^{-1} mid-season and (b) 120 kg N ha^{-1} preplant + 50 kg N ha^{-1} mid-season while the optical sensor-based N decision tool used two preplant N rates (85 and 120 kg N ha^{-1}) with mid-season N rate determined based on NDVI readings. Considering each year, site, cultivar, and two preplant N rates, a total of 53 field evaluations were made between SBN and fixed split N. Of these 53 field evaluations, 11 received >50 kg N ha^{-1}, 39 received <50 kg N ha^{-1} and three received 0 mid-season N recommendation from SBN. For the 11 field evaluations receiving >50 kg N ha^{-1}, nine had higher net return than fixed split N which ranged from \$15 to \$138 ha^{-1}. More than half (22/39) of the field evaluations with plots receiving <50 kg N ha^{-1} from SBN obtained higher net return than fixed split N which ranged from \$5 to \$328 ha^{-1}. Two field evaluations with plots with no recommendation for N from SBN returned lower net profit than fixed split N with losses of as much as \$148 ha^{-1}. Overall, the SBN midseason recommendation returned 30 positive net returns out of 53 field evaluations made. The higher-than-50 kg ha^{-1} mid-season N rates from SBN mostly returned higher yields which offset the additional cost of N fertilizer which eventually resulted in higher net return. However, these plots attained little or no improvement in N use efficiency. The N use efficiency of plots with lower or no N recommendation from SBN was generally improved but these improvements did not consistently translate to higher net return. The savings incurred from applying lesser amount of N was not always enough to offset the cost of grain yield reduction which ranged from 22 to 533 kg ha^{-1}. The results of this study showed the potential of SBN as an N decision tool for rice as well as some aspects where improvement is necessary to ensure the successful application of SBN in managing N fertilizer in mid-southern U.S. rice production systems.

Assessing N Fertilizer Management Practices that Reduce Greenhouse Gas Emissions and Increase Grain Yield in Irrigated Flooded Rice Systems

Adviento-Borbe, M.A. A., Anders, M., Pittelkow, C., Linquist, B., and Van Kessel, C.

Managing efficiently N fertilizer inputs during the growing season can reduce greenhouse gas emissions (GHG) in irrigated rice systems. Field studies were conducted to quantify the impacts of different N fertilizer management practices that aimed to increase N use efficiency on CH_4 and N_2O emissions in flooded rice fields in California and Arkansas. Rice yield and GHG emissions were determined from drill seeded (AR, CA1, CA2; 84-70 kg seed ha^{-1}) and wet seeded (CA3, CA4; 224 kg seed ha^{-1}) farmer's and experimental fields fertilized with various N fertilizer sources (i.e. aqua ammonia, urea, polymer coated urea (Agrotain™), and ammonium sulfate) and fertilizer placements (i.e. broadcast or subsurface once or twice during the growing season) at recommended N rates ranging from 100-168 kg N ha^{-1}. Emissions of CH_4 and N_2O were measured throughout the rice crop cycle using a flux chamber and gas chromatography method. At all sites, grain yields were 3.5 to 6.2 Mg ha^{-1} without N fertilizer application. The addition of N fertilizer increased yield by approximately 113% with no consistent trends among N sources, number and mode of fertilizer applications. Fertilizer use efficiency ranged from 17 to 64% with the highest in wet seeded fields. In all locations, different types of N fertilizer had no effect on annual CH_4 and N_2O emissions however, magnitudes of CH_4 and N_2O emissions were 1.5 and 1.8 times higher with N application compared with unfertilized treatments (81 kg CH_4-C and 0.56 kg N_2O-N ha^{-1} yr^{-1}) , respectively. There were no clear patterns whether application of different N fertilizer sources (urea, polymer coated urea, ammonium sulfate, aqua N) effectively decreased global warming potentials (GWP) because annual GWP were variable in all sites. Yield-scaled annual GWP tended to decrease in split N fertilizer treatments but this was not consistent across sites. Our results show that N management practices that maintain grain yield may have potential to reduce GHG emissions but require further assessment.

Rice Yield as Influenced by Alternative Water Management

Roberts, T.L., Hardke, J.T., Slaton, N.A., Shafer, J.B., Greub, C.E., and Davidson, J.T.

Increasing concerns over the water use associated with rice production in the Delta has led producers to consider alternative water management practices in an effort to preserve water resources and lower input costs. This trial was initiated to determine the influence of cultivar and water management strategy on rice grain yield on both a silt loam and clay soil. Trials were conducted on silt loam soils at the Pinetree Research Station (PTRS) and Rohwer Research Station (RRS) during 2012 and 2013 and on clay soils at the Northeast Research and Extension Center (NEREC) and RRS during 2014 and 2015. Water management treatments included a conventional flood (CF), DD-50 drain (DD-50), intermittent flood (IF) and flush (FL) irrigation treatments. Irrigation timing was managed using soil moisture sensors located in each water management bay and the irrigation "trigger" point varied based on soil texture. The cultivars were chosen to represent commonly produced cultivars in the Delta region and included 'Wells', 'CL152', 'CL XL723' and 'CL XL745', during 2012 and 2013 and 'Roy J', 'CL152', 'XL753' and 'CL XL745' in 2014 and 2015. The experimental design was a full factorial arrangement with cultivar and water management as the main effects of interest. Due to the complex nature of environment and planting date on rice grain yield, ANOVA was conducted, by site-year. The results of the ANOVA indicated a significant cultivar x irrigation treatment interaction for the five site-years included in this study. The three Rice Tec hybrids (XL723, XL753 and CL XL745) were among the highest-yielding cultivars across all locations and water management treatments. The highest yield obtained in this trial was CL XL745 at 12,550 kg ha^{-1} and was achieved in both the CF and DD-50 water management treatments. The lowest overall yield in the trial was with Wells in the FL treatment which only yielded 4331 kg ha^{-1}. Overall, yields for the cultivars were not statistically different across the CF and DD-50 water management treatments. However, in the IF and FL treatments there were very large differences both within and across cultivars. Within these trials there was little disease or weed pressure due to the alternative water management treatments, which suggests that yields could have been substantially lower if these pressures had been present. Data presented in this paper indicates that cultivar is an important consideration when implementing alternative water management practices as there is a significant influence on rice grain yield. Although significant reductions in water usage can be obtained with alternative water management practices, there is some yield penalty when the FL treatment is implemented even in the absence of excess disease and weed pressures.

Rice Water: Multiple Inlet Irrigation for Rice Made Mobile

Henry, C. and Saraswat, D.

Multiple Inlet Rice Irrigation is the practice of using lay-flat poly pipe to distribute water across a contour or precision grade rice field. Adoption of MIRI is still very low in Arkansas, yet has the potential to reduce irrigation cost by 25%. One of the challenges with implementing MIRI is that users must complete many repetitive calculations for each field and they must measure the area of each levee for the calculations. A mobile application has been developed to address this need. The mobile application provides a MIRI plan allowing the user to quickly and easily measure individual levees, pipe placement and distances to optimize pipe lengths. The program also provides the blue gate settings for each levee and the plan can be emailed and saved for use in the field. The program has reminders and help menus that show farmers how to set levee gate heights for MIRI for maximum water savings.

Evaluating Rice Cultivar Response to Water Stress Using Subsurface Drip Irrigation

Henry, C., McClung, A.M., and Gaspar, J.

Nearly 2.6 million acres of rice in the USA are produced using a flooded paddy system. However due to depletion of ground water, climate patterns that have resulted in reduced precipitation, and increasing competition with urban areas for water resources, the future of rice production in parts of the USA is in jeopardy. Little research has been conducted in the USA to develop rice varieties that have the yield potential for production under reduced water use scenarios. The goal of this research is to identify cultivars that possess water stress tolerance.

Fifteen rice cultivars representing nine conventional long grains, two conventional medium grains, and four indica cultivars were evaluated using a subsurface micro-irrigation system over two years at Stuttgart, AR. Each plot was represented by two drill seeded rows (1.7 sq. m) and the subsurface drip pressure compensated line was buried 20 cm on 60 cm intervals (emitter spacing of 20 cm). This resulted in one line per two rows of plants. The plots were fully irrigated until the plants reached the 4-5 leaf stage and then the irrigation treatment levels were applied. The irrigation treatments were arranged in four zones with cultivars randomized within three blocks for each treatment. An Acclima™ controller and sensor array were used to maintain four soil moisture levels at set-points consistent with just above the wilting point and just above the field capacity for a Dewitt silt loam soil (30%, 24%, 20%, and 14% volumetric soil water content). Additionally, weekly readings using a Dynamax soil moisture probe were used to monitor the soil moisture of each individual plot. The four irrigation treatments were separated by a non-irrigated border consisting of four rows. In both years final plant height, grain yield per plant (average of 3-4 plants), and days to harvest were measured while data on days to heading, disease incidence, and water stress symptoms were determined for each plot in only one year. Actual soil moisture treatments, averaged from each plot from respective treatments, were 33.5%, 30.8%, 25.4%, and 20.0% in 2014. In 2015, dryer conditions persisted resulting in actual average treatment levels of 24.9%, 21.5%, 17.9%, and 13.5%.

A range of panicle symptoms were observed in response to increasing water stress including blanking, sterility, delayed tillering, and panicles which did not emerge. Plot soil moisture was used as a covariate in the analysis of variance. Varieties were significantly different for plant yield, with Teqing, Francis and Rondo having the highest yield independent of irrigation treatment levels.

Field Scale Analysis of Alternative Irrigation Practices in the Midsouth

Reba, M. and Simpson, G.

Rice is the staple crop for the largest number of people in the world. Arkansas accounts for nearly 50% of U.S. rice production which is distributed over 1 million ha. Irrigation water use in rice production is high relative to other crops and strategies for using less water while maintaining grain yields are being developed. The majority of rice production relies on groundwater extraction. Declining groundwater levels threaten the long-term use of this source. A detailed study looking at water use on 18 production-sized fields is presented from data collected during production season 2015.

All 18 fields were broken into pairs by proximity, and treatment was randomly assigned. Pairs were adjacent to one another. Twelve of the fields were on precision-leveled ground and six were on zero-grade. All fields were planted with hybrid rice variety XL753. The treatment was irrigation water management and was either alternate wetting and drying (AWD) also referred to as “intermittent flooding” and the other was conventionally flooded. 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. Conventional flooding maintains a constant flood on the crop from the V4-V5 growth stage (4-5 leaf stage) until the R7 growth stage. One dry down event occurred during the production season of 2015.

Data collection included irrigation (flowmeters), water depth (using manual and automated methods) in the field, and yield from all study fields. Due to limited resources, soil moisture was measured on ten of the fields, water quality on four of the fields, and greenhouse gas on two of the fields. Greenhouse gas measurements were made with eddy covariance instrumentation and static vented chambers. Total water applied between treatments averaged 28.4 acre-in and 24.4 acre-in on the conventional and AWD fields, respectively, with no statistical differences between these values. During the single dry down event, water applied was statistically different between treatments where conventional fields had three times the amount of water applied compared to AWD. Yields were not statistically different between treatments and averaged 196 bu ac^{-1}. Milling quality was similar in most cases with confounding effects from weather conditions during harvest. Methane emissions from the conventionally irrigated field was just over twice the amount from the AWD field.

A Solution for Precise Water Management through GPS Variable Slope Land Forming: The Successful Story behind Central America's Leading Rice Farms for Increasing Yields by +85% at Low Affordable Cost

Aguero, J.

This presentation shows the results of the introduction of a precise GPS controlled land forming (leveling) systems with variable slope field design; as an efficient alternative to laser leveling systems in farms in Nicaragua, Costa Rica and Panama from 2011 to 2015; with initial grain yields of 4.1 metric tons per hectare (mt/ha) increasing to 7.53 mt/ha.

Under laser systems, field design model follows a planar surface that best fit the high and low elevations and balance the cut and fill earthwork. Field could have grade or even zero grade, but remains a planar surface. The machine only controls the elevation (z-axis). Typical cut varies from 0.08 m to 0.30 m with volume from 400 to over 800 m3/ha.

With the Global Positioning Systems, machines are able to know position coordinates x,y along with elevation z; allowing new design capabilities such as different slopes along a field. The system subdivides slope line in short segments and calculates the grade between two adjacent points, if natural grade is within the range indicated by designer, it won't cut or fill; or will adjust accordingly.

The resulting design very closely follows the natural terrain profile, dramatically reducing cut and fill and total volume by as much as 70% compared to a planar surface. Typical cut varies from 0.04 m to 0.15 m with total volume from 125 to 175 m3/ha.

Cost of earthmoving is estimated at USD2.00/m3, so a planar surface will cost between $800 to $1,600/ha; while a variable slope field will cost anywhere from $250 to $350/ha. The cost saving is often over $500/ha.

The per area cost of laser leveling is considered a major limition for small and medium rice growers in Central America to adopt precision land leveling; preventing them from saving precious water in a severely drought affected region.

After adopting the GPS land forming systems, leading farms in Central America (Nicaragua, Costa Rica and Panama) have been able to significantly reduce the total volume for irrigated water, from 4.05 l-s/ha down to 2.46 l-s/ha, a 39% reduction.

Variable slope land conformation (leveling) made possible precise water management with shallow (0.03 m) and intermittent flushing, eliminating pools that affected germination, population and root health. It also made possible the implementation of best management practices, like avoiding plant overpopulation by reducing the quantity of seed from 180 kg/ha (+350 plants/m2) on broadcast application over puddled fields to 70 kg/ha (200 plants/m2) now planted in reduced tillage conditions with direct seeding mechanical drill planters.

Another outstanding result is the Nitrogen efficiency use index that raised from 23% to over 45%; harvest index from 35% to 53%; effectively eliminating the previously common plant lodging problems. All these improvements lead to a grain yield gain of 3.43 mt/ha (4.06 to 7.53 mt/ha)

In conclusion, the variable slope GPS land forming (leveling) technology made possible to control irrigation and drainage, reduce irrigation water consumption by 39%, move from puddling to conservation agriculture, reduce seed use by 50% while establishing a good stand; to increase nitrogen use efficiency by 40% and raise yields over 85% at an affordable cost of $300/ha.

Influence of Water Management Practices on Methane Emission in Main and Ratoon Crop in Louisiana Rice Fields

Kongchum, M., Harrell, D., Adotey, N., and Li, J.

Field experiments were conducted to examine the effect of water management practices on methane (CH4) emissions from Louisiana rice fields. Emissions under four water management treatments were studied and included: Continuous Flooding (CF), Straight Head (SH), Intermittent Flooding (IF) and Semi-Aerobic (SA). Gas samples were collected using static diffusion chambers one week prior to flooding and continuously weekly following flooding until harvest.

The highest accumulative CH_4 fluxes for the main crop and for the ratoon crop were observed in SH water treatments (215 kg ha^{-1}) and 230 kg ha^{-1}, respectively. Methane emissions for the ratoon crop were significantly higher than the main crop, particularly at about 4 weeks after re-flooding the field for ratooning. It might be because of the straw leftover after harvesting the main crop, which could be a major carbon source for microbes. Results showed that water management techniques could be used to reduce methane emissions from rice fields. However, a significant yield reduction was also observed in Semi-Aerobic water management.

Comparison of Delayed Flood and Furrow Irrigation in Rice for Yield Components and Nutrient Uptake

Aide, M. and Beighley, D.

The goal of the study was to confirm or deny the value of the furrow rice production culture as compared with the traditional delayed flood rice production culture with respect to particular nutrients as well as agronomic traits. Individual rice varieties involving furrow and delayed flood irrigation regimes showed rough rice yield differences. The mean of all rice variety yields were not significantly different between the irrigation treatments. Arsenic concentrations were significantly smaller in rough rice from the furrow irrigation system. Manganese rough rice concentrations were greater in rough rice from the delayed flood regime.

Optimization of Drip Irrigated Rice Management Practices

Vered, E.

Food security depends largely on irrigated rice production, the staple food of nearly half the world's ever-growing population. Rice is usually grown as a monoculture under continuous flooding with current water consumption estimated at 4 billion m^3. However, growing water scarcity places physical, economical and environmental restraints on this method of rice cultivation.

The most important environmental and health concerns related to flooded systems are loss of nutrients and soil fertility, water pollution by nitrates and residual biocides, enhanced arsenic bioavailability in soils, greenhouse gas emissions - mainly methane (CH4) - and the spread of malaria. Rice research must therefore face the challenge of increasing production while saving water by shifting from submerged rice to new sustainable, aerobic cultivation methods.

During the past four years research has been conducted in several countries, in varying soil types using different rice cultivars. This research has proven the feasibility of growing rice with drip irrigation with significant reductions in water use. As a result of this research, a protocol for growing rice with drip irrigation was prepared and successfully tried in many countries including Australia, Brazil, China, India, Italy, Spain, and Turkey. The growing protocol for drip irrigated rice includes optimization of management practices such as irrigation coefficients, fertigation, and plant population as well as the technical properties of the drip system. Yield, grain quality, arsenic content, nitrogen leaching and methane emissions were measured. An important finding is that the irrigation coefficient must change with plant development and peaks at 150% of pan evaporation values at inflorescence.

Optimization of management practices for drip irrigated rice resulted in increased grain yield, safety and quality as well as greater water productivity. Drip irrigated rice production reduced fertilizer requirements, loss of nutrients, heavy metal uptake by rice plants and CH_4 emissions. We suggest moving from flood irrigated paddy rice to drip irrigation and fertigation on aerobic rice fields to improve rice crop productivity, efficiency and sustainability.

Development and Validation of Alternate Wetting and Drying (AWD) Water Management for Rice Grown on Clay Soils in Mississippi

Atwill, R.L., Krutz, L.J., Roach, D., Bond, J.A., Golden, B.R., and Walker, T.W.

Rice irrigation currently accounts for the greatest amount of irrigation water applied per hectare over corn, soybeans, and cotton in the mid-southern US. 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 hectare meters per year and has done so for 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 several alternate wetting and drying (AWD) irrigation regimes. Three rice cultivars were evaluated in six different rice irrigation treatments. Irrigation treatments included: a continuous flood, allowing the flood to recede to the soil surface, 10 cm below, 20 cm below, 30 cm below, 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. A 200 kg grain yield increase was observed 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 past 20 cm below the soil surface as compared to a continuous flood. Water use efficiency was greater for 10 cm below soil surface compared to other treatments. Data from this experiment in 2015 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. Water management practices that reduce groundwater withdrawals are a viable option for rice producers in the mid-south.

Validation of Soil-test-based Phosphorus and Potassium Fertilizer Recommendations for Rice

Fryer, M.S., Slaton, N.A., Roberts, T.L., Norman, R.J., Hardke, J.T., and Delong, R.E.

Soil-testing is an accepted and widely practiced science for evaluating soil-P and -K availability. Regardless of the extractant, soil-testing has proven to be inconsistent for making accurate fertilizer-P and -K recommendations for flood-irrigated rice (*Oryza sativa* L.). The primary objectives were to assess the accuracy of established soil- and tissue-P and -K concentration interpretations for predicting rice yield response to fertilization at three levels of significance ($p \leq 0.05$, 0.10, and 0.25). Soil-test P (STP) interpretations were 35% accurate in predicting yield response to fertilizer, regardless of the significance level used. Whole-plant-P concentrations at V6-V7 were 50 ($p \leq 0.05$ and 0.10) and 39% ($p \leq 0.25$) accurate. Soil-test K (STK) interpretations were 20 ($p \leq 0.05$ and 0.10) and 14% ($p \leq 0.25$) accurate regarding yield response predictions. Whole-plant-K concentrations at R2-R3 were 47 ($p \leq 0.05$ and 0.10) and 37% ($p \leq 0.25$) accurate by the yield response predictions made. Nearly all of the error in both soil-test- and whole-plant-P and -K concentration interpretations occurred in the suboptimal categories where positive yield responses to fertilization were expected but did not occur. The accuracy ($p \leq 0.05$) of yield response predictions for levels where no fertilizer was recommended was 88% for STP and 80% for STK and 93% for whole-plant P and K concentrations. Overall, whole-plant-P and -K concentrations are better predictors of rice yield response to fertilization than Mehlich-3 STP and STK.

Summary of Phosphorus Research in Mississippi

Golden, B.R., Walker, T.W., Atwill, R.L., Bell, L., and Bond, J.A.

Phosphorus deficiency in rice (*Oryza sativa* L.) generally occurs early in the season and can be identified by very distinct characteristics. Typical symptomology of P deficient rice plants are an overall stunting, dark green color, and erect leaves with little to no tillering. Stems will often appear thin and spindly with the symptomology first occurring on the older leaves. Much of the rice production in Mississippi occurs on precision graded fields where the much of the topsoil has been redistributed allowing for ideal conditions for a P deficiency to occur. Phosphorus deficient rice was identified in MS in the late 1990's, with soil test correlation and calibration trials established in 2002. Across the rice belt yield increases have been shown to P fertilization, however traditional soil test methods have been poor predictors of yield responsiveness. Our objective is to better predict when a yield response to phosphorus fertilization will occur based on routine soil testing.

Field Experiments were established between 2002-2015 at the Delta Research and Extension Center (DREC), and on production farms in the Mississippi Delta area. Soybean [*Glycine max* (Merr.) L.] was the previous crop grown at all site-years. Rice cultivar seeding rates differed among site-years and research locations, In general rice was seeded at rates ranging between 60 and 90 lb seed ac^{-1}. Prior to fertilization the untreated control plots from each replicate were soil sampled for extraction via the Lancaster method to determine soil test P. Most trials received P fertilization between planting and the 2-LF stage of rice growth and development. A limited number of trials evaluated timing in the structure with P application timing ranging from fall to midseason. In all trials phosphorus application rates ranged from 0 to 100 lb P_2O_5 ac^{-1} in 25 lb P_2O_5 ac^{-1} increments. At the 5-leaf stage, prior to establishing a permanent flood, urea was applied at total N rates to maximize rice grain yield at research station locations, on producers farms nitrogen management was conducted by the producer. Total, aboveground P uptake was determined near the mid-tillering stage by harvesting whole plants in a 3 ft. section of row from the first inside row of each plot. Plants were dried to a uniform weight, weighed, ground to pass a 1-mm sieve, digested, and whole plant P concentration was determined by ICP. Grain yield, adjusted to 12% moisture content, was determined by harvesting each plot with a small-plot combine. In the field each experiment was arranged as a randomized complete block and was compared to an untreated control. At each site the suite of P fertilization rates and/or application timings was replicated no less than 5 times. For the purpose of this summary all trials were analyzed separately to determine if rice responded to P fertilization. The Fishers Protected Least Significant Difference (LSD) procedure ($p = 0.20$) was used to compare treatment means when appropriate. A secondary analysis using single degree of freedom contrasts comparing plots receiving P fertilization to the untreated control was also used to determine responsiveness. All statistical analyses were performed using SAS version 9.4.

Rice grain yield was significantly influenced by P fertilization rate at 16 of 34 site-years. Averaged across both responsive and non-responsive site-years, P fertilization increased rice grain yield by 225 lb ac^{-1}. When considering only sites that responded positively ($p<0.20$) to P fertilization yields were increased above the untreated control by approximately 585 lbs ac^{-1}. Evaluation of distribution of soil test levels at responsive sites (n = 16) suggested that approximately 46% fell below 10 ppm soil test P, 62% < 20 ppm soil test P, and 85% < 30 ppm soil test P. The remaining 15% of responsive samples had soil test P levels greater than 30 ppm. Relative yield from the untreated control at responsive sites ranged from 75 to 95%. For numerous years 30 ppm had been observed as a critical level for soil test P regardless of extractant. When examining non-responsive sites the distribution across soil test levels was startling. For non-responsive sites (n=18) approximately 75% of sites had soil test P below 30 ppm P. On non-responsive sites relative yield from the untreated control ranged from 94 to 100%. This data further illustrates the need for additional research centered on determining additional methods to determine crop responsiveness to soil test P, either with differing extractants or combining soil extractable P with other factors such as pH.

Pre-treatment of Rice Seedling with 1–Methylcyclopropene (1-MCP) Increases Plant Stand and Tiller Number in Transplanted Rice

Mohammed, A.R. and Tarpley, L.

Rice (*Oryza sativa* L.) seedling growth in the nursery and the transplanting shock experienced by seedlings affect the subsequent plant stand, growth and development of transplanted rice. The study's objective was to determine if application of 1–methylcyclopropene (1-MCP) to rice seedlings prior to transplanting can prevent the transplanting shock. Plants were transplanted 14, 21, 28 or 35 days after emergence with root pruning (0%, 25% or 50%). Three days prior to transplanting, one set of plants was treated with 1-MCP (25 g a.i ha^{-1}) and the other set was treated with Latron (adjuvant 0.25%; control). Plant height, numbers of tillers and leaves, and chlorophyll concentration (SPAD index) were determined weekly. Leaf photosynthetic rate was measured 5 days after transplanting. Root dry weight, shoot dry weight and root length were determined at harvest (4 weeks after transplanting). Our results indicated that root pruning did not have an effect on plant height, number of leaves, root dry weight, or root length. However, root pruning had negative effects on number of tillers, chlorophyll (SPAD), shoot dry weight and net photosynthetic rate. Plants treated with 1-MCP showed greater number of tillers, chlorophyll concentration, root dry weight, and net photosynthetic rate, compared to plants of the control. Our results indicate that application of 1-MCP prior to transplanting can prevent the transplanting shock in rice. We appreciate the funding provided by AgroFresh Inc., Philadelphia, PA, USA, in support of this project.

The Distribution and Build-up of Salinity in Rice Fields and Its Effect on Yield

Marcos, M., Sharifi, H., Grattan, S.R., and Linquist, B.A.

The scarcity of quality irrigation water is a key issue facing California rice growers, forcing many to adopt water management systems that may result in increased salinity and yield reductions. Field water salinity levels have been shown to vary depending on water management, however the distribution and build-up of dissolved salts is unclear. This study quantified the spatial and temporal variation of salinity in rice fields, with the aim of developing water management strategies to mitigate the effects of salinity on yield while concurrently reducing water use. Throughout the 2014 and 2015 growing seasons, the water salinity levels of 10 fields were monitored weekly using electrical conductivity (EC) meters. 9 sampling points, distributed throughout the top, middle and bottom checks were established in each field. In 2014, the water salinity levels were sufficiently low (season averages below 0.92 dS/m), at all sampling points, to avoid yield losses. In 2015, two fields experienced slight yield reductions due to salinity; these yield reductions were observed in plots with season average water EC as low as 1.2 dS/m. Consistent seasonal water salinity patterns were observed among the fields studied. In both years, there were early-season spikes in field water EC during the period in which rice is thought to be most susceptible to salinity. The highest field water EC measurement obtained from the early-season spikes was 2.45 dS/m in 2014 and 6.06 dS/m in 2015. The early season spikes occurred with greatest magnitude in plots furthest from the inlet. A strong positive relationship was found between the distance from the inlet and water EC. Results indicate that allowing water to subside early in the season creates spikes in field water EC levels that are magnified further down the field. The water salinity spikes occur when rice is most susceptible to damage from salinity, thus having the potential of reducing yield, especially in areas furthest from the inlet.

Estimating Yield Potential in Temperate High-yielding, Direct-seeded Rice Production Systems

Espe, M.B., Yang, H., Cassman, K.G., Guilpart, N., Sharifi, H., and Linquist, B.A.

Accurate estimation of a crop's yield potential (Yp) is critical to addressing long-term food security via identification of the exploitable yield gap. Due to lack of field data, efforts to quantify crop yield potential typically rely on crop models. Using the ORYZA crop model, we sought to estimate Yp of irrigated rice for two major rice varieties (M-206 and CXL745) in three major regions of US rice production that together represent some of the highest yielding rice regions of the world. However, three major issues with the crop model had to be addressed in order to achieve acceptable simulation of Yp; first, the model simulated leaf area index (LAI) and biomass poorly for all direct-seeded systems using default settings; second, cold-induced sterility and associated yield losses are poorly simulated for environments with a large range of diurnal temperature variation; lastly, simulated Yp is sensitive to the definition of physiological maturity used. Except for the simulation of cold-induced sterility, all issues could be remedied within the existing model structure. However, the simulation of cold-induced sterility represents a significant challenge to accurate simulation - one that will require changes to ORYZA's structure to address. Estimates of Yp from the adjusted model were validated against large multi-year data sets of experimental yields covering the majority of US rice production areas. Validation showed the adjusted model simulated Yp well, with most top yields falling within 85% of Yp for both varieties (74% and 70% observed yields within 85% of Yp for CXL745 and M-206 respectively). Maximum estimated Yp was 14.3 and 14.5 t ha-1 for the Southern US and CA, respectively.

How Tolerant are the U.S. Rice Cultivars to Heat?

Reddy, K.R., Walker, T., and Gajanayake, B.

High temperatures during panicle initiation and grain-fill can cause substantial reduction in grain yield and quality. An experiment was conducted in sunlit controlled environment chambers to evaluate 21 rice cultivars/hybrids high temperature during the reproductive period. Three day/night temperatures (optimum, 28/20, 32/24, and 36/28°C were imposed at 52 days after seeding and continued for another 85 days at the respective treatments. Plants were irrigated with optimum water and nutrients based on treatment-based measured evapotranspiration. Plant growth and yield-related parameters were determined at the final harvest. Cultivars varied for many yield-related parameters and their response to high temperatures. Individual trait value at high temperature treatment was divided by value at optimum temperature to develop trait-based indices. Then, all indices were added at each high temperature and at both the high temperature treatments to develop relative total high temperature response index for each cultivar. Variability among the indices was used to categorize rice cultivars to temperature tolerance. Based on the screening methods, Antonio, Nipponbare, R41004197, CL162, Colorado, and CL152 were recorded as heat sensitive and CL745, CL151, and Cheniere were identified as heat tolerant cultivars. The identified heat tolerant cultivars may be useful for breeders to develop new rice lines, which could withstand high temperature conditions during the reproductive period.

We evaluated the percent reduction in yield to determine which varieties best maintained yield potential due to limited available water. This was done by dividing each of the three deficit irrigation level plot yields by the fully irrigated treatment average yield for each cultivar. The cultivars that had the highest yield from this analysis were PI312777, Rondo, and Saber. These varieties may maintain better yield stability than the other cultivars when exposed to limited water conditions. There was no cultivar by irrigation treatment interaction found. Such results may be useful in understanding cultivar response to limited water conditions.

Minimizing Ammonia Volatilization using Experimental Zinc Sulfate Coated Urea Fertilizers on Four Important Louisiana Rice Soils

Adotey, N., Harrell, D.L., Kongchum, M., Li, J., Leonards, J., and Fluitt, J.

Minimizing ammonia volatility from surface applied urea fertilizers remains a priority in rice production because of the potential economic and environmental constraints. Novel approaches employed in reducing ammonia volatility have focused on modifying urea granules with chemical urease inhibitors such as N-(n-butyl) thiophosphoric triamide (NBPT) and boron (B) or by physically coating the urea with a resin, polymer or nutrient. The potential synergic effects of using a urease inhibitor combined with a nutrient coating have not been evaluated. The objective of the study was to evaluate ammonia volatilization of experimental zinc sulfate coated urea fertilizers with or without NBPT and/or B from four soils in a closed environment.

A laboratory study was carried out to evaluate the efficacy of experimental zinc sulfate coated urea (ZSCU) fertilizers to suppress ammonia volatilization. The experiment was conducted using a completely randomized design with 8 Nitrogen (N) sources and 4 soils. Treatments were replicated three times (n=96). Experimental ZSCU fertilizers included: RCO3 (ZSCU only); RCO5 (ZSCU + 0.17% B); RCO4 (ZSCU + 0.17% B + 0.06% NBPT) and RCO4S (ZSCU + 0.17% B + 0.06% NBPT + a Ca shell coating). Each was compared with urea and three rates of NBPT-treated urea fertilizers. Rates correspond to 0.33, 0.5 and 1 times the recommended NBPT (0.09%) application rate. Nitrogen (N) fertilizer granules (2-2.38mm) were surface applied on each soil at a rate of 135 kg ha^{-1}. Four soils were selected based on varying soil pH and included: Crowley H, Crowley L, Mowata and Kinder silt loams. Ammonia volatility was closely monitored in customized temperature regulated boxes over 14 days after fertilization (DAF). Statistical analysis was carried out for cumulative N loss at 14 DAF using PROC GLM and contrast analysis in SAS.

Cumulative N loss was significantly ($P=0.0121$) influenced by the interaction between soil and N source at 14 DAF. Cumulative N loss at 14 DAF for the Mowata, Crowley H, Crowley L and Kinder soils were 14, 15.5, 25.8 and 27.5%, respectively, and were 2.7, 1.6, 1.9 and 2.2 times greater than 5 DAF. Cumulative N loss was significantly higher in Crowley L and Kinder soils compared to other soils. The range of N loss RCO3, RCO4, RCO4S and RCO5 observed across soils were 9.9-20.8, 4.4-11.5, 2.6-11.6 and 6.3-12.6%, which reduced N loss over unmodified urea by 14-35, 55-69, 55-81, and 31-58%, respectively. In Crowley L and Kinder soils, experimental fertilizers with only coatings and/or B showed significantly greater N loss as compared to those (RCO4-RCO5) containing urease inhibitors. In contrast, N loss from Mowata and Crowley H soils did not differ among experimental zinc sulfate coated urea fertilizers with the exception of RCO3. Modification of urea with NBPT at application rates of 0.03, 0.06 and 0.09% sufficiently suppressed N loss up to 27-60%, 37-64%, and 40-60% respectively across the four soils. A difference was not noted between NBPT application rates regardless of soil. Nitrogen loss for ZSCU fertilizer with B and NBPT was similar to NBPT-treated urea.

In conclusion, experimental ZSCU fertilizers significantly reduced ammonia volatility. All experimental fertilizers except RCO3 performed similar to NBPT treated urea. Although soil pH influences ammonia volatility, this study demonstrated that other soil properties can mask this effect as observed in Crowley H.

Summary of N-STaR N Rate Recommendations in Arkansas during 2015

Scott, C.L., Roberts, T.L., Williamson, S.M., Hardke, J.T., Slaton, N.A., and Greub, C.E.

Historically, nitrogen (N) recommendations for rice in Arkansas were based on the following three parameters: soil texture, cultivar, and previous crop. This process often resulted in over-fertilization, which can decrease possible economic returns and increase environmental N loss. The 2012 launch of the University of Arkansas N-STaR Soil Testing Lab in Fayetteville, Arkansas made the Nitrogen Soil Test for Rice (N-STaR) available to the public. N-STaR is a site-specific soil based N test that uses direct steam distillation results from 0-45 cm (silt loam soils) and 0-30 cm (clay soils) soil samples to deliver more accurate, field-specific N recommendations to Arkansas rice farmers. To streamline the task of summarizing the results of the N-STaR program in Arkansas, soil samples submitted to the University of Arkansas N-STaR Soil Testing Lab during 2015 were classified by county and soil texture. A total of 1199 samples were received. These samples came from 118 fields across 19 Arkansas counties. Mississippi and Arkansas counties submitted the largest number of fields to be evaluated, with 41 and 31 fields respectively. Of the total samples received, 68 were from silt loam fields, 1 sample was from a sandy field and 49 were from clay fields. The N-STaR N rate recommendations for these samples were then compared to the producer's estimated N rate, the 2015 Recommended Nitrogen Rates and Distribution for Rice Cultivars in Arkansas and the standard Arkansas N rate recommendation of 165 kg N ha^{-1} for silt loam soils and 180 kg N ha^{-1} for clay soils and subsequently divided into three categories: those with a decrease in recommendation, no change in recommended N rate, or an increase in the N rate recommendation.

Comparisons between the N-STaR N rate recommendations and the producer's estimated N rates showed 59 fields with a lesser N-STaR N rate recommendation than the producer's estimate. Of those 59 fields, 40 were silt loam fields and 19 were clay. The average decrease in these recommendations was 33 kg N ha^{-1}. No difference in N-STaR recommendation and producer's estimate was found in 3 fields, 2 clay and 1 silt loam. Forty-five fields had an N-STaR N recommendation that was higher than the producers estimate, with an average increase of 20 kg N ha^{-1}. The comparison of N-STaR rate to the standard N rate revealed 105 fields with an N-STaR recommendation that was lower than the standard by an average of 42 kg N ha^{-1}. Fifty-seven of those were silt loam fields and 48 were clay fields. Four fields showed no difference between the standard and N-STaR recommendation. Three of those were silt loam and one was clay. All of the 9 fields that received a higher than standard N-STaR recommendation were silt loam fields. The average increase in recommendation was 10 kg N ha^{-1}. When the N-STaR recommendation was compared to the cultivar recommendation, 79 fields had a lower N-STaR recommendation, with 41 of those being silt loam and 38 being clay. The average decrease was 37 kg N ha^{-1}. Two fields, both of which were clay, showed no difference in recommendation between N-STaR and cultivar rates. Sixteen fields, all silt loam, had a higher N-STaR recommendation by an average of 17 kg N ha^{-1}. County was found to be a significant factor ($p < 0.0001$) in all three comparisons when N-STaR called for a decrease in N rate. Soil texture was a significant factor in fields where N-STaR suggested a decrease in N rate in the cultivar recommendations ($p < 0.05$) and the standard N rate comparison ($p < 0.0005$) but was also significant ($p < 0.05$) in fields that called for an N rate increase in the producer's estimate comparison. Cultivar was significant ($p < 0.0005$) in fields where N-STaR dictated a reduction in N rate.

Nitrogen Mineralization in Organic Rice Fields with Relation to Soil Amendment

Valdez Velarca, M., Dou, F., Gentry, T., and Guo, J.

Since 1995, organic rice acreage has increased almost six fold with up to half of the acreage being grown in the southern US. Despite the rapid expansion of the industry (up to 20,000 ha/year), it has failed to meet the market demand, resulting in increasing pressure from foreign organic rice imports. The restricted availability of nutrients, particularly nitrogen (N), is one of the primary reasons for low yields in organic farming.

To determine the effect of soil amendment on organic rice production, a greenhouse trial in Beaumont, TX, was conducted from May to August 2015 in order to study the effects that organic soil amendment (Nature Safe) with six different rates of application (0, 50, 100, 200, and 250 kg N/ha) had on nitrogen mineralization and rice yield components in comparison with conventional rice production (urea fertilizer). The treatments (organic, conventional and control) were applied to a complete randomized block design of 96 pots with soil collected from organic certified field and planted with rice variety XL753. This poster presents the results regarding the effect of the different treatments on the rice yield components.

Using the Trimble GreenSeeker Handheld to Determine Rice Response to Midseason Nitrogen

Williamson, S.M., Roberts, T.L., Hardke, J.T., Slaton, N.A., Greub, C.E., Davidson, J.T., Mazzanti, R.S., and Baker, R.

Traditionally most direct-seeded, delayed-flood rice producers in Arkansas have applied nitrogen (N) fertilizer using a two-way split application with the majority of the N fertilizer applied pre-flood and the remaining 45 or 30 lbs N/A applied at midseason or boot respectively, depending on cultivar. Many farmers striving to increase their N management efficiency already use best management practices such as the Nitrogen Soil Test for Rice (N-STaR) to pinpoint field specific N rates, applying NBPT treated urea to a dry soil surface, and by obtaining and maintaining a quick flood. Previous research has shown that equivalent rice yields may be obtained with a lower total N rate, when a single preflood N management plan is properly implemented. However, many producers are reluctant to move towards a single preflood N application due to the yield potential tied to this early season N application as well as the inability to determine if the N rate was sufficient to produce maximal yields. While hybrid cultivars continue to benefit from 30 lbs N/A at booting to prevent lodging, most of Arkansas semi-dwarf stiff-strawed cultivars do not consistently exhibit an increased yield response to the 45 lbs N/A midseason N application as long as pre-flood N has been properly managed. Unexpected N losses are always a possibility and often leave producers questioning the efficacy of a salvage midseason N application. There is no question that soil testing drives fertilization decisions earlier in the season, but farmers have largely relied on visual guesswork after rice is flooded and has reached internode elongation. Thanks to new optical sensor based technology, farmers now have a real-time, non-subjective tool to evaluate the vegetative response of their crop which can help answer the question- will I benefit from a midseason N application? At six of the 2015 Rice Research Verification (RRVP) fields, two N-rich strips were established in each field using the current standard N rate for that soil texture plus 200 lbs N/A to eliminate any question of inadequate N supply. The N rates for these RRVP fields were determined by N-STaR and applied as a single pre-flood optimum N rate. Normalized Difference Vegetative Index (NDVI), the most commonly used vegetative index of photosynthetic activity, was measured at 10 random 50-100 feet strips across the field at three weeks post-flood using the Trimble GreenSeeker Handheld and compared to the reference strip to determine a response index defined as the NDVI of the reference strip divided by the NDVI of the strip of interest. An average response index less than 1.2 indicates relative grain yield would not benefit from additional midseason N application. Only one of the six fields evaluated called for additional midseason N on half of the field. The Trimble GreenSeeker Handheld offers producers and consultants an easy to use, in-season assessment tool to aid in N management decisions.

Preliminary Relationships between Rice Yield and Tissue Potassium Concentrations with Field-moist and Oven-dry Mehlich-3 Extractable Potassium

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

Soil samples submitted for routine soil analysis are oven-dried in preparation for extraction to determine nutrient availability indices. Previous work has shown oven-dry, Mehlich-3 soil-K is an excellent predictor of rice (*Oryza sativa* L.) whole-plant K concentration at the late-boot stage but is less accurate for predicting relative rice yield response to fertilizer-K. Research has shown that K extracted from field-moist soil is a superior nutrient-availability index for predicting relative soybean [*Glycine max* (L.) Merr.] and corn (*Zea mays*) yield response to fertilizer-K than oven-dry soil. The research objective was to compare field-moist and oven-dry, Mehlich-3 extractable soil-K as predictors of whole-plant K concentration at the late boot stage and relative yield of rice that received no fertilizer-K (relative to K-fertilized rice). Soil samples were collected in the winter or spring (preplant) of 2015 from short- and long-term K fertilization trials in Arkansas. Soil samples were collected from eleven total sites that consisted of nine loamy and two clayey soils. Each trial included four or five fertilizer-K rates ranging from 0 to 112 or 150 kg K ha^{-1}.

The amount of K extracted from field-moist soil was similar or less than K extracted from oven-dry soil. For the loamy soils, the difference between oven-dry and field-moist soil-K ranged from -13 to 149 mg K kg^{-1} and the ratio (Oven-dry soil-K/Field-moist soil-K) ranged from 0.90 to 2.34. In general, the silt loam soils showed that field-moist soil-K was lower than oven-dry soil-K when oven-dry soil-K was <100 mg K kg^{-1}. When field-moist soil-K was >100 mg K kg^{-1} it was numerically equal or greater than oven-dry soil-K. The difference (oven-dry – field-moist) in K extracted from two clayey soils was more than 100 mg K kg^{-1} greater for the oven-dry soil. The first-year (preliminary) findings show that the relationship between relative yield and soil-K availability (oven-dry or field-moist K) was linear, positive, and stronger for field-moist soil. Field-moist soil-K explained 87% of the variability in late-boot stage K concentration and 55% of the variability in relative rice yield compared to 50 and 33% for oven-dry soil, respectively. The preliminary relationships suggest that Mehlich-3 extraction using field-moist soil may provide a more accurate assessment of soil-K availability that can possibly be used across soil textures. Additional research will be performed to develop a more robust database that can be used to develop moist-soil K fertilizer recommendations.

Effects of Silicate Slag Application on Soil pH and Uptake of Heavy Metals by Rice

Paye, W., Tubana, B., Babu, T., Datnoff, L., and Harrell, D.

While silicon (Si) fertilization through silicate slag application is a recognized agronomic practice in many rice production systems in the world, its effect on soil pH and heavy metal content of rice has not been well-documented. This study was conducted to evaluate the effect of silicate slag application on pH and availability of heavy metals in flooded rice soils. Field trials were conducted in Southwest Louisiana from 2013 to 2015. Treatments included five rates of silicate slag (12% Si) at 1, 2, 4, 6, and 8 tons ha^{-1}, with two lime treatments of 2 and 4 tons ha^{-1}, and a control. Treatments were arranged in a randomized complete block with four replications. After slag application, rice variety CL111(or Jupiter or CLXL 729) was drill-seeded at 20 cm row spacing at the rate of 300 seeds m^{-2} in plots measuring 1 m x 3 m. Soil samples collected at harvest were analyzed for pH, soil Si, and heavy metal contents while plant samples were analyzed for elemental composition. Plant-available soil Si was extracted using different solutions: 0.5 M acetic acid, 0.01 M calcium chloride, 1 M sodium acetate, 0.5M ammonium acetate, 0.1 M citric acid and deionized water. Silicon content in sample extracts was determined using Molybdenum Blue Colorimetric (MBC) assay. Silicon content of both straw and panicle was determined using Oven Induced Digestion procedure followed by MBC. Soil pH was measured using a 1:1 (weight/ volume) soil to water solution while heavy metal content of rice panicle was determined by HNO_3-H_2O_2 digestion followed by Inductively Coupled Plasma-Optical Emission Spectroscopy procedure. Analysis of variance and correlation analysis were performed for all measured variables using SAS 9.4. Silicate slag significantly increased soil pH in several site-years by as much as 1.4 unit ($P<0.05$). Correlation between slag rate and soil Si content varied from site to site and by extraction procedure. For example, St. Landry in 2013 soil Si content based on 0.5 M acetic acid extraction procedure was significantly increased (r^2 =0.68) while a weaker correlation (r^2 =0.18) was obtained for Crowley. For Gilbert and Mamou sites in 2013, 1 M sodium acetate showed good correlation between slag rate and soil Si concentration (r^2 = 0.53) but this was not observed in 2014 for both sites. For Lake Arthur in 2013, soil Si was significantly increased (r^2 =0.43) as determined by 0.1 M acetic acid but not in 2014. On the other hand, correlation between panicle Si and soil Si based on 0.5 M acetic acid extraction procedure obtained a positive correlation with an r value of 0.65 across sites for 2013 and 2014. The panicle (r = -0.39) and As (r = -0.33) content declined with panicle Si at a rate of 0.007 and 0.05 µg g^{-1} per every unit increase in Si (%), respectively. The panicle As (r = -0.41) content was also negatively correlated with the straw Si content. There was no evident correlation observed between panicle Si content and Al, Cu, Fe, Pb, and Se. Contrary to previous reports, panicle Si content had a positive correlation with Mn (r= 35). As previously documented, the mechanisms by which Si inhibits heavy metals toxicity in plants is either by forming insoluble silicate compounds with these heavy metals and causing them to precipitate or by restricting their translocation within the plant. The outcomes of this study thus far do not only demonstrate that silicate slag application has the potential to improve soil pH, but could also improve yield and grain quality of rice, especially in soils where heavy metal contamination could be of concern.

Effect of Silicon Fertilization on Arsenic Dynamics in Soils and Uptake by Rice

Agostinho, F., Tubana, B., Santos, G., and Datnoff, L.

Rice may contain large quantities of arsenic (As) and contribute significantly to As intake by humans. Depending on the environmental conditions, As can exist in four valence states: arsenite (+3), arsenate (+5), metalloid arsenic (0), and arsine gas (-3). The inorganic forms, arsenite and arsenate, are the most toxic forms to humans and are predominant on anaerobic and aerobic soils, respectively. Silicon (Si) is recognized as an agronomic essential nutrient for rice production known to alleviate biotic and abiotic stresses in plants. Studies have shown that Si concentration may affect As uptake by rice. A greenhouse experiment was carried out to evaluate the role of elevated level of Si on the concentration of different As species in flooded soil and As uptake by rice. The treatments included five As rates (0, 10, 20, 40 and 120 mg kg^{-1}) in the presence or absence of soil-applied Si as wollastonite (23% total Si). The treatments were arranged in a randomized complete block design with four replications. Arsenic speciation was conducted for soil samples collected at heading stage and post-harvest by sequential extraction procedure which separates soil As into easily-soluble, aluminum (Al)-bound, iron(Fe)-bound, reducible, acid-soluble, and residual forms. Biomass, roots, and grains Si and As uptake were also determined by Oven Induced Digestion procedure followed by Molybdenum-Blue-Colorimetry and nitric acid-hydrogen peroxide digestion followed by Inductively Coupled Plasma – Optical Emission Spectroscopy, respectively. Silicon application significantly increased soil Si content from 44 to 102 $\mu g\ g^{-1}$ at heading with further increase to 200 $\mu g\ g^{-1}$ at harvest (P<0.001). Arsenic application significantly increased soil total As content (P<0.001) where the highest rate of 120 mg As kg^{-1} resulted in an increase by 55 $\mu g\ g^{-1}$; this is 11 times higher than the control. Increases in Al-bound and Fe-bound As species were substantial contributing the most to total As content among the As species. Except for Fe-bound As, the concentration of different species of As in the soil was not affected by Si fertilization which suggests that the level of soil Si attained after Si treatment was not sufficient to impose competition across As species for soil binding sites. At heading and harvest root As content tended to decrease in Si-treated rice compared to untreated rice. Earlier studies showed that a mutually antagonistic relationship between As and Si in the plant begins with their competition for root entry points and transporters. At harvest, straw Si content was decreased from 3.4 to 1.8% with the highest As application rate. There was a reduction by 0.3 mg kg^{-1} in As grain content of rice which received Si application (P<0.01). Reports indicated that decreases of As concentration in rice was due to decreased As transport in grain. Poor growth of rice treated with 120 mg As kg^{-1} may have also resulted from reduced nutrient uptake. The outcomes of this study suggest that high level of soil Si may present invaluable benefits to the quality of rice through reduction in As content in grains and consequently intake by humans.

Rice Physiological Responses to Water Management Systems: Flooded, Saturated and Aerobic Rice

Mohammed, A.R. and Tarpley, L.

Declining availability of water and lack of rainfall is threatening the traditional way of growing rice under flooded conditions. Efficiency in the use of water is critical to safeguard food security especially of rice—the staple food for more than half of the world's population. A study was conducted in the greenhouse at Texas A&M Agrilife Research Center at Beaumont, Texas to evaluate different water management systems for rice production. The U.S. rice cultivar 'Cocodrie' was grown in pots filled with a clay-rich soil, which were placed in boxes lined with plastic to hold the flood water surrounding the pots. Plants were grown under three water regimes: 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. Our results indicate that plants grown under different water regime had similar numbers of tillers per plant; shoot, and 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.

Factors Affecting Rice Yield under Alternate Wetting and Drying Irrigation: Results of a Meta-analysis

Carrijo, D., Lundy, M., and Linquist, B.

Alternate wetting and drying (AWD) is an alternative irrigation management in rice that has the potential to reduce water inputs and greenhouse gas emissions (GHG). However, despite these benefits, AWD has not been widely adopted, in part because its effect on yield is not clear. To address this concern we conducted a meta-analysis to: 1) quantify the effect of AWD on rice yields, water use and GHG (methane, CH_4 and nitrous oxide, N_2O) compared to rice grown continuously flooded (CF); and 2) identify environmental conditions and management practices where rice yields obtained under AWD are most competitive. The literature search generated a dataset comprised of 58 studies and 532 observations (side-by-side comparisons of AWD and CF rice yields). The meta-analysis was conducted using bootstrapping procedures to obtain 95% confidence intervals for the effect of AWD on grain yields, water use and GHG emissions. Overall, AWD decreased grain yields by 4.78% but reduced total water use by 27% on average. The analysis on GHG was limited by a small dataset, but showed that, on average, AWD reduced CH_4 from 3512 to 1822 kg CO_2 eq. ha^{-1} $season^{-1}$ but increased N_2O from 250 to 692 kg CO_2 eq. ha^{-1} $season^{-1}$. As a result, AWD did not have a significant reduction on global warming potential (CH_4 and N_2O). Further analysis of the effects of AWD on yields examined the role of soil (texture, pH, and carbon content) and various management practices including the timing and severity of the drying cycles, establishment practice (transplanting vs direct seeding), and varietal choice (hybrid vs inbred). Yield penalties caused by AWD were minimized in soils with pH<7 and carbon content (C)>1% and no yield penalties were observed when AWD was conducted during only one part of the season (vegetative or reproduction phase instead of throughout the whole season). The most important factor causing yield penalties in AWD was the severity of the drying cycle. When the soil water potential did not drop below -20 kPa or the water level did not drop more than 15 cm below the soil surface, yield losses were not significant. When either of these two thresholds was crossed (i.e. the dry event was more severe) yield losses occurred, especially under any of these conditions: 1) soil pH≥7; 2) soil C≤1%; 3) soil clay <40%; 4) non-hybrid varieties were used; or 5) AWD was conducted throughout the entire season. These findings demonstrate under what conditions AWD can be a plausible alternative to CF systems while saving water.

Alternate Wetting and Drying as an Effective Management Practice to Reduce Methane in Arkansas Rice Production

Runkle, B.R. K., Suvočarev, K., Smith, S.F., and Reba, M.L.

Approximately 15% of the global 308 Tg CH_4 emitted by anthropogenic sources is currently attributed to rice cultivation. Arkansas is the leading state in US rice production (42%) and occupies over 43% of total land planted to rice in the US. Although rice production is generally water-intensive, some rice farmers have adopted a conservation practice, 'Alternate Wetting and Drying' (AWD), in which the flood is released periodically during the growing season. In addition, implementing AWD can reduce CH_4 emissions due to the periods of aerobic conditions. To assess the magnitude of this reduction, conventionally flooded (CONV) and AWD fields were identically instrumented for the 2015 season and fluxes of CH_4 and CO_2 were measured using the eddy covariance technique with high-speed, high-precision open path gas analyzers and sonic anemometer. Other biophysical variables were monitored to determine the relative dominance of potential drivers. Quasi-continuous, half-hourly CH_4 fluxes from the AWD and CONV fields during their similar initial flood (18 May – 10 June) were well correlated ($R^2 = 0.76$), likely indicating similar mechanisms controlling CH_4 emissions in both fields during the flooded period. After the initial dry down event in the AWD field (11 June), daily median CH_4 fluxes continued to rise to 7.80 mg CH_4 m^{-2} h^{-1} on 12 June before subsiding to a local minimum of 0.162 mg CH_4 m^{-2} h^{-1} on 20 June. Daily median CH_4 fluxes between 9.24 and 16.0 mg CH_4 m^{-2} h^{-1} were observed in the CONV field during this same period. Cumulative emissions from both fields through the growing season demonstrated a 75% reduction in CH_4 emissions by the AWD treatment, preventing emission of 58 Mg (tonne) CO_2e from this 25 ha field. The substantial decrease in CH_4 emissions by AWD in the growing season supports and expands upon previous chamber-based research and offers strong evidence for the efficacy of AWD in reducing CH_4 emissions in AR rice production. The presentation will also quantify the counterbalancing potential for increased respiratory CO_2 emissions during dry periods and will provide process-based relationships between biophysical parameters and CO_2 and CH_4 emissions.

Rice Vegetation Nitrogen Status - Development of Sensitive Signatures for Proximal Remote Sensing

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

Rationale. Nondestructive methods for detecting rice vegetation nitrogen (N) concentration generally depend on change in reflectance or transmittance of radiation in the Visible-Near Infrared (VNIR) range of 400-1100 nm. These methods tend to depend on change in chlorophyll concentration or to the red-edge (a reflectance spectral feature that resembles the edge of a cliff, the ‘cliff’ leading up to the high reflectance region of the very near infrared), both of which respond to the statuses of various nutrients besides nitrogen and to various environmental stresses. In this study, we sought to develop a method for detecting rice vegetation nitrogen status using reflectance in the Short-Wave Infrared (SWIR) range of 1100-2500 nm. The SWIR contains bands affected by protein level, but is not strongly affected by chlorophyll; most nitrogen in rice leaves is found in protein. Methods. Ten rice genotypes of diverse origin, including temperate and tropical japonicas, indicas, and NERICA were grown in replicated field research plots at Beaumont, Texas, USA. A wide range of nitrogen fertility: 0, 112, or 224 kg N/ha, was utilized. The SWIR hyperspectral reflectance was collected from individual leaves using an Ocean Optics NIRSpec with controlled light source. Leaf reflectance spectra and leaf N concentration were related using two opposite approaches: (1) All Possible Ratios [Tarpley et al., 2000. Crop Sci. 40:1814-1819] and (2) Contiguous waveband clustering followed by Partial Least Squares Regression (PLSR). Results & Discussion. The cluster of ratios of wavebands of best fits included a waveband associated with protein. The highest-loading cluster of the PLSR is influenced by protein. Most protein bands were relatively high loading in the PLSR. The predictions based on the PLSR using the top six factors explaining variation in rice leaf N concentration provided both good precision and accuracy. Conclusion. A good linear relationship between SWIR reflectance and rice leaf N concentration was obtained over a wide range of leaf N concentration and across diverse genotypes suggesting the ability to detect rice leaf N concentrations at levels in which remediation practices can be applied before economic damage occurs. Acknowledgments. We appreciate the support from Arcadia BioSciences for other aspects of this project

What is Autumn Decline?

Allen, J.M., Roberts, T.L., Wamishe, Y., and Hardke, J.T.

Autumn Decline, Akiochi disease, and hydrogen sulfide toxicity are all names referring to the same phenomenon that can occur in rice (*Oryza sativa* L.). Though this phenomenon is not fully understood, a variety of factors may influence the occurrences and severity of this disease. This disorder appears to be caused by excessive sulfur and iron in the root zone. High levels of sulfur have been found in the soil and irrigation water in fields where Autumn Decline has been identified. Autumn Decline occurs in anaerobic soils and appears to be caused by the overproduction of hydrogen sulfide, which is toxic to rice roots. Hydrogen sulfide is produced in anaerobic conditions from the reduction of sulfate by anaerobic soil microorganisms. The main symptom of Autumn Decline is the blackening of the roots caused by a buildup of iron on the roots. Other above-ground symptoms appear similar to nutrient deficiencies though they cannot be corrected with fertilizer additions due to the lack of adequate roots and their functionality. If not addressed quickly, plants are more susceptible to opportunistic fungi that cause crown rot and recovery is not likely. Currently, there is only a rescue technique for fields affected by Autumn Decline and there is very little information to predict when and where the symptomology will occur other than previous field history. To reverse the symptoms of Autumn Decline, oxygen needs to be reintroduced into the root zone by draining the field temporarily, which often occurs during reproductive growth when drought stress can lead to severe yield losses. In fields with a history of Autumn Decline, using sulfate-containing fertilizers and an irrigation source containing sulfur should be avoided. Though historically this disease has been a problem later in the season near the boot stage, scouting for this disease should begin as early as 2-3 weeks after permanent flooding has been established. Future research will be aimed at understanding the soil physical and chemical attributes that contribute to Autumn Decline and address why this disorder occurs sporadically within the same field when planted to rice. A better understanding of the soil biological and chemical components that induce the production of hydrogen sulfide is needed in order to prevent or cure the yield losses associated with Autumn Decline.

Evaluating Management Practices to Reduce Chalkiness in Rice Grain

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

Chalkiness in rice grains has become an obstacle for selling USA rice in Turkey and Latin America countries. Research has shown that conditions such as potassium and silicon deficiency, high nighttime temperature, and water stress, can increase rice grain chalkiness. The objective of this study is to develop nutrient and hormone programs to reduce the proportion of broken grains and chalkiness in rice and increase its marketability to consumers in the United States and foreign countries. Field tests were conducted at the Missouri Rice Research Farm at Glennonville, MO and University of Missouri-Lee Farm at Hayward, MO. Two varieties or hybrids were planted at each location in four replications. Each rice received management treatments with an untreated check, soil applied potassium, soil applied calcium silicate, and internode elongation applied potassium fertilizer. Foliar treatments were gibberellic acid and kinetin applied at 50% heading. Plots were harvested with a combine for yield and grain milling and chalkiness. Rice grain yields of CL151 cultivar were significantly higher than those of CL111. Averaged across cultivars, yields were significantly reduced by applications of potash at internode elongation and foliar gibberellic acid at heading. Panicles were separated into top, middle and bottom thirds to determine if location on the panicle affected rice transparency. Rice transparency is inversely related with chalk, and higher numbers indicate a lower chalk value. Rice grain located at the top of the panicle was found to have significantly higher transparency than those kernels located in the middle and bottom portions of the panicle. Rice kernels in the top mature earlier than lower portions, indicating that this difference could be affected by temperature or soil moisture. Rice transparency was also affected by genotype. Cultivar CL111 produced significantly more grain transparency than CL151.

Diversity of Soil Microflora Structure under Different Direct-seed Rice Patterns

Zhou, D., Wu, S., Chu, C., and Fan, J.

Microbes can sensitively reflect the health status and differences of soil. In this paper, the methods of plate culture and Biolog-eco system were combined.

The differences of soil microbial populations, floras and functional microorganism groups in rice fields were investigated under 3 different direct-seed rice patterns: artificial scatter, mechanical drilling at row spacing of 25 cm, and precision hill-drop drilling at seed spacing of 25 cm x14 cm, and the correlations between the ecological differences of soil microorganisms and the soil chemical properties were also analyzed. The results showed that the compositions of soil microflora were obviously different under the different direct-seed rice patterns. At full tillering stage or booting stage, the total quantities of soil cultivable microorganisms were nearly the same between the precision hill-drop drilling and the artificial scatter, but the total quantities varied greatly, being up to 10^7 at full tillering stage and only 10^5 at booting stage. The total quantity of cultivable microorganisms under the mechanical drilling varied little between full tillering stage and booting stage, always remaining at 10^6, but the number and ratio of fungal population were always the highest. The B/F values (population ratio of bacteria to fungi) under artificial scatter were always the maximum, being 1.59 and 0.69 times higher than those respectively under the mechanical drilling and the precision hill-drop drilling at full tillering stage, and 48% and 22% higher than those respectively under the mechanical drilling and the precision hill-drop drilling at booting stage. In terms of soil microbial diversity index, the precision hill-drop drilling was better than the artificial scatter at both full tillering stage and booting stage, though their differences were not significant.

Summarized: Under three different direct-seed rice patterns, the soil microbial diversity indexes of the precision hill-drop drilling were biggest. The balance of soil microorganism diversity of the artificial scatter and the precision hill-drop drilling was better than the mechanical drilling.

Challenges and Future of Microalgal Derived Fertilizers for Rice Production

Moncayo, L., Jochum, M., Way, M., and Jo, Y.

Nitrogen is one of the most important limiting factors in rice production, which heavily relies on synthetic chemical fertilizers. Previous studies conducted in Asia have demonstrated the potential use of nitrogen-fixing cyanobacteria-based biofertilizers as a chemical alternative in rice production. However, the cyanobacteria-based fertilization is often less efficient and inconsistent in comparison with conventional chemical methods. The objective of this study was to determine efficacy of microalgal fertilizers to rice plant growth and yield. In the greenhouse, rice seedlings were treated with one or two-time applications of microalgal fertilizers including live cyanobacteria (*Anabaena* sp. and *Nostoc muscorum*) having the capability of nitrogen fixation or microalgal biomass (lysed *Chlorella* and *Scenedesmus* sp.). The effect of these biofertilizers on plant growth was measured and compared with the urea treatment or non-treated control. Field evaluations for the microalgal fertilizers were conducted at rice fields in Beaumont, Texas for two years. In 2013, rice plots were applied once with live nitrogen-fixing cyanobacterial inoculum (mixture of *Anabaena* sp. and *N. muscorum*) or microalgal biomass (*Chlorella* sp. and *Scenedesmus* sp.). In 2014, rice plots received two-time applications with an indigenous *Nostoc* strain and microalgal biomass (*Chlorella* sp. and *Scenedesmus* sp.). Rice yields from the microalgal fertilizer treatments were compared with the urea treatment (conventional standard) or non-treated control. Under greenhouse conditions, microalgal biomass consistently resulted in a significant increase of seedling height compared with the non-treated control and similar to or better than the urea treatment, whereas the effect of live cyanobacteria treatments on seeding growth was inconsistent. In the field, microalgal fertilizer treatments did not improve rice yields over the non-treated control. Microalgal biomass can improve rice seedling height under the controlled environment but not in the field condition, indicating application at much higher rates may be needed for achieving yield benefits in the field. The inoculation of live nitrogen-fixing cyanobacteria strains tested in this study did not provide consistent benefits for seedling growth or yield, demonstrating difficulties, which the future use of microalgal fertilizers must overcome.

Yield Performance of Rice Varieties in Main and Ratoon Crops in Texas

Zhou, X.G., Samford, J., Vawter, J., and McCauley, G.

Varietal selection is one of the most important factors affecting the profitability of rice production. Ratoon cropping is a common practice in Texas and Louisiana to increase productivity. Selecting a variety that has high yield potential and good milling quality in the main and ratoon crops can maximize income returns. Farmers often make a decision on varietal selection based on the performance of rice varieties under local environments. Providing updated data on variety yield performance in Texas would help Texas farmers achieve their goals. In this study, we evaluated the performance of rice varieties on yield, head rice and total milled rice in the main and ratoon crops in Texas over the last four years.

A field trial was conducted at Eagle Lake, Texas in 2012, 2013, 2014 and 2015. These trials consisted of 23 varieties: three conventional hybrid varieties (XL723, XL753, and XP760), two Clearfield® hybrid varieties (CLXL729 and CLXL745), eight Clearfield® inbred varieties (CL111, CL151, CL152, CL162, CL163, CL172, CL271, and CL Jazzman) and ten conventional inbred varieties (Antonio, Bowman, Catahoula, Cheniere, Colorado, Lakast, Mermentau, Presidio, Rex, and Roy J). Antonio and Colorado were released in 2012 by the Texas Rice Breeding Program. These variety treatments were arranged in a randomized complete block design with four replications. Plots consisted of nine 4.9-m rows, spaced 19 cm between rows. Rice was drill seeded at 39 kg/ha for the hybrid varieties and 78 kg/ha for the inbred varieties in early April each year. Plots were applied with 90 kg N /ha at preflood and 34 kg N /ha at boot for a total of 135 kg N /ha for the conventional and Clearfield® hybrid varieties and with 56 kg N /ha at preplant, 67 kg N /ha at preflood, 34 kg N /ha at PD, and 34 kg N /ha at boot for a total of 191 kg N /ha for the Clearfield® inbred varieties. For the conventional inbred varieties, plots were applied with 56, 78, 45 and 45 kg N /ha at preplant, preflood, PD and boot, respectively, for a total of 224 kg N /ha. Weed and insect control as well as irrigation followed local production recommendations. Rice was harvested using a plot combine late August each year. For ratoon crop production, all plots received 112 kg N /ha of urea and were flooded immediately after harvest. Rice was harvested using a plot combine at maturity. Grain yield was determined and adjusted to 12% moisture content. Milling quality (% head rice and % total milled rice) also was determined.

Except XP760, the hybrid varieties (XL723, XL753, CLXL729 and CLXL745) consistently had the highest yields in both main and ratoon crops, with the combined yield of 16,477 kg /ha or more. Their milling quality (% head rice and % total milled rice) was generally similar to that of the inbred varieties including Presidio. The Clearfield® inbred varieties performed well on yield in either main or ratoon crop, achieving similar or better yields compared to Presidio, except for CL Jazzman with poor ratoon yield potential. Antonio (9,812 kg /ha) and Colorado (9,254 kg /ha) had higher main crop yield than Presidio (8,784 kg /ha). However, both Antonio (4,058 kg /ha) and Colorado (3,400 kg /ha) had ratoon crop yield lower than Presidio (5,045 kg /ha). Antonio was higher than Colorado and Presidio in percent main crop head rice.

Fast-tracking Rice Varietal Testing and Adoption in Different Ecosystems in the Philippines

Vergara, G.V., Collard, B., Pamplona, A., Gregorio, G., Manangkil, O., and Padolina, T.

Accelerating the development and adoption of climate-smart rice varieties in different rice-growing ecosystems in the Philippines is one of the objectives of the Food Staples Sufficiency Program of the Philippine Department of Agriculture (DA). IRRI and DA, through the Philippine Rice Research Institute, have done collaborative research work on various technologies, such as advanced techniques in plant breeding and molecular tools, stratified multi-environment testing (MET), statistics, quality seed production, and participatory varietal selection trials in farmers' fields. In 2014 and 2015, introgression of genes/QTLs conferring submergence, drought, and salt tolerance, as well as resistance to diseases such as bacterial leaf blight, blast, and tungro, and insects such as the brown planthopper, were done in the background of popular high-yielding local varieties, particularly NSIC Rc222 and NSIC Rc160. Most of these lines are now in the BC3F3 stage and are undergoing field testing. Data analyses from six locations for MET1 and seven locations for MET2 allow faster identification of higher-yielding and stable-breeding lines. During the 2015 dry season trials for module 1 (early-maturing), seven IR lines and two PR lines outranked the best check variety. For module 2 (late-maturing), two PR lines and one IR line proved to be promising lines and ranked as good or slightly better than the check varieties. At the National Cooperative trials in 2014, the varieties for release were identified and targeted for each ecosystem. The released varieties were composed of 5 lines of irrigated inbreds, 14 lines of irrigated hybrids, 2 lines of saline-prone, and 3 lines of upland and/drought-prone). Seventeen breeding lines for different ecosystems were identified by the local rice technical working group (RTWG) for release and for quality seed production in 2015. Seed kits containing released varieties for different ecosystems were dispatched to the DA regional field offices in the past three seasons for researcher-managed PVS trials. After each season, the best performing entries in terms of yield and farmers' preferences are identified. Quality seed production and distribution are done through the Philippine seed system. The progress made in the last 2 years shows a remarkable increase in local rice production.

Abstracts of Papers on Economics and Marketing
Panel Chair: Michael Salassi

Economic Factors Driving USDA's 2015/16 U.S. Domestic Rice Market Baseline Projections

Childs, N.

USDA's 2015/16 long-term annual supply and demand baseline results for the U.S. rice industry are presented for both long-grain and combined medium/short-grain rice. An all-rice baseline—an aggregate of the by-class model results—is reported as well. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, stock holdings, and season-average farm prices by class. Underlying economic factors driving these projections for both classes of rice are explained. Because almost half of the total U.S. rice crop is exported annually, expectations regarding the world rice market—including trading prices—affect domestic baseline forecasts as well.

Changing market conditions necessitate annual long-term baseline projections, as market participants and policy makers need updated forecasts for planning, budgeting, and decision making. Each year, USDA develops both a domestic and international 10-year supply and demand baseline for rice. By-class models are developed only for the domestic market.

The baseline effort cuts across multiple commodities including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding global and domestic population and income growth, interest rates, and exchange rates. The 2015/16 baseline forecasts were developed in November 2015.

U.S. rice acreage is projected to slowly expand over the next decade, with long-grain accounting for most of the expansion. Domestic use is projected to continue expanding over the baseline, growing at a slightly faster pace than population. Exports grow slowly over the next 10 years, allowing the U.S. to maintain about 8 percent of the global export market. The stocks-to-use ratio stabilizes around 15 percent, near its long-term average. Farm prices for both long-grain and medium- and short-grain rice slowly increase over the baseline.

Economic Factors Driving USDA's 2015/16 International Rice Baseline Forecasts

Childs, N.

USDA's 2015/16 long-term annual supply and demand baseline results for the global rice market are presented. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, and stock holdings for 31 countries (including the United States) and nine multi-country regions. Aggregated, these 42 models account for total global rice production, supply, and use. Economic factors driving long-term trends in key individual countries and regions are explained, as well as significant changes from the previous baseline. Markets are not segmented by class.

Each year, USDA develops both a domestic and international 10-year supply and demand baseline for rice. The baseline effort stretches across multiple commodities, including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding population and income growth for individual countries, interest rates, and exchange rates. The 2015/16 baseline forecasts were developed in November 2015. USDA's annual baseline projections are used by market participants and policy makers for planning, budgeting, and decision making. Particular emphasis is placed on major importers and exporters.

International Rice Baseline Projections: 2015-2025

Chavez, E. and Wailes, E.

This updated rice outlook presents a baseline of the likely direction of key supply and demand variables in the global rice economy and the degree of variability on selected variables. The baseline projections serve as benchmark for impact analysis on changes on policies, markets, and environment. It includes deterministic projections based on existing policies and stochastic analysis that shows the range of possible future outcomes based on historical yield distribution. The deterministic and stochastic estimates are generated using the Arkansas Global Rice Model, a statistical simulation and econometric framework which covers 61 countries/regions developed and maintained by the Arkansas Global Rice Economics Program with the Department of Agricultural Economics and Agribusiness at the University of Arkansas in Fayetteville. The estimates are generated through intensive iterations with the Food and Agricultural Policy Research Institute based at the University of Missouri, Columbia which maintains comprehensive U.S. agricultural and other commodity models. The main driver of recent rice prices is Thailand's coming back into the global rice trade substantially as a relief measure from its excessive rice stockpile which resulted from the country's politically-inspired controversial and costly Paddy Pledging Program implemented in 2011. The premium of Thai price over other Asian rice prices reached above $100 up until September 2013; but has since gone down and is currently at par with the other prices after the same program was cancelled in early 2014. China will remain an important importer; and Cambodia and Myanmar will assume increasing roles in global trade.

With abundant supplies, and assuming normal weather, long-grain international rice prices are expected to remain in the range of $442-535 per mt over the next decade. The premium of U.S. export price over the Thai price is projected to contract from $116 in 2015 to $45 in 2025 which is more in line with the historical norm, improving U.S. rice export competitiveness. By rice type, U.S. medium-grain export prices will remain strong, with a premium of $300-400 over long-grain over the period 2016-2025.

Total trade is projected to grow at 1.2% annually, from 41 mmt in 2015 to nearly 48 mmt in 2025. While India, Thailand, Vietnam, Pakistan, and the U.S. remain the biggest exporters, the bulk of the growth comes mainly from Thailand, Cambodia, Myanmar, and Vietnam. Thailand is expected to re-take its dominant position in the global rice market over the same period. The fastest-growing regional import markets are the Economic Community of West African States (ECOWAS) and the Middle East.

A net increase in global rice area harvested of 1.5 million hectares is projected, with increases in Nigeria, Cambodia, Bangladesh, and Cote d'Ivoire offset by decline in China. Production grows at 0.9% per year with 0.8% coming from yield and the rest from increased area harvested. About 66% of the output growth comes from India, Bangladesh, Indonesia, Cambodia, Myanmar, and Thailand combined.

Total world rice consumption grows at 0.9% annually, from 488 mmt in 2015 to 524 mmt in 2025, solely coming from population growth of 1.1% as rice per capita use declines by 0.3% per year—from 66 to 64 kg over the same period. India, Bangladesh, Indonesia, Nigeria, the Philippines, and Myanmar together account for nearly 30 mmt or 63% of the total global growth in consumption.

Some uncertainties remain: India's reliability as an exporter with expanded PDS; the high margins between Western Hemisphere and Asian prices; likelihood of Sub-Saharan Africa and Southeast Asia achieving targeted productivity levels and attaining self-sufficiency; government subsidies; availability of water; and weather.

Information Content of USDA Rice Reports and Price Reactions of Rice Futures

Darby, J. and Mckenzie, A.

Rice is a predominant food staple in many regions of the world, and it is important to determine how efficiently the U.S. rice market helps to ensure world food security. This question can be answered by gauging the price discovery performance of the U.S. rice futures market and the economic usefulness of the U.S. government's supply and demand forecasts. So, to this end, we employ two event study approaches: (1) to examine variability in returns on report-release days as compared to returns on pre- and post-report days, and (2) to regress price reactions on changes in usage and production information. It is found that the USDA provides the rice futures markets with valuable information and rice futures respond to the information in an economically consistent manner.

GM Rice Commercialization and Its Impact on the Global Rice Economy

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

Genetically-modified (GM) rice is regarded by many as a promising technology, while many others still consider it controversial and remain passionately against its use. Hence it warrants more in-depth analysis. To date, no GM rice has been commercialized. In this study, we assess the potential impacts of GM rice commercialization on the global rice market using two complementary modelling frameworks: the Arkansas Global Rice Model (AGRM) and the RiceFlow model. We generated stochastic and dynamic analyses, considering scenarios of adoption, diffusion and acceptance of Bt (Bacillus thuringiensis) rice by Bangladesh, China, Indonesia, Nigeria, and the Philippines are compared against baseline projections.

The results focus on world trade, world and domestic prices, resource savings, domestic production, consumption, stocks and imports. Bt rice adoption has the potential to significantly impact the global and national rice economies of Bt rice adopters and net rice exporters. Total rice trade, international price, and domestic prices decline as global rice production, consumption, and stocks expand.

Ex ante analysis of adoption of Bt rice by selected major global rice importers has a market logic as these countries are hypothesized to be the most likely early adopters of the technology to satisfy domestic use. On the other hand, major rice exporters are unlikely to adopt given current policy in key importing nations, which reflects the market risks associated with the consumption of GM rice as outweighing the potential benefits.

Some of the benefits associated with the adoption of Bt rice are yield improvement from reduced pest damage, lower costs of production with reduced application of insecticide, and improved health outcomes of producers' lower exposure to insecticide contamination.

We used two scenarios in the analysis: (1) adoption rate of 40% of the rice area in Bangladesh, China, Indonesia, Nigeria, and the Philippines at 5% yield gain; and (2) Bt adoption rate of 20% for Nigeria and 40% for the other four countries to assess the effect of asymmetric adoption of technology. The adoption function of Bt rice is assumed to follow the same pattern as GM crops in the U.S. for a 9-year projection period up to 2023. For the analysis using RiceFlow model, there is an additional assumption of 50-percent reduction in pesticide use.

The results suggest that the adoption of Bt rice in selected importing countries will lead to lower demand and rental price for land (except in Nigeria), higher production, and a significant import substitution effect. Land rental prices in large producing countries such as China can decrease significantly by more than 10%, thus increasing the competitiveness of the whole domestic rice sector, not only of adopters.

At the global level, impacts on production and consumption are for the most part marginally higher, except for the international reference price which is estimated to decrease by 6% a year as a result of lower demand for imports in Bt rice-adopting countries with the improved yield assumption.

Lagging in Bt rice adoption can have significant welfare costs as estimated for the case of Nigeria which expands its imports due to smaller output gains under the assumed lower adoption rate. This provides the incentive for countries to keep up with the leaders in technological adoption.

Constraints to Adoption and Acceptance of GM Rice

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

Policies toward acceptance of GM rice by key rice producing and importing countries are reviewed. Surveys of consumers and producers and policy decision-makers provide a basis to evaluate the potential economic benefits and risks associated with GM rice. A large-scale project to assess constraints was achieved through several research activities: 1) Qualitative policy analysis of the regulatory landscape for GM rice in the following countries: Bangladesh, China, India, Japan, Colombia, Honduras, Tanzania, the European Union, and the United States; 2) Statistical analyses of producer and consumer contingent valuations of willingness to pay and willingness to grow GM rice in China, Bangladesh, Tanzania, Ghana, Colombia, and Honduras. We examine in particular GM events associated with pest tolerance and micro-nutrient fortification; and 3) Global impact of GM rice adoption in selected countries. We focus on major rice importers who are more concerned about domestic self-sufficiency than international approval of GM rice that would constrain export trade. The results show similarities and differences across countries with respect to regulatory environment, consumer and producer preferences and global impacts. The analyses conducted by this project provide a cross-sectional assessment of the constraints and challenges facing governments, consumers, producers, bio-science companies, and international organization and foundations who are concerned about the future of food availability, food quality, environmental sustainability and the global rice economy. The research on this important topic must and will continue. Genetic improvements in a wide range of traits are necessary for one of the world's most basic staple foods. Acceptance and commercialization of GM rice has benefits and risks, however, refusing to accept GM rice poses greater risks for food supply, for sustaining the environment and to meet the health challenges of a very large population who heavily depend on rice as a basic food staple.

Detailed and updated research results are posted on the project website at http://gmrice.uark.edu/index.html. Drafts of the country policy landscape chapters reflect the diversity of rice in the national food economies of the selected countries. Stark differences in the regulatory environment exist across countries and pose major constraints and challenges to the harmonization and commercialization of GM rice in the global economy.

A Value Chain Assessment of the Cuban Rice Economy and Export Potential for the United States

Wailes, E. and Durand-Morat, A.

The objective of this study is to describe and analyze the status and future prospects of the Cuban rice sector. Rice is a key food staple however Cuba imports most of its supply of rice. Cuba has the highest per capita consumption levels of rice in the Western Hemisphere. Rice is produced throughout the island but primarily in three major production zones. The import of rice is primarily supplied by Vietnam and secondarily by Brazil and occasionally other countries. Prior to the Castro-led revolution, Cuba was an extremely important export market for the United States. With easing of political and diplomatic relations, there is growing interest in a potential role for U.S. rice exports into Cuba. The study is based on primary data collected from an extended field study trip and secondary data from various sources. The study provides an assessment of the current policy environment and the level of commitment by the Cuban government to invest in both production and processing capacity of the rice sector. We address the question of whether it can compete effectively with imports and if so what kinds of investments and policies would be needed to achieve a higher level of domestic production to meet growth in domestic consumption.

The study provides an assessment of the current levels of farm and processing technologies. We assess the production constraints and potential for productivity improvements. The research and extension institutions are described and based on interviews we evaluate the key bottlenecks associated with achieving higher yields and improving the quality of rice.

Infrastructure of the production sector including irrigation, transportation, drying and storage, milling and distribution is assessed. An estimate of the needed investment required to upgrade the domestic rice infrastructure is developed. Given the dependence on imports, the port facilities and import protocols are assessed based on interviews and site visits.

Finally, we provide an assessment of the consumption characteristics of rice in Cuba. We assess the distribution and pricing systems and consumer preferences for rice. An analysis of the value chain for both domestic and imported rice is much needed and is provided in this study.

Climate Change Impact on Rice Policy in Bangladesh: Using A Stochastic Simulation Approach

Nahar, A., Luckstead, J., and Wailes, E.

Agriculture is the main source of livelihood for rural households in Bangladesh. Rice is the most significant cereal food and is grown on about 71% of the total agricultural area and 77% of the area dedicated to crop production. This indicates that rice dominates agricultural production and, with a per capita consumption of 221 kg per year, rice is the major source of calorie intake in Bangladesh. With an average per capita consumption of approximately 416 grams per day, rice contributes to about 42 percent of per capita daily calorie intake, which is one of the highest in the world. While Bangladesh has achieved significant growth in domestic rice production, it is still a predominantly net food importing country with about 3 million Mg (tones) of rice import each year. As part of the Millennium Development Goals, the government of Bangladesh is trying to achieve national food security by 2015.

Bangladesh had been identified as highly vulnerable to the effects of climate change. Rice is particularly vulnerable because it is grown in low-lying coastal regions. These regions are susceptible to rising sea levels and changes in weather patterns which could lead to a substantial decline in land and productivity of rice farms. Therefore, the negative effects of climate change on rice production has the potential to negatively impact rural households who depend mostly on agricultural income and the government ability to achieve food security. This could lead to increased food insecurity and higher levels of poverty, especially for the poorest and most vulnerable.

The objective of this paper is develop a farm household rice production model to quantify the impact of potential land loss and yield reduction from climate change on prices, production, consumption, welfare, and the ability of government to achieve self-sufficient in rice production. In the model a representative farm household maximizes utility with respect to consumption of rice, household items, and leisure subject to their budget constraint, total time availability, total land availability, and unemployment constraint. The farmer earns income from rice production and off-farm employment. Assuming the unemployment constraint is binding, production and consumption decisions are not separable. All input prices for rice production are fixed, and the price of rice is determined in equilibrium.

The model will be calibrated to the Bangladesh rice market for 2014. We will numerically solve the model to endogenously determine prices, production, consumption, and welfare. The initial baseline simulation will replicate the 2014 data. We will then run three alternate scenarios: 1) decrease in land suitable for rice production, 2) decline in productivity, and 3) reduction in both land and productivity due to climate change. We compare the results of each of the counterfactual scenarios to the benchmark scenario to quantify the potential impacts of climate change on Bangladesh rice production. We will also consider a range of sensitivity analyses for different climate change patterns.

Rice Blast in the Mid-South of the United States: Economic Appraisal of Genetic Resistance

Tsiboe, F., Shew, A.M., and Nalley, L.L.

In 2014 rice producers in Arkansas, Mississippi and Louisiana planted over 48,000 hectares of rice to non-blast resistant varieties. Rice blast is one of the most frequent and costly diseases of rice in the Mid-South, caused by the *Magnaporthe oryzae* fungus. The yield losses associated with blast outbreaks in Arkansas have been estimated from 10 to 80%, and the cost of mitigating blast via fungicide can reach over $70 per hectare. Even then, the fungus can cause yield loss depending on the extent of infection at the time of application. Unlike other traditional row crops in the United States, there is currently no commercially available genetically modified (GM) rice. Consequently, disease packages for rice cultivars are not as robust as their GM crop counterparts. A recent USDA/NIFA project at Kansas State University (KSU) has begun researching the potential of cisgenic breeding as a method to combat rice blast disease. Cisgenesis involves the introduction of genetic material from a crossable—sexually compatible—plant. Traditional breeding techniques could possibly achieve the same results as those from cisgenesis, but would require a longer time-frame. Rice breeders at KSU are taking blast resistant genes from wild (low yielding) rice varieties and inserting them into currently cultivated (high yielding) cultivars.

For cisgenically-bred rice to be released to the public and subsequently adopted, the benefits to private companies and producers will need to be substantial because many parts of the world still classify cisgenic breeding as a GMO in regulatory protocols. Thus, this research estimated the economic benefits of planting the entire Mid-South in the United States with rice cultivars that are blast resistant. For the time period 2002-2014, the economic benefits of blast resistance were estimated by comparing actual yield losses and fungicide costs due to blast to the counterfactual that all planted cultivars were cisgenically-bred and blast resistant with no yield losses. This would mimic the scenario in cisgenic breeding where a rice plant in the first generation (i.e.—F1) would be identical to its parent with the exception that it would be blast resistant. This information is critical to plant breeders, producers, and policy makers because it gives a relative value to blast resistance in rice.

Yield and hectare data by cultivar were collected at the county level for Arkansas, Mississippi and Louisiana from 2002-2014. Moreover, data was collected on the blast susceptibility of each cultivar planted. From this dataset, the total hectares of cultivars susceptible to blast were estimated for each state, and a model was developed to simulate blast outbreaks, concurrently estimating the subsequent yield losses. Given the rich literature on blast research and associated yield losses, we were able to run multiple scenarios with varying costs associated with infection rates and yield losses. For example, even in large scale blast outbreaks, like in Louisiana in 2012, not all susceptible cultivars were affected and not all infected cultivars had equivalent yield losses. Thus, iterations of the model included the following scenarios: (1) a preventive fungicide application on all blast susceptible hectares as recommended by University Extension Services; (2) a simulated blast outbreak with two fungicide applications on the infected hectares and no associated yield loss (3) a simulated blast outbreak with two fungicide applications on infected hectares and associated yield loss. From these scenarios plant pathologists, plant breeders, producers and policy makers can have tangible estimates of the benefits of both blast resistance and cisgenic breeding to make more informed decisions.

Our results show that more than 800,000 hectares were planted to blast susceptible varieties of rice between 2002 and 2014. The initial scenario estimated the cost of preventive fungicide for all years on all susceptible hectares at over $26 million. The second scenario estimated a blast outbreak on 178,516 hectares of land with an associated mitigation cost of $11.5 million for two fungicide applications. Then, using the simulated infection rates from scenario two, the third model estimated the total cost of two fungicide applications and associated yield losses at $76.5 million. Furthermore, we modeled each scenario for each of the twelve years of data to show the progression of the economic impacts of blast in the Mid-South, and also explored the differential impacts across Arkansas, Mississippi and Louisiana. The value of cisgenically-bred, blast resistant rice is significant for Mid-South producers, and this appraisal of the costs of blast will provide researchers, policy-makers and industry professionals the foundation needed to further promote blast resistance through cisgenic breeding.

Crop Insurance Program for Rice Producers in Arkansas: Past, Present and Future

Mane, R. and Watkins, K.B.

Several crop insurance products are available to help rice producers mitigate different types of risk. This talk deals with three different aspects of crop insurance products available to rice producers. First, it provides an overview of past, present, and future trends of government crop insurance products using data from the USDA Risk Management Agency (RMA). Second, it provides a general summary of private crop insurance products available to rice producers, and third, it provides information on the upcoming Margin Protection (MP) crop insurance product. Based on RMA data from 2004 to 2014, there has been an increase of 52 percent in revenue protection policies earning premiums from 997 to 2,120. In the same time period, yield protection policies earning premiums had a relatively modest increase of 22 percent from 807 to 1,038. However, there has been a significant decrease of 60 percent in catastrophic (CAT) policies earning premiums from 2,984 to 1,209. A similar trend is observed in the number of policies earning premiums for net acres covered under the different crop insurance programs. Rice producers purchased less yield protection insurance products relative to revenue protection policies during the eleven year period, reflecting the fact that yield risk is small for rice production due to irrigation. About 61 percent of rice producers had coverage levels above 70 percent for revenue protection whereas 62 percent had yield protection policies with coverage above 70 percent. The value of total indemnities as a percent of total rice production value was small for all eleven years, ranging from 0.2% in 2012 to 6% in 2011, implying that many rice producers purchasing crop insurance received no indemnity payments during the eleven-year period. The second aspect of crop insurance analysis is the increased purchase of private crop insurance products by Arkansas producers. Based on literature and personal correspondence with different stakeholders, Crop Hail (CH) is one of the largest selling private crop insurance products in Arkansas. The crop hail insurance products are popular because they can be purchased at any time of a crop cycle based on weather conditions. Based on the National Crop Insurance Services (NCIS) 2014 annual report, Arkansas had the third highest crop-hail loss ratio with an estimated $14.4 million paid in premiums by farmers.

A third aspect of crop insurance is the potential role of a new product to be offered to rice producers in 2016 called Margin Protection (MP). Margin Protection provides coverage against an unexpected decrease in operating margin resulting from increased input costs. Allowed MP inputs subject to price change in rice production include diesel, urea, DAP (Diammonium Phosphate), potash, and operating interest. Based on simulated results of three Arkansas counties, MP has a low probability (5.2 percent and 18 percent at 85 and 90 percent coverage levels) of triggering an indemnity in Arkansas County when compared to Poinsett and Desha counties. There is a 32 and 35 percent probability of triggering indemnities at 90 percent coverage for Poinsett and Desha counties respectively. The higher probabilities of indemnities in Poinsett and Desha counties may be due to higher variability in yields for those counties.

Economic Evaluation of Seed Rate and Nitrogen Application Strategies to Minimize Lodging in CL151

Falconer, L., Corbin, J., and Walker, T.

The objective of this study was to evaluate the economic impact of seeding rate in combination with multiple nitrogen fertilizer schemes related to lodging for the rice variety CL151. Replicated treatments consisted of a factorial combination of three seed rates (161, 323 and 483 seeds m^{-2}) and 10 combinations of nitrogen (N) rates and splits. Partial budgets were developed to estimate returns above seed, fertilizer, harvest, hauling and drying costs (NRAC) with all other expenses assumed to be constant across all experimental units. The NRAC for each experimental unit was calculated using the following equation:

$$NRACi = (Yi*P) – (SRi*SP) – (FRi*FP) – (FRi*FAP) – (Yi*HC) – (Yi*DC) – AHCi \quad [1]$$

where NRACi = the net return above seed, fertilizer, harvest, hauling and drying costs, Yi = rice yield in kilograms per hectare for the experimental unit, P = rice price in dollars per kilogram, FRi = nitrogen fertilizer applied to the experimental unit in kilograms per hectare, FP = nitrogen cost in dollars per kilogram, FAP = fertilizer application cost in dollars per kilogram, HC = hauling cost in dollars per kilogram, DC = drying costs is dollars per kilogram and AHCi = the harvest cost per hectare for the experimental unit adjusted for the severity and amount of lodging experienced.

To test the sensitivity of results to changes in rice and nitrogen prices, the NRAC were calculated for two scenarios based on the low and high average annual prices reported for rice in Mississippi along with low and high nitrogen prices based on urea over the 2010 to 2012 time period. Harvest costs were adjusted using the lodging score assigned to that experimental unit. Baseline combine field speed for lodging score 1 was estimated at 4.83 km/h, with field speed for lodging scores 2 through 5 estimated at 4.02, 3.22, 2.41 and 1.61 km/h respectively. Harvest costs for each lodging score were calculated for each experimental unit using the following equation:

$$AHCi = ((1 - \%Lodgedi)*HC1) + (\%Lodgedi * HCLodgingScorei) \quad [2]$$

where AHCi = the harvest cost per hectare for the experimental unit adjusted for the severity and amount of lodging experienced, %Lodgedi = the percentage of the experimental unit lodged, HC1 = the estimated cost per hectare to harvest erect rice and HCLodgingScorei = the estimated harvest cost per hectare based on the lodging score for the experimental unit.

The calculated AHC ranged from $109.96 per hectare to a high of $184.83 per hectare based on the percentage of each experimental unit that was lodged and the degree of lodging. 8.5% of the experimental units had some lodging and incurred a harvest cost higher than the baseline. The seeding rate (P> 0.1334) and seeding rate*nitrogen management scheme interaction term (P> 0.2888) were not significant for AHC. The impact of nitrogen management scheme on AHC was found to be statistically significant at the (P <.0001) level. When analyzed separately for impacts on yield, both the seeding rate and seeding rate*nitrogen management scheme interaction were significant. These results indicate the transformation used to calculate the AHC shown in Equation 2 absorbs the seeding rate and seeding rate*nitrogen management scheme impacts. The highest AHC least square mean for nitrogen management scheme was for the 252 kg per hectare pre-flood application and was significantly higher than all other nitrogen management schemes.

The highest NRAC least square mean for nitrogen management scheme in the low rice-nitrogen price scenario was for the 201 kg per hectare pre-flood application. The NRAC for this scheme was significantly different (higher) than any other nitrogen management level unlike the yield results where there was no difference between the 252 kg per hectare pre-flood application and the 201 kg per hectare pre-flood application. This result would be explained by the significantly higher AHC for the 252 kg per hectare pre-flood application.

The high rice-high nitrogen price scenario resulted in a statistically significant difference in the calculated NRAC for the 323 seeds per square meter rate relative to the alternative seeding rates. The highest least square mean for nitrogen management scheme was for the 201 kg per hectare pre-flood application, consistent with the results from the low rice price-low nitrogen price scenario.

Economics of Weed Suppressive Rice Cultivars in Flood- and Furrow-Irrigated Systems

Watkins, K.B., Gealy, D.R., Anders, M.M., and Mane, R.U.

Weeds are a major constraint to rice production. In the U.S, weeds in rice are controlled primarily with synthetic herbicides. Intensive herbicide application in rice also has many potential drawbacks, resulting in environmental pollution, human health concerns, and development of weed resistance. Because of these shortcomings, many have proposed the use of weed suppressive or allelopathic rice cultivars to reduce heavy dependence on synthetic herbicides. Water is also a constraining input in rice production and is becoming more limiting in many areas in the U.S. where rice is grown. In Arkansas, groundwater is the primary irrigation source for rice, and groundwater levels are declining in much of Arkansas due to continued withdrawals at pumping rates that are unsustainable. Concerns about groundwater depletion have prompted rice producers to consider production systems that use less water. One such system is furrow irrigation. Weed management in furrow irrigation is inherently challenging. Prolonged moist conditions under furrow irritation allow several terrestrial weeds normally controlled by flood to emerge. Weed suppressive cultivars may be beneficial for aerobic rice systems like furrow irrigation.

An economic analysis of both weed-suppressive and weed non-suppressive rice cultivars under flood and furrow irrigation was conducted using yield and herbicide application data from a weed suppressive cultivar study conducted during the years 2009, 2010, and 2011 at Stuttgart, Arkansas. Net returns to herbicide application were calculated as gross returns less herbicide costs for each cultivar-irrigation-herbicide level combination. Herbicide levels were classified as "low,", "medium," and "high" herbicide intensity. The study also employed Bayesian statistical analysis to calculate probabilities of monetary gains for additional herbicide application beyond the "low" herbicide level. Probabilities of exceeding target monetary gains were calculated by rice cultivar and irrigation treatment for "medium" and "high" herbicide intensity relative to "low" herbicide intensity. The cultivars evaluated in the study included two weed suppressive cultivars ("Rondo" and the allelopathic cultivar "PI312777"), a commercial Clearfield hybrid ("CLXL729"), and four other weed non-suppressive varieties ("Bengal," "Wells," "Lemont," and "CL171AR").

Interpretation of cultivar net returns to herbicide application varied depending on water management. Under flood irrigation, net returns for Rondo and PI312777 were highest on average under medium herbicide intensity, while net returns for all other cultivars evaluated (CLXL729, Bengal, Wells, Lamont, and CL171AR) were highest on average under high herbicide intensity. Net return variability as measured by the coefficient of variation was correspondingly lower for Rondo and PI312777 under medium herbicide intensity and lower for all other cultivars under high herbicide intensity. Under furrow irrigation, net returns were highest on average and less variable under high herbicide intensity for CLXL729, followed by Rondo, and PI312777. The remaining cultivars (Bengal, Wells, Lemont, and CL171AR) had much lower average net returns at all three herbicide intensities, with Lemont generating negative returns at all three herbicide intensities.

Interpretation of the Bayesian statistical analysis also varied depending on water management. Under flood irrigation, the probabilities of receiving monetary gains in excess of \$247 ha^{-1} (\$100 ac^{-1}) from additional herbicide were highest for medium relative to low herbicide intensity for Rondo (99.7%) and PI312777 (82.7%) but were highest for high relative to low herbicide intensity for all other cultivars evaluated (99.8% for CLXL729, 98.7% for Bengal, 100% for Wells and Lemont, and 99.5% for CL171AR). Under furrow irrigation, the probabilities of receiving monetary gains in excess of \$247 ha^{-1} (\$100 ac^{-1}) were highest under high relative to low herbicide intensity for all cultivars, but were measurably much larger for CLXL729 (87.5%), Rondo (87.9%), and PI312777 (69.5%) than for the other cultivars evaluated (39.1% for Bengal, 20% for Wells, 2.2% for CL171AR, and 0% for Lemont).

Based on the net return results and the Bayesian statistical analysis, the following conclusions may be drawn. Under flood irrigation, the intensity of herbicide management can vary depending on a cultivar's weed suppressive ability. Weed suppressive cultivars can achieve higher profitability using less herbicide inputs relative to weed non-suppressive cultivars under flood management. Under furrow irrigation, cultivar selection appears to be much more critical than management of herbicide intensity. Weed suppressive cultivars or commercial hybrids appear to be better fits for furrow rice systems than weed non-suppressive cultivars based on the results of this study.

Assessing the Economic Impact of the Clearfield Rice Technology in the U.S.

Durand-Morat, A. and Wailes, E.

The Clearfield® System (CL) is to date the only alternative to selectively eliminate red rice from a rice field with the use of an herbicide. Red rice infestation can cause severe yield losses that vary by variety, red rice density, and the duration of the interference. More than 20 CL materials (between conventional and hybrid rice) have been released in the U.S. since 2002, most of them long grain. CL medium-grain and aromatic rice varieties have been made recently available.

The use of the CL rice technology grew significantly after its introduction, reaching 65% of the rice acreage in the southern U.S. in 2012. This technology is also well established in other countries around the globe, most notoriously in Brazil, Argentina, Uruguay, and Malaysia.

Statistical analysis of field data is performed to assess the effect of the CL rice technology on yields and cost of production. Yield and cost gap estimates are subsequently incorporated into the RiceFlow model, a partial, spatial, supply-chain equilibrium model of the global rice economy, to assess the impact of the technology on the U.S. rice market. The model is calibrated to calendar year 2013, and rice is disaggregated into 9 commodities: 3 types (long grain, medium/short grain, and fragrant rice) and 3 milling degrees (paddy, brown, and milled rice).

Furthermore, the U.S. is disaggregated into the key rice producing states and production technologies, namely, CL and non-CL varieties. The impact of the CL technology is assessed by removing the benefits granted by it. The results indicate that the CL rice does not offer yield or direct costs benefits vis-à-vis conventional rice, and that more subtle unmeasured effects may be at play.

We hypothesized that by simplifying farm operations, the CL rice technology generates cost savings associated with farm management. Since these benefits are not incorporated in the rice crop budgets analyzed, we ran a sensitivity analysis on the impact of these management costs on the rice sector using RiceFlow. We find that the CL rice technology generates sizable benefits to the U.S. rice industry.

The CL rice technology helps improve the overall quality of the long grain crop. Based on information provided by contacts from the private sector, we estimate these benefits for the U.S. rice sector to amount to US\$ 133.5 million since 2009.

Economy-wide, our estimations suggest that the CL rice technology have generated sizable contributions to the economy of all rice states in 2013, but primarily Arkansas and Louisiana. Just by improving the quality of the U.S. rice crop, this technology generated around US\$ 42 million in extra revenue in 2013. When other more subtle benefits, such as lower management costs, are considered, the benefits in 2013 more than double.

An Evaluation of the Economic Impacts of Transitioning from DCP Payments to 2014 Farm Bill Provisions for U.S. Rice Producers

Raulston, J.M., Outlaw, J.L., Knapek, G.M., and Richardson, J.W.

This study examines the farm level impact of transitioning from the Direct and Counter-cyclical Program (DCP) provisions of The Food, Conservation, and Energy Act of 2008 to the Price Loss Coverage (PLC) program that became law upon passage of The Agricultural Act of 2014. Direct Payments, called production flexibility contract (PFC) payments at the time, originally appeared in their modern form in the 1996 farm bill. These fixed payments were replaced with a similar policy tool, Direct Payments (DPs), in the 2002 farm bill. Direct Payments remained in place until their repeal upon passage of the 2014 farm bill. Eligible producers were paid a fixed annual payment based on their DP Yield, Base Acres, a commodity-specific DP Rate, and a payment fraction. The rate was $0.05181 per kg ($2.35 per hundredweight) for all rice, and producers' individual base acres and payment yields were based on historical plantings and yields specific to their farms. In addition, Counter-cyclical Payments (CCPs) provided an additional safety net payment for producers when marketing year average prices fell below $0.23149 per kg ($10.50 per hundredweight). The difference in this shortfall was the CCP rate. The CCP rate was multiplied by base acres, a farm-specific CCP yield, and a payment fraction to determine CCP payments. The CCP program was essentially replaced with Price Loss Coverage in the 2014 farm bill. PLC payments work similarly; however, a higher target price, now called a reference price, was established for long-grain rice at $0.30865 per kg ($14.00 per hundredweight). This study will examine the differences in government safety nets between the two farm bills given current market conditions utilizing a representative farm approach.

This study utilizes AFPC data for ten representative rice farms in major rice production regions of the United States. Representative farms are developed by focus groups of producers that provide all information necessary to simulate an agricultural operation in a given production region. This information is gleaned through a face-to-face, consensus-building interview process with follow-up update meetings occurring every two to three years. Base acres and payment yields were obtained during the face-to-face meetings with producers. The farms were simulated using AFPC's whole farm simulation model and 500 stochastic outcomes from FAPRI's December 2015 baseline.

This study assumes all AFPC representative farms elected and enrolled long-grain rice base acres in Price Loss Coverage (PLC). Although AFPC whole-farm analysis takes land tenure into consideration, this study examines government payments in total, not accounting for landowner shares (if any). Furthermore, this study assumes a business structure and sufficient engaged individuals in the operation such that payment limits are non-binding.

Given current projected market prices, the average annual estimated 2014-2018 DCP payments (both DP and CCP payments) range from $186.66 to $296.18 per base hectare ($73.92 to $119.86 per base acre). For every representative farm, average annual estimated PLC payments for the 2014-2018 period are higher, ranging from $276.41 to $409.77 per base hectare ($111.86 to $165.83 per base acre). Direct payments are fixed by nature, having a 100% probability of a payment. Due to the low $10.50 per hundredweight target price under the 2008 Farm bill, the current relatively low price projections would result in no CCP in 2014-2016, and probabilities of a CCP would be less than one percent in 2017 and 2018. Conversely, 2014 farm bill programs would include no fixed payment; however, price loss coverage (PLC) payments would have probabilities of payments in excess of 85% in each year of the 2014-2018 projection period given current price projections. The Coefficients of Variation (CV) associated with the DCP program in the 2008 farm bill are less than one percent for all AFPC representative farms. The CV is substantially higher for PLC payments, exceeding 16% for all AFPC representative farms in this study. The higher CV indicates a higher relative risk on the PLC payments under the 2014 farm bill as compared to the DCP program under the 2008 Farm Bill.

Although Direct Payments were viewed favorably from a WTO compliance standpoint, they became politically unpopular as they were viewed as providing support even when market conditions were favorable. Given the relatively high reference price, the Price Loss Coverage (PLC) program is expected to provide a much stronger safety net for producers when prices are on the decline as compared to the previous CCP program, and, as evidenced through the results of this study, will likely provide even higher levels of support than the previous DP program given current market conditions.

Policy Sequencing to Optimize the National Rice Development Strategies for Southern African CARD Member Countries

Razafinjoelina, S., Wailes, E., and Durand-Morat, A.

Rice is grown in more than 75% of African countries accounting for almost 800 million people. It is the main staple food in 10 African countries but per capita consumption in others is rising in such a way that consumption will double in coming years. In 2009, Africa imported 9.8 million MT of milled rice which represents a large share of the world market and 40% of Africa's total rice consumption. This high dependence on imports makes the continent vulnerable to international market shocks which in turn are a threat to food security and political stability as observed during the 2008 food crisis.

In response, several African nations developed a National Rice Development Strategy (NRDS) as part of the Coalition for African Rice Development (CARD) initiative. The initiative aims to ensure self-sufficiency and food security within member countries by doubling rice production from 14 million tons in 2008 to 28 million MT by 2018.

This study provides an evaluation of the consequences of policy sequencing in the rice sector for selected Southern African countries. Analyses explore how the optimization of policy sequencing (value-adding, demand-lifting, and supply-shifting) can be implemented to help countries achieve food security and autonomy.

In previous research, Demont drew several conclusions that serve as the basis of this study. For instance, Demont proposed the three-stage sequence for the policy actions required to upgrade rice value chains that encompass value-adding, demand-lifting, and supply-shifting strategies. He also provided a qualitative assessment of certain NRDS by developing a typology according to sector development patterns and investment priorities. This allowed the categorization of the CARD countries into three distinct groups which in turn will enable the definition of policy actions that is a better fit for each country. The three categories include coastal countries with dominant consumer preferences for imported rice, coastal countries with dominant consumer preference for local rice and landlocked countries with more or less urban bias as a result of transportation barriers but general with dominant consumer preference for local rice. Additionally, Demont concluded that urban African consumers are willing to pay for quality upgrading of domestic rice, African rice with upgraded quality can compete with imported rice in urban markets, both intrinsic and extrinsic quality attributes contribute to competitiveness of rice, varietal quality improvement and upgrading of processing add substantial value, and labeling and information build value and improve the reputation of African rice. These hypotheses are analyzed in this study. The analysis needs to be taken into account by policy makers who are currently implementing ambitious national rice development strategies throughout Africa. For instance, the Southern African countries concerned by this study figures mostly in Groups 2 and 3 which imply that the population in these countries have a preference for local rice eliminating the need for the first policy sequencing stage and therefore, focus needs to be in demand-lifting and supply shifting strategies.

This assessment specifies a baseline investment policy implied by the NRDS which, using quantitative modeling frameworks (RICEFLOW and AGRM), we estimate outcomes for rice sector prices, supply, consumption, and trade based on the investment and policies implied by the NRDS. The analysis of the policy sequencing compared to the benchmark will assess the shifting forward of value adding investments on the same previously mentioned parameters using model scenarios.

Rice Value Chain Development and Policy Sequencing in East Africa

Muthee, F., Wailes, E., and Durand-Morat A.

Rice is an important food crop for half of the human race constituting 29% of the total grains produced in the world. In East Africa, rice has emerged as a popular and important food crop owing to increased urbanization over time with urban dwellers preferring it for its ease of cooking, relatively longer shelf life and versatility of. In Kenya, it is the third most important crop after wheat and maize with the growth in annual consumption estimated at 12% as compared to 4% and 1% for the other two important food crops, wheat and maize respectively. In 2012 the government of Rwanda pronounced rice a priority crop upon the acknowledgement of the potential for its production in the marshlands. A key concern with the growing consumption is that domestic production in these East African countries does not meet the growing demand leading to overdependence on imports. Kenya imports about 75% to meet the national demand for rice. In Tanzania production would need to increase by 100,000 tons to meet the growing population and the high per capita consumption (25 kg) of rice. While Rwanda is 75% self-sufficient, the consumers especially in the urban areas prefer imported rice which is deemed of higher quality as compared to the domestic rice which has higher percentage of broken from poor milling. The domestic rice is sold to the rural population with less purchasing power.

Under the support of Coalition for Africa Rice Development (CARD), 21 Africa countries developed National Rice Development Strategies (NRDS) in 2008 with the aim of improving the rice sectors in these countries. Demont categorized the African countries into three groups: 1) Coastal countries with dominant consumer preferences for imported rice; 2) Coastal countries with dominant consumer preference for local rice; and 3) Landlocked countries with more or less urban bias as a result of transportation barriers but in general with dominant consumer preference for local rice. Demont concluded that in order to achieve the goals of NRDS especially for the first group of the countries, the urban bias needs to be reversed first by refocusing the development strategy to value adding and demand-shifting investments on the local rice sector. This study provides a quantitative assessment of the Demont hypothesis by using a global rice model to evaluate the policy sequencing consequences of value-adding, demand-shifting and supply-lifting.

Rice Development Strategy in Malaysia: A Policy Analysis Matrix Approach

Ali, R., Wailes, E., and Durand-Morat, A.

Rice receives special treatment and attention in Malaysia as it remains a single important food staple for the nation. As a result, the national food policies and development plans have focused on rice for decades based on policy instruments and strategies to achieve self-sufficiency and reduce its dependency on rice imports. To realize this objective, massive investments have been made on research and development, upgrading infrastructure and irrigation systems, diffusion of farming and processing technologies, and provision of direct subsidies and border protection using tariffs. Nevertheless, domestic rice production only achieved only 65 to 70 percent sufficiency for many years, while the remainder was met with imports. In fact, Malaysia has become one of the world’s largest rice importers, bringing in around 1 million metric tons annually. Using a Policy Analysis Matrix (PAM), the primary objective of this study is to evaluate the profitability and competitiveness of rice production in Malaysia and identify constraints and opportunities for improvement. The primary data for the study were collected from a comprehensive survey carried out by the Malaysian government in 2014, while the secondary data were obtained from the most recent report of rice costs and production for 2009/2010 seasons and published economic reports for various years. The result of the PAM analysis reveal that Malaysian rice sector is less profitable and has no comparative advantage. Thus rice development strategies are inefficient in achieving national production targets and food security objectives. Hence, the existing national policies on rice sector should be revised to focus on improving the quality of domestic rice production and promoting diversification of the agricultural sector into more profitable enterprises. As a member of both the ASEAN and Trans-Pacific Trade Partnership, Malaysia has agreed to lower rice import barriers and will need to adopt policies which improve rice quality to sustain current production levels but also promote diversification of the agricultural sector into other commodities where it has a competitive advantage.

Trans-Pacific Partnership: What Can It Mean for the Global and U.S. Rice Markets?

Durand-Morat, A. and Wailes, E.

Negotiations on the Trans-Pacific Partnership (TPP) concluded on October 2015 after more than 5 years of intensive negotiations. The fate of TPP pended on reaching an agreeable deal on a few key sectors among developed country members, including rice, and it is expected that agricultural interests will continue to play an important role in the legitimization of TPP, primarily in Japan and the U.S.

Most TPP partners grant low protection to their rice markets and therefore generate minimal trade distortions. For instance, Australia, Brunei, Canada, New Zealand, and Singapore maintain zero import tariffs, while Chile, the U.S., and Vietnam apply low import tariffs (all below 10%). Mexico maintains a MFN import tariff of 9% on paddy rice and 20% on brown and milled rice, but rice imports from the U.S. are duty free under NAFTA. Malaysia maintains a MFN import duty of 40%, but grants a 50% preference to Vietnam under ATIGA. Peru maintains a price band system with an associated specific duty that can reach high levels if the reference world price falls largely below the lower bound. Japan has historically maintained high market prices and rice farm incomes through trade protection, income support programs, and domestic diversion programs.

Using RiceFlow, a partial spatial equilibrium model of the global rice economy, we dynamically assess the impact of the negotiated rice market access outcome and the initial market access ambitions of the U.S. rice sector regarding access to the Japanese market. We also analyze the impact of the rice policy reforms being advanced in Japan. The model is calibrated to calendar year 2013.

The results suggest that the extent of the impact of TPP on the rice market depends greatly on the concessions granted by Japan. The scenarios considered in this study suggest TPP will have a marginal aggregate impact on global rice supply, demand, and trade. Even for the TPP region, the agreement will have marginal impact on aggregate rice supply and demand.

The TPP agreement is expected to boost intra-TPP trade significantly. The U.S. stands to gain the most out of the concessions granted by Japan, assuming that it can accommodate the increasing demand, overcome some environmental limitations currently constraining the production of rice in California, and advance in the development of Calrose-quality medium grain varieties suitable for the Mid-South.

Vietnam stands to expand exports to Malaysia at the expense of non-TPP Asian suppliers. Stakeholders from rice industries in Chile, Mexico, and Peru have raised awareness about the potential surge of imports from Vietnam as a result of TPP, but we find no evidence of such an effect in recent trade history. Quality is likely the main constraint facing Vietnamese rice in the Western Hemisphere markets participating in TPP.

Abstracts of Posters on Economics and Marketing
Panel Chair: Michael Salassi

Economic Evaluation of Flexible Rice Rental Rates on Producer Net Return Risk

Salassi, M., Deliberto, M., and Abderrahmane, A.

With the passage of the 2014 Farm Bill and the elimination of fixed direct payments to rice farming operations, the expected financial performance of rice production in Louisiana will certainly be altered. Direct payments to rice farms, whose value has been capitalized into land values and rental rates over time, no longer exist. A central question being asked by both rice tenant producers and rice land owners is: How will the loss of direct program payments impact the financial performance of rice production in Louisiana and how should equitable rice rental arrangements, both cash and share arrangements, adjust to reflect this change in expected farm program income support. The general objective of this research is to investigate potential changes in equitable rice rental arrangements expected in reaction to the passage of new farm program income support provisions of the Agricultural Act of 2014 and to evaluate the potential impacts on grower net returns and income risk.

Alternative typical crop land rental arrangements associated with rice production were specified for evaluation and analysis. More specifically, these rice rental arrangements were evaluated under participation in the PLC program to estimate comparable grower and landlord net returns under each rental agreement. Three equitable cash rental arrangements (fixed dollar, fixed price, and fixed yield) were specified along with three equitable share rental arrangements (60/40, 70/30, and 80/20). Stochastic models were developed to estimate distributions of grower net returns above variable production costs with participation in the PLC Program under alternative rental arrangements. Flexible rental rates were included to allow for fixed rates under each type of rental arrangement to adjust to specified levels in situations where market price and/or harvest yield of rough rice fell below specified trigger levels. Mean-variance analysis along with stochastic efficiency with respect to a function were utilized in evaluating net return simulation results. Results indicated that the use of flexible rental arrangements for rice production can be successful in mitigating net income risk to producers associated with occurrences of low market prices and/or harvest yields for both cash and share rental arrangements.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Ming-Hsuan Chen

Novel Strategies for Capturing Blueberry Phytochemicals in Rice Products and Co-Products

Boue, S.M., Daigle, K., Beaulieu, J.C., Patindol, J., and Heiman, M.

Consumption of phytochemical-rich plant foods is associated with lowered risk of several diseases, including diabetes, cardiovascular disease and certain cancers. Several studies have confirmed that blueberries contain high antioxidant activity mainly due to the high concentrations of anthocyanins. Blueberry juice processing generates waste by-products, consisting of seeds, stems, and skins that are all part of the presscake residue that are a rich source of anthocyanins. The USDA recommends consumption of at least five servings of fruits and vegetables per day, however surveys have indicated that over 50% of the population have not achieved this objective. New strategies to incorporate healthy phytochemicals into diets are thus needed to increase consumption of health-promoting polyphenols, particularly blueberry anthocyanins from both juice and presscake waste. Rice co-products (flour and bran) contain proteins that can noncovalently bind with phenolic compounds. Additionally, porous rice starch and flour have the ability to encapsulate phenolics. The objectives of this study were to develop methods to complex and encapsulate blueberry phytochemicals utilizing several rice materials and determine their storage stability.

Cypress rice bran and flour (white and brown) were used in this study. Porous rice flour and starch were prepared from rice flour (Remyflo R7-150) and starch (Remy B7). Both blueberry juice and presscake extracts were utilized. Tifblue blueberries were pressed to generate juice. The presscake was washed with water, filtered, and lyophilized before extraction. Presscake was extracted using water containing citric acid for rice flour and bran sorption, and 100% ethanol at 60ºC for 3h for porous starch and flour encapsulation. Rice bran and flour were mixed with juice and presscake extracts at varying ratios for 10 minutes at RT. Samples were then filtered and lyophilized. Colorimetric assays were utilized to determine total phenolic and anthocyanin contents. Storage stability was conducted at 37ºC.

Rice bran displayed higher phenolic and anthocyanin content when compared to rice flour samples. Also, porous starch and flour had higher phenolic and anthocyanin content when compared to normal rice starch and flour. Enhanced storage stability was observed when analyzing phenolic and anthocyanin content of stored rice blueberry samples compared to extracted blueberry controls.

Sources and Ramifications of Rice Kernel Size Differences

Counce, P.A. and Siebenmorgen, T.J.

Rice grain yield is determined by the number of grains per unit area which in turn in controlled largely by grains per panicle. Rice grain quality is determined by both the nature of kernels themselves but also by the variation of kernel size within rice lots. Rice lots with less kernel size variation produce greater head rice yield than lots with more variable kernel sizes. Kernel thickness, in particular, is the most important dimension of kernel size variability within a lot. The source of this kernel to kernel variation could possibly arise from several sources including variation in emergence in the field, variation among tillers and variation within panicles. Even in uniform fields there is kernel size variation and our previous work found variation among tillers for kernel size was usually relatively minor. A number of scientists have reported large kernel size, weight and quality variation within rice panicles. The reported kernel differences within rice panicles is sufficient to explain kernel variation in rice lots. Data from field studies to support this are lacking.

We conducted a two year field study to compare several characteristics of rice panicles and kernel variation as they relate to rice grain yield and to quality. Three cultivars (Cypress, LaGrue and RoyJ) were common in each experiment. Field plots were arranged in randomized complete blocks. Rice development was followed on the selected panicles in each field plot from R3 through R9. When each monitored panicle reached R9, that panicle was harvested and the grain from upper and lower panicle halves was counted and weighed (after moisture equilibration).. In addition, the plots were harvested for yield and milling quality determined at near-optimum grain moisture.

The grain size variation within panicles appears to be the major source of kernel size variation within rice lots. Head rice yields were correlated to individual kernel weights on the lower halves of panicles but not to those on the upper halves. As the number of grains per panicle increased, size variability increased in many cases. Since increasing rice grain yields is largely dependent on increasing the grain number per panicle, breeding to decrease size variation seems impractical. This is because the premium for marginally better quality rice is less than the value derived from increased yields from higher yielding cultivars with more grains per panicle. Moreover, the inherent differences can likely not be completely eliminated regardless of the yield. One solution to the problem for millers would be to sort rice lots by kernel size fractions so that the different size fractions can be milled separately. This solution could greatly improve rice quality in many cases, particularly for milled rice customers with high quality requirements.

Is There Variation in Resistant Starch Concentration among High Amylose Rice Varieties?

Chen, M.-H. and McClung, A.M.

Resistant starch (RS) is 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. RS in food lowers postprandial glucose concentration and has potential in prevention of colon cancer and inflammatory bowel disease. Increasing RS in rice may improve or lower its glycemic index and promote colon health. Rice is consumed after cooking and the majority of RS in rice comes from retrograded amylose forming ordered crystalline regions during cooling of gelatinized starch. Previous studies have utilized rice varieties with amylose concentrations ranging from waxy (0% amylose) to high amylose and showed that RS concentration was positively correlated with amylose concentration. The objective of this research was to determine the variation in RS concentration among just high amylose rice varieties that were collected from diverse origins.

Forty high amylose rice varieties were selected from two rice germplasm collections. One is the Rice Diversity Panel 1 consisting of 421 varieties collected from 10 geographic regions where rice is grown. The other one is the USDA Core collection consisting of 1790 entries from 114 countries. Because amylose concentration is affected by the growing environment, for the first round of selection high amylose varieties were identified based on genetics using alleles associated with the *Waxy* gene including the RM190 SSR marker and alleles of the intron 1 and exon 6 SNP markers that predict high amylose rice. Combined with previous phenotypic data, forty varieties that had the highest amylose concentration were selected and grown in Stuttgart, AR in 2014 and 2015. Three US cultivars, Bengal (low amylose), Presidio (intermediate amylose) and Dixiebelle (high amylose) were also grown for comparison. The milled rice was cooked at 1:2 (w/v) rice to water ratio for a total of 20 min (3 min for water inside the beaker to start boiling and then additional 17 min to cook the rice). The 17 min cooking time was the minimum cooking time necessary for both Presidio and commercially purchased long grain from AR. The percent fully cooked rice kernels, which was defined as having fully cooked centers with no opaque area, was determined by compressing 10 cooked kernels under glass and observing visually. The RS was determined based on the *in vitro* method of AACC 32.40. The RS concentration obtained using this method has been shown to be very similar to RS collected from an ileostomy, *in vivo*.

A 2.3-fold difference in RS concentration was found among the 40 varieties. Thirty-four of the 40 varieties had higher RS concentration than Dixiebelle. There was no correlation between % fully cooked kernels and RS concentration suggesting the high RS concentration was not due to under- cooked rice that contained non-gelatinized starch, which is not digestible. In both years, RS concentration was positively correlated with amylose concentration. It is well known that there is a difference in cooked rice texture among high amylose rice varieties that can be distinguished by the RVA parameter, Setback from Trough (SB) viscosity, and is genetically controlled by a functional SNP in exon 10 of the *Waxy* gene. Among these 40 varieties plus Dixiebelle, 18 varieties were high-SB genotypes and 23 were low-SB genotypes. Mean comparison showed that the SB phenotype was significantly different between the high-SB and low-SB genotypes; while there was no significant difference in RS concentration between the two. Therefore, high RS rice can be selected for the cooked rice texture that best suits consumer's preference. In conclusion, we identified rice varieties with higher RS than typical US high amylose cultivars that might improve health of the consumer.

Influence of Resistant Starch and Slowly Digestible Starch on Rice Texture

Bett-Garber, K.L., Lea, J.M., Watson, M.A., McClung, A.M., and Chen, M.-H.

Rice, comprised mainly of starch, serves as a significant source of caloric energy world-wide, therefore differences in starch digestibility are important to human health. Rice starch consists of three forms based on digestibility, rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). With the increasing incidence of diabetes, there is interest in developing rice varieties which have less rapidly digestible starch, however it is unclear if that would impact palatability. The objective of this study was to assess the association of rice starch digestibility with cooked rice texture. Seven rice cultivars that differed in starch composition were milled, cooked, and presented to a descriptive panel for evaluation of 14 texture attributes. In addition, apparent amylose (AA) content and rapid visco analyzer viscosities (RVA) were determined. Principal component (PC) analysis was used to discover relationships between rice starch composition, texture attributes and physicochemical properties.

Among the varieties, eleven of the texture attributes were significantly affected by resistant starch content. Eight of those attributes were different based on slowly digestible starch content. Greater contents of resistant starch caused the cooked rice to be harder, more springy, have greater intactness of chewed particles, required greater number of chews prior to swallowing, and have greater amounts of residual particles after swallowing. In contrast, greater contents of rapidly digestible starch caused the cooked rice to have more initial starchy coating, more surface slickness, to be more sticky, have a more uniform bite, and be more cohesive during mastication.

The apparent amylose content impacted the results, but the unexplained nuances were elucidated by the interactions of three starch fractions. PC analysis of texture attributes and starch fractions resulted in three PC's explaining 92.3% of the variance. PC1 (75.2%) was explained by apparent amylose content. PC2 (9.95%) was explained by the resistant starch content. PC3 (7.01%) was explained by slowly digestible starch content. PC analysis on RVA viscosities and starch fractions resulted in the three PC's explaining 87.6% of variance. PC1 (49.1%) was explained by apparent amylose content, while PC2 (27.3%) was explained by resistant starch. PC3 (10.8%) was explained by slowly digestible starch content. These results demonstrate that in addition to apparent amylose content the starch fractions influence the cooked texture.

Preserving Rice Quality: Fine-Mapping and Introgressing a Fissure Resistance Locus

Sater, H.M., Moldenhauer, K.A., Pinson, S.R.M., Siebenmorgen, T.J., Boyett, V.A., Mason, R.E., and Grunden, E.

Rice (*Oryza sativa L.*) kernel fissuring is a major concern of both rice producers and millers. Fissures are small cracks in rice kernels that increase breakage among kernels when transported or milled, which decrease the value of processed rice. This study employed molecular gene tagging methods to fine-map a fissure resistance (FR) locus found in 'Cybonnet', a semidwarf tropical *japonica* cultivar, as well as transfer this trait to rice genotypes of taller, non-semidwarf plant height that are better adapted to some rice production systems. Three QTLs for FR were previously reported; the FR locus with strongest effect resides near the semidwarf *sd-1* locus on the long arm of chromosome 1, explaining associations observed between increased FR and reduced plant height. This study began with F2 progeny from a cross between a U.S. inbred breeding line with standard height (*Sd1Sd1*) and high kernel breakage upon milling, and Cybonnet, which is semidwarf (*sd1sd1*) and noted for having improved milling quality due to increased FR. Simple sequence repeat (SSR) molecular markers were used to select ten F2 progeny plants that retained at least one copy of the *Sd1* allele but also contained evidence of genetic recombination in the region of chromosome 1 known to contain *Sd1* and *qFIS1-2*, so that the position of *qFIS1*-2 relative to *Sd1* could be determined more precisely, and so that the FR allele could be recombined with the *Sd1* allele . Three of the ten selected plants were also homozygous at the two known FR QTLs that are not closely linked to *sd1;* another four plants were homozygous at one but not both of the two additional FR loci. The F2:3 progeny generated were genotyped prior to being phenotyped; only individuals homozygous for the new recombination underwent laborious evaluation for FR. Progeny from four of ten populations have been phenotyped. Marker-trait linkages observed in the first two populations indicated that *qFIS1-2* resides distal to RM1068. Research efforts were then focused on just those populations whose recombination points were distal to RM1068 (i.e., at a base pair location higher 1:38439184). Results from the four populations observed to date indicate that the *qFIS1-2* locus resides distal to RM1068 at 1:38439184 but anterior to RM3482 at 1: 39720039, or approximately 6 to 10 cM distal to *sd-1* on chromosome 1. The recombination documented in this study verifies that the previously identified *qFIS1-2* is linked to but not pleiotropic with *sd1* and thus can be recombined with *Sd1* during introgression breeding to increase the FR of rice cultivars having standard height.

Rice Fissure Resistance QTLs from 'Saber' Complement Those from 'Cypress'

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

The economic value of broken rice is about half that of whole milled rice, so one goal of producers, millers, and rice breeders is to reduce grain breakage during the dehusking and milling processes. One of the primary causes of rice breakage is fissuring, or cracking, of the rice before it enters the mill. A common cause of rice fissuring is the exposure of drying, mature kernels to humid field or postharvest conditions that cause the kernels to reabsorb moisture. Fissures may be caused by rain or dew in not-yet-harvested fields. A few rice varieties produce grain more resistant to fissuring than others, and breeders would like to incorporate these genes into improved rice varieties. Unfortunately, evaluating numerous breeding lines for fissure resistance is laborious even if the laboratory evaluation method is used, and the environment in which the seed samples were produced can impact results. Use of molecular gene-tags to accomplish marker-assisted selections (MAS) is particularly desired by breeders for traits such as kernel fissure resistance which are both costly/laborious to measure and environmentally sensitive.

Three QTLs for rice kernel fissure resistance (FisR) were previously discovered using selectively genotyped 'Cypress' x 'LaGrue' F_2 progeny, and verified in a set of 'Cybonnet' x 'Saber' recombinant inbred lines (CbSa-RILs). Association between plant height and FisR was first detected among the Cypress x LaGrue F_2 progeny, and later shown to be due to close linkage between a FisR QTL and the *sd-1* semidwarf locus on the long arm of chromosome 1. A second FisR QTL mapped also to chromosome 1, but was not closely linked (> 50 cM distant) to *sd-1*. The third FisR QTL mapped to the short arm of chromosome 8. Cybonnet is another FisR cultivar, and its sole FisR parent was Cypress. The same three FisR QTLs originally identified in Cypress were confirmed in the CbSa-RILs, with the FisR alleles now attributed to Cybonnet. The CbSa-RILs, being pure breeding, also provided improved FisR phenotypic data due to replication across years and locations (2 replications each for TX2007, AR2007, TX2009, and TX2011). The three FisR QTLs were initially discovered using selective genotyping, where the population was first phenotyped and only progeny exhibiting extreme phenotypes were molecularly genotyped. Marker-trait linkages were detected as unequal distribution of molecular alleles between the phenotypically divergent groups. Selective genotyping resulted in identification of nine CbSa-RILs that were consistently more FisR than Saber and Cybonnet. While the high FisR of three of these RILs could be explained by their containing all three FisR alleles originally identified from Cypress, the other six FisR RILs contained 2, 1, or even 0 of the known Cypress FisR alleles. Saber is also known to be FisR, and a likely source of FisR alleles yet to be mapped in the CbSa-RILs.

To better identify all FisR QTLs segregating among the CbSa-RILs, we needed to collect molecular marker data tagging the whole length of the 12 rice chromosomes. For this, we used a SNP chip designed to identify polymorphisms between *japonica* genotypes. Of the 384 SNPs, 28 proved noninformative due to both parents being either null or heterozygous at that locus, 212 were polymorphic, and clustering among the 144 monomorphic SNPs suggested several genomic regions to be identical by descent between Cybonnet and Saber, which are known to share ancestors. The QTL regions previously identified on chromosomes 1 and 8 were further saturated with the addition of 20 SSR loci. QTL mapping among the 286 CbSa-RILs confirmed the existence of three FisR alleles originating from Cypress, two on chromosome 1, and one on chromosome 8. Even though the CbSa-RILs were all of semidwarf plant height, they showed linkage between markers linked to *sd-1* and FisR. This finding clarified that a FisR gene is linked to but not pleiotropic with the *sd-1* locus. The FisR QTLs contributed by Cybonnet (and originating from Cypress) were all of higher confidence (LOD score) and had larger phenotypic effect than the two that originated from Saber, which mapped to chromosomes 5 and 12. A grain thickness QTL was also found co-located with the FisR QTL on chromosome 12. However, shape does not appear to be a large driving factor of FisR in that the largest QTLs found for each of the three grain dimensions (length, width and thickness) were not associated with variance for FisR in these long grain crosses. The markers we identified as linked to the FisR genes from Cypress, Cybonnet and Saber can be used by breeders to improve the incorporation and stacking of these FisR alleles into improved U.S. rice varieties via MAS.

Identification of Genes and Physiological Factors that Reduce Accumulation of Arsenic in Rice Grain

Pinson, S.R.M., Heuschele, D.J., Salt, D.E., Smith, A., and Tarpley, L.

The arsenic (As) levels in rice grains and food products can reach toxic levels when produced under certain growing conditions. The World Health Organization (WHO) recently set a CODEX limit of 0.2 ppm inorganic As in milled white rice, and lower limits may be set for baby food products. While studies have shown that sufficient genetic variation for grain-As exists to support breeding efforts, it is not known what biochemical and physiological mechanisms are used by these rice cultivars to limit the accumulation of As in their grains. Possibilities include reduced As-uptake by roots, reduced transfer from roots to shoots, and increased sequestration in roots or leaves rendering the As immobilized in plant tissues and unable to enter grains. The present study aimed at identifying genes and physiological mechanisms that can be used to develop cultivars that limit the concentration of As in their rice grains.

The *c.* 1800 rice accessions in the USDA Core collection, originating from 114 countries, were in a replicated field study that included both flooded and unflooded (aerated) plots. A 200-fold difference was observed for concentration of total-As in the grain; grain-As was 10x higher under flooded conditions than unflooded. Under flooded conditions, accessions in the *indica* ancestral lineage showed higher grain-As concentrations than in tropical *japonicas;* lower yet were the temperate *japonicas.* Within each ancestral group, mean and maximum grain-As were lower among early maturing accessions than among later maturing accessions. 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.

Across the range in heading time among the USDA Core accessions (50 – 130 days), accessions that accumulated significantly higher-than-average grain-As (aka "grain-accumulators") and others with significantly lower grain-As (aka "grain-excluders") concentrations were identified. A set of 16 rice accessions (8 grain-accumulators and 8 excluders, including 'Lemont' and 'Jefferson') were selected from among the USDA Core accessions, and grown in soil amended with arsenic (monosodium methyl arsenate herbicide, MSMA) as well as in native or non-amended flooded field plots. Application of MSMA has been used for decades to select rice cultivars resistant to As-induced straighthead disease. Association was found between grain-As and straighthead response, with none of the grain-As accumulators being resistant to straighthead. Reduced As uptake and/or increased As detoxification (e.g. sequestration) in vegetative tissues might be contributing to both straighthead resistance and grain-As exclusion. Only accessions resistant to straighthead set seed in the As-amended plots; both leaf-As and, grain-As concentrations were higher when grown in As-amended soil than in native soil. Seven of the 8 grain-accumulators had higher As concentrations in their flag leaves before grain fill than at grain maturity, consistent with As being translocated out of their flag leaves during grain fill. In contrast, all 8 of the grain-excluders continued to accumulate As in their flag leaves during grain fill, suggesting that sequestration of As in leaves contributes to grain-exclusion.

To identify and study the genes that control grain-As, grain-excluders were crossed with grain-accumulators to create 15 different segregating progeny populations. Mendelian segregation patterns (i.e. 1:2:1 or 3:1) of concentration of total As in grain among F_2 progeny, indicative of single major-gene control of grain-exclusion of As, were seen in five F_2 populations, three of which have been selectively genotyped to date. Interestingly, although increased grain arsenic was associated with later maturity among the numerous divergent USDA Core accessions, in contrast, all three F_2 populations found to segregate for a single major gene affecting grain-As show early maturity to be associated with increased grain-As. Marker-trait associations observed in two populations indicate the presence of a grain-As locus on the short arm of chromosome 11; data from the third population points to a different locus, on the long arm of chromosome 10. Selective genotyping allows genes to be mapped to chromosomal regions using a subset of phenotypically extreme progeny. The reduced population size reduces genotyping costs, but does not support fine-mapping of genes. Fine-mapping of the grain-As genes is now being pursued among the F_3 progeny, during which association between grain-As and sequestration/translocation of flag leaf-As will also be validated.

Differences in How Rice Plants Process Arsenic in Their Cells

Heuschele, D.J., Pinson, S.R. M., and Smith, A.

Arsenic (As), a carcinogenic heavy metal, is a problem in some drinking water and staple food supplies around the world. Rice plants readily uptake arsenic and transport a portion of it into the grain. Arsenic is also toxic to plants; therefore mechanisms that reduce toxicity or accumulation have evolved. Plants, such as rice, may regulate uptake, transport, sequestration/tolerance or a combination of all three to prevent toxic effects of heavy metals. A previous study of 1700 international accessions found some rice lines with high As concentrations in their grain (a.k.a. "grain-accumulators") and others with low concentrations of As in their grain (a.k.a. "grain-excluders"). This study investigated which physiological responses, uptake, transport, or sequestration/ tolerance explained the grain As concentration difference of these two groups.

Rice seedlings of six varieties, 3 grain-accumulators and 3 grain-excluders from the above noted study, were grown hydroponically to V-3 then exposed to 12.5 ppm As^{III} for 0, 24, 48 and 72 hours. Rice root and leaf tissues were sampled for As concentrations and key products known to be involved in tolerance and sequestration pathways for other heavy metals within plants. Arsenic uptake and transport rates between tissue types were similar for grain-accumulators and grain-excluders, therefore uptake and transport do not explain the difference between the two groups. In general however, grain-accumulators died more rapidly from As-exposure suggesting that As-tolerance or sequestration may have an important role in determining grain-As concentrations.

Heavy metal tolerance and sequestration both use the same key metabolic compound, glutathione (GSH). GSH is utilized differently depending which type of mechanism is activated. In heavy metal tolerance, GSH aids in the breakdown of toxic secondary compounds such as reactive oxygen species (ROS) and methylglyoxal (MG), whereas in As-sequestration, GSH either directly binds to As or forms phytochelates (PC) that bind to As for transport to the vacuole or outside of the cell. In order to differentiate between As-tolerance and As-sequestration, we measured the key products within each pathway: ascorbic acid (AsA), lactic acid (LA), glutathione (GSH), cysteine (used in GSH production), and four types of PC. AsA and LA concentrations, key products in As-tolerance, did not differ between the groups suggesting that As-tolerance is not the process that distinguishes the grain-accumulators from grain-excluders. However, AsA concentrations in both groups did reduce over time suggesting that ROS produced from initial As toxicity are being neutralized via the breakdown of AsA, but AsA is not being recycled. Lactic acid increased in one variety indicating that MG metabolism, another mechanism of heavy metal tolerance, occurs in rice in response to As stress. This is one of the first times As activation of MG metabolism has been documented in rice. Leaf GSH concentrations were significantly different between grain-accumulators and grain-excluders. Grain-accumulators had more GSH than grain-excluders, but the levels remained the same over time, while grain excluders increased in GSH over time. GSH can neutralize ROS like AsA and the increasing concentration of GSH found over time alone does not differentiate between tolerance and sequestration.

Preliminary data indicates PC synthesis is also significantly different for grain-accumulators and grain- excluders. While PC are being produced in both groups, grain-excluders appear to continually increase the production of specific types of PC, whereas grain- accumulators have an initial increase without continued production. Our results suggest that grain-excluders are utilizing AsA and GSH to implement As-tolerance and substantial As-sequestration, unlike grain-accumulators which are employing mainly As-tolerance. Activation of both tolerance and sequestration pathways allows grain-excluders to survive longer before becoming overwhelmed by high As concentrations. Activation of As sequestration only among the grain-excluders suggests that As sequestration is likely also preventing larger amounts of free-As from being transported to grains in field-grown plants.

Rapid Inexpensive Analysis of Inorganic Arsenic in Rice Grain

Chaney, R.L., Green, C.E., and Poet, A.

Rice grain contains inorganic arsenic (iAs) which is now regulated in international rice commerce and may become regulated in US foods. The present US-FDA method for analysis of iAs in rice involves an extraction with dilute nitric acid and heat, followed by High Pressure Liquid Chromatography (HPLC) to separate the As species, and then measurement by inductively coupled plasma (ICP) mass spectrometry (MS). This method is slow (15-20 min/sample), costs between $200 and $350 per sample, and uses very expensive analytical instruments which require highly trained operators to operate and maintain. Thus a simple and less expensive method for analysis of iAs in finely ground rice grain is needed to support the rice industry needs for compliance with iAs limits.

A simpler method was published by Pétursdóttir et al. (2014) which uses simple hydride generation (HG) of arsine gas and analysis of the As in the arsine by several methods. By increasing the concentration of HCl in the HG system, any dimethylarsinic acid (DMA, the major organic form of As in rice) was nearly totally rejected in the analysis of iAs. We examined the carry over of DMA-As into the HG-ICP-Atomic Emission Spectroscopy (AES) measured iAs from the NIST Rice standard (1568b) and other in-house rice samples to check the reliability of the new method. Digests of rice samples were spiked with a range of DMA levels before the dilute nitric acid extraction step (FDA extraction method) in order to examine the carry over of DMA-As into the HG-ICP-AES measured iAs. We selected 4 M HCl in the final pre-reduced sample solution as the HCl level to obtain maximum rejection of DMA yet protect the equipment from unnecessary HCl exposure.

Because this HG-iAs analysis requires only a normal ICP-atomic emission spectrometer (AES), the equipment cost and staff training needed to operate and maintain the analysis equipment is much lower than the FDA HPLC-ICP-MS method. Alternatively, atomic absorption spectrometry (AAS), atomic fluorescence spectrometry (AFS) or ICP-MS could be used to make the iAs analysis following Hydride Generation of arsine from the prepared samples. The practical detection limit using commercially available HG equipment is about 20 ug/kg dry rice, and lower detection limits can be achieved by using ICP-MS to measure the arsine-As, or alternative HG equipment with less dilution) of the arsine produced during HG.

Although we cannot supply a full cost estimate because amortization, lab space costs, and equipment used costs vary among laboratories, it is clear that the lower staff training required to use and maintain the ICP-AES than ICP-MS in As analysis, and the variability introduced by HPLC separation rather than direct HG analysis, make this simple iAs analysis method for finely ground brown or milled rice an advance needed by the rice industry.

Influence of Infrared and Conventional Drying Methods on Physicochemical Characteristics of Stored Rice

Ding, C., Khir, R., and Pan, Z.

Our consecutive studies have proved that high moisture diffusivity corresponding to high drying rate for rough rice can be achieved by using infrared (IR) drying. Simultaneously, effective disinfestation, disinfection and stabilization have also been achieved without compromising milling quality. As the result, extended shelf life of both rough and brown rice were achieved. Through this present study the impact of infrared and conventional drying methods on physicochemical properties of rough, brown and white rice was investigated. Samples of freshly harvested medium grain rice variety M206 with initial moisture content of 25.03 ± 0.21 % (d.b.) were used. They were dried using IR, hot air at 43 °C, and ambient air for comparison. For IR drying, rice samples were heated to a temperature of 60 °C under radiation intensity of 4685 W/m^2, followed by 4 h tempering and natural cooling. Each dried rice sample was divided into three portions and respectively used as rough, brown and white rice for the storage study. These samples were then stored at 35.0±1.0 ºC and relative humidity of 65.0±3.0 % for up to ten months. The physicochemical and cooking properties of rice samples were periodically determined over the storage duration. Yellowness index, water uptake and volume expansion ratio for rice dried with IR were significantly less than those of rice dried with ambient air. IR drying likely caused a slight denaturation of protein and annealing of starch that located on the surface layer of rice kernels, resulting in decreased gelatinization temperature, enthalpy, and viscosity, and reduced the changes in microstructure, but retained cooking characteristics after storage. Therefore, IR drying is recommended as a promising technique to achieve high drying efficiency and improved stability of physicochemical properties of rice during storage.

Economically Optimal Timing of Insect Control in Rice Mills: A Real Option Approach

Duan, S. and Adam, B.

Insect control is a concern for handlers of grain and grain-based products during storage, processing, and packing. Conventional structural fumigations can cause both unnecessary treatment costs and more rapid evolution of insect resistance to the fumigants. Meanwhile, consumers are increasingly concerned about insect-free and pesticide-free food products. Food producers and processers face a challenge to effectively control insects with judicious use of chemicals. Manager of food processing facilities, including rice mills, face the dilemma that postponing a treatment (such as fumigation) in order to save money risks allowing an insect population to increase to the point of causing economic damage. This damage includes buyer discounts due to presence of insects or insect damage, cost of extra treatments needed, or rejection by a buyer. Estimating these costs is difficult because insect populations and potential damage are difficult to predict, and although the probabilities of catastrophic costs from insects (e.g. recalls) are low, the costs are high. Conversely, fumigating too early may allow the remaining insect population to rebound sufficiently that another expensive fumigation is necessary earlier than it would have been. Managers need economic guidelines to make insect control decisions that fully consider treatment costs, effectiveness, and costs of failing to control insects.

This study values the tradeoff between fumigating now and fumigating later using a real option approach, which measures the risk tradeoff in money terms by using financial option theory, modeling the decision much like a call option in financial markets is valued. Specifically, we consider a mill manager who faces a timing decision to shut down the whole facility for fumigation. The result will identify a “trigger value”, or optimal time, to treat insects during the processing period. The approach can be easily expanded to value the risk/reward tradeoffs of alternative insect control strategies, including integrated pest management strategies that include sampling and monitoring, helping food processing firms make better insect control decisions. The results may be especially useful in helping managers understand the tradeoffs among the insect treatment choices they have.

An Integrated Web-Based Grain Pest Management System for On-Farm Storage and Rice Mills

Yang, Y., Wilson, L.T., Arthur, F.H., Mckay, T., Campbell, J.F., Adam, B., Beuzelin, J.M., and Wang, J.

Objectives: Red flour beetle, *Tribolium castaneum* Herbst, is a major pest in rice mills. The objectives of this study are to 1) Develop an integrated red flour beetle management system integrating population prediction, targeted surface pesticide treatment and sanitation, focused monitoring, and economic analysis, and 2) Identify the best combination of measures (surface treatment, sanitation, monitoring) to achieve optimal red flour beetle control.

Methods: The integrated system is based on our existing Post-Harvest Grain Management Program (http://beaumont.tamu.edu/GrainManagement), which is designed to develop strategies to optimize the control of lesser grain borer, *Rhyzopertha dominica* (Fabricius), and rice weevil, *Sitophilus oryzae* (L.), the two primary pests in storage rice. Major components of the red flour beetle population model include: 1) Development and survival of the red flour beetle as affected by temperature and relative humidity; 2) Adult reproduction as affected by temperature, relative humidity, adult age, and population density; 3) Adult and larval cannibalism as affected by adult and larval density; 4) Adult dispersal as affected by population density and environment conditions; and 5) Effects of different control measures on population survival. These components have been integrated into a generic distributed-delay population model that simulates red flour beetle population dynamics.

Results: The web-based interface is dynamically linked to site-specific weather data for prediction of grain temperature and moisture, and pest population dynamics in rice on-farm storage and milling facilities. It allows users to evaluate different management options and identify the best combination of measures to achieve optimal pest control.

Stored-Product Insect Flight Activity in and around Rice Mills

Campbell, J.

The community of stored-product insects can have a significant economic impact on the rice milling industry because of their ability to infest rough and milled rice and the milling by-product material that accumulates in structures and equipment where rice is processed. Monitoring is a critical component of an Integrated Pest Management program since it provides information on the species present and temporal and spatial patterns in their abundance and distribution. Monitoring information also provides feedback on the quality of the pest management program and helps with the targeting and evaluation of specific treatments. However, limited information is available on stored-product insect activity at rice mills. Here we present the results of multi-year monitoring programs at rice mills using pheromone baited traps to assess the temporal and spatial patterns of stored-product insect activity. Monitoring was conducted using two types of traps placed outside structures, in elevators storing rough rice, in mill structures, and in warehouses where milled rice was stored. Insects monitored included those that infest whole rough rice kernels [e.g., *Sitophilus oryzae*, the rice weevil; *Sitotroga cerealella*, the Angoumois grain moth; and *Rhyzopertha dominica*, the lesser grain borer] and those that primarily exploit partially and completely milled rice, milling by-products (hull, germ, bran, and broken kernels), and damaged rice kernels [e.g., *Tribolium castaneum*, the red flour beetle (Coleoptera: Tenebrionidae) and pyralid moths such as *Plodia interpunctella*, the Indianmeal moth]. Spatial and temporal patterns of insect activity were detected, with certain species tending to be found in specific areas of facilities even though they are capable of dispersal throughout a mill location. Monitoring results were also used to assess the impact of different treatments, to help identify areas that need targeting for treatment, and to identify important sources of infestation.

Stored-Product Insects Associated with Rice Spillage at Rice Mills

Mckay, T., Starkus, L., Campbell, J., and Arthur, F.

Rationale: The US is a major exporter of rice. Because the predominant market for rice is direct human consumption, as opposed to outlets such as livestock feed as with other non-wheat grains, the need to maintain product quality is essential for the US rice industry. We have been conducting research in integrated pest management at rice mills in Arkansas. The main insect target of our research is the red flour beetle, *Tribolium castaneum*, but we are also interested in all stored product insects that may contribute to infestations in stored rice and around rice milling facilities.

The spatial and temporal distributions of red flour beetles (RFB) in four rice mills in northeast Arkansas have been examined. RFBs are being monitored using pheromone-based dome traps baited with kairomone and placed inside the mills. Monitoring is also being conducted outside of the mills, including around storage bins, rice receiving areas, by-products storage and shipping. Previous research has shown that stored product insects can infest rice placed outside of rice mills. Research is needed to determine the role outside spillage plays as a source of insect immigration into rice processing facilities.

Methods: The extent of outside spillage accumulations around these facilities is currently being documented along with what insects exploit these spillage accumulations. We are currently in the process of analyzing spillage data collected over the summer of 2015.

Results: Preliminary data indicates that each facility is very different in the number of insects collected in these spillage accumulations. However, over the entire dataset, over 13 species of stored product insects used these spillage accumulations as refuge, including the RFB. Other species collected included the rice weevil (*Sitophilus oryzae*), rusty grain beetle (*Cryptolestes ferrugineus*), and hairy fungus beetle (*Typhaea stercorea*). Lepidopteran species, such as the Indianmeal moth (*Plodia interpunctella*) and Almond moth (*Cadra cautella*), and a few booklice (Psocoptera) were also collected.

During this study, we also noticed rice and other debris can accumulate under traps and within trap holders. Because it was observed that insects and other arthropods were using the traps as a refuge, we wanted to examine the insects associated with these small rice accumulations. We examined the diversity and abundance of insects under traps during the summer months. Each mill had a very different complex of insects under the traps. Rice debris at Mill 1 predominantly contained broad-nosed grain weevils (*Caulophilus oryzae*). Traps located near windows had the most stored product insects under traps. Booklice were also very abundant at Mill 2 within rough rice storage and broad-nosed grain weevils and hairy fungus beetles were abundant at Mill 3.

Particle Size and Aerosol Efficacy

Arthur, F. and Campbell, J.

Rationale: Aerosols are increasingly being used as an alternative to fumigants to control insects inside rice mills. Aerosol particle size will vary depending on the application equipment, the dispersal patterns, and the time after initial dispensation of aerosols. There is little published data regarding efficacy of aerosols at different particle sizes. This study was conducted to evaluate efficacy of aerosols applied at 2 and 16 microns.

Methods: This study was conducted at MRI Global, Kansas City, MO, using a specially designed chamber and equipment to precisely apply the aerosols at the desired particle sizes. Test insects were adults of the confused flour beetle, *Tribolium confusum* Jacqueline DuVal. Concrete exposure arenas were created in the bottom of a plastic Petri dish (62 cm^2). The insecticide was 1% active ingredient pyrethrin. Adult beetles were exposed for different time intervals at the two micron sizes, and knockdown was assessed upon removal from the chamber. Then, the beetles were either kept in the same arenas in which they were exposed, transferred to new untreated arenas with a flour food source, or transferred to clean untreated arenas. All arenas were then returned to a laboratory counter at the USDA-ARS Center for Grain and Animal Health Research, Manhattan, KS, where they were held at ambient conditions (about 25°C and 40% relative humidity). Recovery, knockdown, and mortality was then assessed daily.

Results: No beetles recovered from exposure to aerosol for 10 minutes at 16 microns when they were held in the same arenas in which they were exposed. There was recovery in the transfer arenas but as exposure interval increased to 30 minutes there was no recovery. In contrast, there was little knockdown of beetles at 2 microns even with a 90 minute exposure interval. The concentration was then increased by a factor of 4, and was in fact greater than the concentration at the 16 micron particle size. However, though knockdown was almost 100% all beetles eventually recovered. Particle size was much more important than concentration in conferring toxicity of the confused flour beetle to pyrethrin aerosol.

Residual Efficacy of Grain Protectants

Arthur, F.

Rationale: The insect growth regulator methoprene was re-introduced to the grain market in 2002 as s-methoprene (Diacon® II), with application rates of either, 1, 2.5, or 5.0 ppm. The label was amended in 2012 at new rates of 1.25 or 2.5 ppm (Diacon® IGR). This study was conducted to evaluate methoprene for long-term protection on rough rice and brown rice.

Methods: Four replicate 11-kg lots of brown rice and rough rice, along with untreated controls, were treated at the application rates of 1.25 and 2.5 ppm. Each individual lot was held in a 19 L capacity plastic bucket and these buckets were held on the floor of a 27 metric ton grain bin on the grounds of the USDA-ARS-Center for Grain and Animal Health Research, Manhattan, KS. One day after treatment, and at every two months for twelve months, approximately 80 g from each rice type and replicate was placed in each of two vials. Ten mixed sex adult lesser grain borers, *Rhyzopertha dominica* (Fauvel), and ten newly-emerged mixed sex adult Angoumois grain moth, *Sitotroga cerealella* (Oliver) were placed in the other vial. These vials were held in a growth chamber set at 27°C-60% relative humidity, 16:8 hour light-dark cycle, for 3 months. At this time, the rice in the vials was weighed, the progeny adults sieved and counted, and assessments were made of weight loss, feeding damage and insect damaged kernels.

Results: Methoprene suppressed lesser grain borer progeny production on brown rice and rough rice for the 2-year storage period. There was some progeny production of Angoumois grain moth, and also insect damaged kernels, on treated brown rice and rough rice but far less than what occurred in the untreated controls. There were little differences between the two rates.

Improving Drying Efficiency and Safety of Rough Rice Using Pulsed Light Technology

Bei, W., Khir, R., and Pan, Z.

Contaminated rough rice is a potential hazardous source for human consumption or workers handling the grain during post-harvest processing and storage. Pulsed light (PL) technology has been proven effective in food decontamination. Increasing the light intensity or treatment time could swiftly increase the temperature of food products. Using the thermal effect in an appropriate way may achieve simultaneous drying, disinfection and detoxification for rough rice. The objective of this study was to investigate the feasibility of simultaneous disinfection, drying and detoxification of rough rice using PL and holding treatment. Freshly harvested rice samples were inoculated by *A. flavus* to produce aflatoxin B_1 (AFB_1) and B_2 (AFB_2) contamination and treated using PL under different intensities and durations followed by holding treatment at 60ºC. After PL treatment, the colonies of *A. flavus* spores, moisture removal, toxicity and mutagenic activity of the residual AFB_1 and AFB_2 in rough rice were evaluated. The PL treatment under intensity of 1.08 Wcm^{-2} for 21 s led to a reduction of 0.29 log cfu g^{-1} on the population size of *A. flavus* spores. After holding treatment for 240 min, a 5.2 log cfu g^{-1} reduction was achieved. The corresponding total moisture removal reached 3.3% points. A PL treatment intensity of 1.60 Wcm^{-2} and time of 80 s reduced AFB_1 and AFB_2 in rough rice by 75.0% and 39.2%, respectively; while a treatment time of 15 s reduced AFB_1 and AFB_2 in rice bran by 90.3% and 86.7%, respectively. The mutagenic activity of AFB_1 and AFB_2 was completely eliminated by PL treatment, while the toxicity of these two aflatoxins was significantly decreased. No adverse effect on milling quality was detected after the treatment. It is concluded that the combined PL and holding treatment can achieve disinfection, drying and aflatoxin degradation for rough rice.

The Value of Waiting to Treat: A Real Option Approach to Timing Insect Control in Rice Mills

Duan, S.

Insect control is a concern for handlers of grain and grain-based products during storage, processing, and packing. Conventional structural fumigations can cause both unnecessary treatment costs and more rapid evolution of insect resistance to the fumigants. Meanwhile, consumers are increasingly concerned about insect-free and pesticide-free food products. Food producers and processers face a challenge to effectively control insects with judicious use of chemicals. Manager of food processing facilities, including rice mills, face the dilemma that postponing a treatment (such as fumigation) in order to save money risks allowing insect population to increase to the point of causing economic damage. This damage includes buyer discounts due to presence of insects or insect damage, cost of extra treatments needed, or rejection by a buyer. Estimating these costs is difficult because insect populations and potential damage are difficult to predict, and although the probabilities of catastrophic costs from insects (e.g. recalls) are low, the costs are high. Conversely, fumigating too early may allow the remaining insect population to rebound sufficiently that another expensive fumigation is necessary earlier than it would have been. Managers need economic guidelines to make insect control decisions that fully consider treatment costs, effectiveness, and costs of failing to control insects.

This study values the tradeoff between fumigating now and fumigating later using a real option approach, which measures the risk tradeoff in money terms by using financial option theory, modeling the decision much like a call option in financial markets is valued. Specifically, we consider a mill manager who faces a timing decision to shut down the whole facility for fumigation. The result will identify a “trigger value”, or optimal time, to treat insects during the processing period. The approach can be easily expanded to value the risk/reward tradeoffs of alternative insect control strategies, including integrated pest management strategies that include sampling and monitoring, helping food processing firms make better insect control decisions. The results may be especially useful in helping managers understand the tradeoffs among the insect treatment choices they have.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2018 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 2018 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 37th 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 37th RTWG meeting in 2018, or earlier as stated in the Call for Papers issued by the 37th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2018 RTWG meeting and their email and mailing addresses are presented following this section. In case of other questions or in the absence of being able to access the Call for Papers, contact:

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Agricultural Economics and Agribusiness
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2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
    a. Include a statement of rationale for the study.
    b. Briefly outline methods used.
    c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 37th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 37th 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 37th 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 2018 PANEL CHAIRS

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IN MEMORY OF

Robert “Bob” Cogburn

Robert “Bob” Cogburn died January 27, 2015, in Nacogdoches, TX, at the age of 79. Bob received a BS in biology from Texas A&M University and an MS in entomology from the same institution. Bob was a USDA-ARS entomologist specializing in stored insect pests of rice. He worked for many years at the USDA-ARS Rice Research Unit/Texas A&M AgriLife Research and Extension Center at Beaumont, TX, from where he retired in 1995. Bob published over 40 scientific articles on the biology and management of stored insect pests or rice, such as lesser grain borer, rice weevil, and flour beetles. Bob was responsible for identifying the factors associated with “speck back peck,” a quality issue facing the parboiling industry. He also discovered lesser grain borer infestations in stored rice could originate in the field prior to storage. Bob was active in the RTWG through 1994 and other rice regional projects for many years. Bob is survived by his lovely wife of 57 years, Laura, four children and several grandchildren. Bob loved to golf, fish and hunt. Bob will always be remembered for eloquent/thoughtful presentations, a great sense of humor, a hearty laugh and love of animals---especially Basset Hounds!

IN MEMORY OF

Julian Craigmiles

Dr. Julian Craigmiles died February 4, 2015, in Beaumont, TX. He was 94 years old and married to Mary for 67 years. Julian and Mary had three children, three grandchildren and five great-grandchildren. Dr. Craigmiles served as Resident Director of the Beaumont Center from 1964-1982; he directed rice research and extension activities, as well as conducted research on soybean production in SE Texas. Julian was largely responsible for developing soybean varieties and production practices adapted to SE Texas conditions. In 1982, Dr. Craigmiles received the RTWG's Distinguished Service Award. Prior to 1964, Dr. Craigmiles was a Professor and Head of Forage Crops at the University of Georgia Experiment Station at Tifton. He received BS and MS degrees from University of Georgia and a PhD degree from Cornell University. Dr. Craigmiles also served in the Marine Corps as a fighter pilot in WWII with over 100 missions to his credit. He was called up for duty again during the Korean Conflict where he flew the Banshee jet earning the rank of Colonel. After retiring from the Beaumont Center, Julian was hired by UCLA to conduct rice research in Egypt. Julian was a kind and gentle man with a good sense of humor. Although his duties at the Beaumont Center were mainly administrative, he spent as much time in the field as behind his desk.

IN MEMORY OF

Robert G. Fjellstrom

Dr. Bob Fjellstrom served as a Molecular Plant Geneticist with the USDA-ARS from 1998 to 2014. He spent most of his ARS career located at the Rice Research Unit in Beaumont, Texas, and then later was transferred to the Dale Bumpers National Rice Research Center in Stuttgart, Arkansas. Bob established the molecular genetics laboratory at the Beaumont location where he led the project in developing genetic markers linked to a wide variety of traits important to the U.S. rice breeding community, including grain cooking quality traits, milling yield, and blast and sheath blight disease resistances. His research has been documented in 40 journal publications and 85 research presentations, many of which were made at RTWG. He was very skilled at writing and could draft scientific manuscripts that required only minimal edits prior to acceptance by a journal. He was a participant in the Uniform Regional Rice Nursery, providing genetic marker assessment of elite breeding lines to the southern U.S. breeders. Bob helped to transfer this marker technology to over 17 U.S. and international labs in support of breeding programs. He was sought out as a collaborator on many research projects and was successful in helping to bring in over $6 million in extramural funds for rice research. During his relatively short career, he significantly impacted rice breeding methodology by helping to develop genetic markers as a routine selection tool for U.S. breeders. Even though he left a strong scientific legacy, he will be most remembered for his gentle spirit, keen wit, and devotion to his family.

IN MEMORY OF

Glenn Whitney

Dr. Glenn Whitney died at the age of 78 on November 30, 2014, in Franklin, TN. Glenn was a graduate of Texas A&M University and a rice pathologist with the Texas Agricultural Experiment Station located at the Texas A&M AgriLife Research and Extension Center at Beaumont. Glenn spent 25 years at this location where he evaluated fungicides and developed IPM programs for diseases attacking rice. In 1986, Glenn received *The Distinguished Rice Research and Education Team Award* from the RTWG for helping develop best management practices for the newly released semi-dwarf varieties. Glenn is survived by Martha, his loving wife of 57 years, and their two children, Kevin and Kelley (plus grandchildren and great grandchildren). Glenn was active in church (Forest Hills Baptist Church) where he sang in the choir. He also enjoyed golfing and other outdoor activities. Glenn's hearty laugh and sunny disposition are truly missed.

GUIDELINES FOR RTWG AWARDS

1.0 The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

1.1 The Distinguished Rice Research and/or Education Award

1.1a Individual category – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research, (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress and promise technical advances in the rice industry.

1.1b. Team category – Same as the individual category, except that one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

1.2 The Distinguished Service Award - Awards to be made to designated individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2.0 The Awards Committee shall consist of the Executive Committee.

3.0 The duties of the Awards Committee are as follows:

3.1 To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee Members cannot nominate or write letters of support for an individual or team for the RTWG awards.

3.2 To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority vote. The Awards Committee Chair (same as the Executive Committee Chair) can only vote in case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

3.3 The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting.

3.4 The Awards Committee shall select appropriate certificates for presentation to the recipients of the Awards.

4.0 Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three (3) recommendation letters and vitae of nominee. Fifteen (15) complete copies of each nomination must be submitted. A one-page summary of accomplishments should also be included with each nomination. This summary will be published in the RTWG Proceedings for each award participant.

4.1 Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

4.2 A member of an organization, described in 4.1, may nominate or co-nominate two persons.

4.3 Nominations are to be sent to the Awards Committee for appropriate committee consideration.

4.4 The deadline for receipt of nominations shall be three months preceding the biennial meeting.

4.5 Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

Past RTWG Award Recipients

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients
1972	D.F. Houston	L.B. Ellis	None
Davis, CA	R.D. Lewis	H.M. Beachell	
	N.E. Jodon	C.R. Adair	
	E.M. Cralley	W.C. Dachtler	
1974	J.G. Atkins	R.A. Bieber	None
Fayetteville, AR	N.S. Evatt	J.T. Hogan	
	M.D. Miller	B.F. Oliver	
	T. Wassermand		
1976	D.H. Bowman	T.H. Johnston	None
Lake Charles, LA	R.F. Chandler	M.C. Kik	
	J.N. Efferson	X. McNeal	
	J.P. Gaines		
1978	J.W. Sorenson, Jr.	D.T. Mullins	R.K. Webster
College Station, TX	R. Stelly		
1980	M.L. Peterson	W.R. Morrison	B.D. Webb
Davis, CA	L.E. Crane	F.T. Wratten	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Arkansas 'Get the Red Out' Team	
1982	C.C. Bowling	L. Drew	R.J. Smith, Jr.	B.A. Huey
Hot Springs, AR	J.P. Craigmiles		F.L. Baldwin	
1984	M.D. Morse	E.A. Sonnier	California Rice Varietal Improvement Team	
Lafayette, LA	L.C. Hill	D.L. Calderwood	H.L. Carnahan	J.N. Rutger
			C.W. Johnson	S.T. Tseng
			J.E. Hill	J.F. Williams
			C.M. Wick	S.C. Scardaci
			D. M. Brandon	
1986	D.S. Mikkelsen	J.B. Baker	Texas Rice Breeding and Production Team	
Houston, TX			C.N. Bollich	B.D. Webb
			M.A. Marchetti	G.N. McCauley
			J.E. Scott	J.W. Stansel
			F.T. Turner	A.D. Klosterboer
			E.F. Eastin	M.O. Way
			N.G. Whitney	M.E. Rister

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1988	M.D. Androus	H.L. Carnahan	Arkansas DD-50 Team	
Davis, CA	S.H. Holder	B.A. Huey	N.R. Boston	G.L. Davis
	M.D. Faulkner	W.R. Grant	F.N. Lee	N.P. Tugwell
	C.H. Hu	F.J. Williams	D.A. Downey	G.L. Greaser
			T.H. Johnson	G. Rench
			B.R. Wells	M.S. Flynn
			B.A. Huey	T.C. Keisling
			R.J. Smith	F.J. Williams
			D. Johnson	
1990	H.R. Caffey	B.R. Jackson	None	
Biloxi, MS	O.R. Kunze			
1992	C.N. Bollich	A.A. Grigarick	J.W. Stansel	
Little Rock, AR	B.D. Webb	C.M. Wick		
1994	S.H. Crawford	K. Grubenman	M.C. Rush	
New Orleans, LA	J.V. Halick	R.N. Sharp		
	R.J. Smith			

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1996 San Antonio, TX	P. Seilhan	K. Tipton	D.M. Brandon	
1998 Reno, NV	G. Templeton 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 Researrch Team	
2016			D. Groth	
Galveston, TX	Rolfe J. Bryant	Lawrence M. White, III	D. Harrell	
	Farman Jodari		S. Linscombe	
			E. Webster	
			Individual	
			Terry Siebenmorgan	

RICE TECHNICAL WORKING GROUP HISTORY

Meeting	Year	Location	Chair	Secretary	Publication Coordinator(s)
1^{st}	1950	New Orleans, Louisiana	A.M. Altschul		
2^{nd}	1951	Stuttgart, Arkansas	A.M. Altschul		
3^{rd}	1951	Crowley, Louisiana	A.M. Altschul		
4^{th}	1953	Beaumont, Texas	W.C. Davis		
5^{th}	No meeting was held.				
6^{th}	1954	New Orleans, Louisiana	W.V. Hukill		
7^{th}*	1956	Albany, California	H.T. Barr	W.C. Dachtler	--
8^{th}	1958	Stuttgart, Arkansas	W.C. Dachtler	--	--
9^{th}	1960	Lafayette, Louisiana	D.C. Finfrock	H.M. Beachell	--
10^{th}	1962	Houston, Texas	H.M. Beachell	F.J. Williams	--
10^{th}	1964	Davis, California	F.J. Williams	J.T. Hogan	--
11^{th}	1966	Little Rock, Arkansas	J.T. Hogan	D.S. Mikkelsen	--
12^{th}	1968	New Orleans, Louisiana	M.D. Miller	T.H. Johnston	--
13^{th}	1970	Beaumont, Texas	T.H. Johnston	C.C. Bowling	--
14^{th}	1972	Davis, California	C.C. Bowling	M.D. Miller	J.W. Sorenson*
15^{th}	1974	Fayetteville, Arkansas	M.D. Miller	T. Mullins	J.W. Sorenson
16^{th}	1976	Lake Charles, Louisiana	T. Mullins	M.D. Faulkner	J.W. Sorenson
17^{th}	1978	College Station, Texas	M.D. Faulkner	C.N. Bollich	O.R. Kunze
18^{th}	1980	Davis, California	C.N. Bollich	J.N. Rutger	O.R. Kunze
19^{th}	1982	Hot Springs, Arkansas	J.N. Rutger	B.R. Wells	O.R. Kunze
20^{th}	1984	Lafayette, Louisiana	B.R. Wells	D.M. Brandon	O.R. Kunze
21^{st}	1986	Houston, Texas	D.M. Brandon	B.D. Webb	O.R. Kunze
22^{nd}	1988	Davis, California	B.D. Webb	A.A. Grigarick	O.R. Kunze
23^{rd}	1990	Biloxi, Mississippi	A.A. Grigarick	J.E. Street	O.R. Kunze
24^{th}	1992	Little Rock, Arkansas	J.E. Street	J.F. Robinson	M.E. Rister
25^{th}	1994	New Orleans, Louisiana	J.F. Robinson	P.K. Bollich	M.E. Rister
26^{th}	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

- 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

2016

I. Purpose and Organization

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

The RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by the States, Federal Government, and other members. The current disciplines or Panels represented are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization & Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Each Panel has a Chair who, along with the Secretary/Program Chair, solicits and receives titles, interpretive summaries, and abstracts of papers to be presented at the biennial meeting. The papers are presented orally in concurrent technical sessions or via poster. Each Panel over the course of the meeting develops proposals for future work, which are suggested to the participating members for implementation.

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

Other members of the Executive Committee are elected biennially by the membership of the RTWG; they include the Chair who has served the previous term as Secretary/Program Chair, a Geographical Representative from each of the seven major rice-growing states (Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas), the Immediate Past Chair, and an Industry Representative. The rice industry participants elect an Executive Committee member from one of following areas: i) chemical, ii) seed, iii) milling, iv) brewing industries, v) producers, or vi) consultants. The Publication Coordinator also is on the Executive Committee. The Coordinator of the RTWG website is an ex-officio member of the Executive Committee.

Standing committees include: i) Nominations, ii) Rice Crop Germplasm, iii) Rice Variety Acreage, iv) Awards, and v) Location and Time.

II. Revised Memorandum of Agreement

The previous Memorandum of Agreement is published in the 33rd RTWG Proceedings in 2010. The following is a revised Memorandum of Agreement accepted by the 34th RTWG membership in 2012.

REVISED MEMORANDUM OF AGREEMENT

FEBRUARY 2012

INFORMAL UNDERSTANDING

among

THE STATE AGRICULTURAL EXPERIMENT STATIONS

and

THE STATE AGRICULTURAL EXTENSION SERVICES

of

ARKANSAS, CALIFORNIA, FLORIDA, LOUISIANA, MISSISSIPPI, MISSOURI, AND TEXAS

and

THE AGRICULTURAL RESEARCH SERVICE,
THE ECONOMIC RESEARCH SERVICE,
THE COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

and

OTHER PARTICIPATING AGENCIES

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

and

COOPERATING RICE INDUSTRY AGENCIES

Subject: Research and extension pertaining to the production, utilization, and marketing of rice and authorization of a Rice Technical Working Group.

It is the purpose of this memorandum of agreement to provide a continuing means for the exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by State Agricultural Experiment Stations, State Agricultural Extension Services, the United States Department of Agriculture, and participating rice industry groups. It is believed this purpose can best be achieved through a conference held at least biennially at the worker level of those currently engaged in rice research and extension. Details of the cooperation in the seven states are provided in formal Memoranda of Understanding and/or appropriate Supplements executed for the respective state.

The agencies represented in this memorandum mutually agree that overall suggestions of cooperative review and planning of rice research and extension in the several rice producing states and the United States Department of Agriculture shall be developed by a Rice Technical Working Group (henceforth designated RTWG), composed of all personnel actively engaged in rice investigations and extension in each of the agencies, as well as participating rice industry groups.

It is further agreed that there shall be a minimum of three Administrative Advisors to the RTWG to represent the major agencies involved, including:

1) A director of an Agricultural Experiment Station from a major rice-growing state elected by the Station Directors of the rice-growing states,

2) A director of a State Cooperative Extension Service from a major rice-growing state elected by the Extension Directors of the rice-growing states, and

3) A USDA Administrative Advisor from ARS named by the Administrator of Agricultural Research Service.

The RTWG shall convene at least biennially to review results and to develop proposals and suggested plans for future work. It is understood that the actual activities in research and extension will be determined by the respective administrative authorities and subject to legal and fund authorizations of the respective agencies.

Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (chair and secretary), subject to consultation with the remainder of the Executive Committee.

The Executive Committee shall consist of 15 members:

Officers (2):

Chair -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

Secretary/Program Chair -- (normally moves up to Chair).

Geographic Representatives (7):

One active rice worker in state or federal agencies from each of the major rice states -- Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas.

These Geographic Representatives will be responsible for keeping all governmental rice workers and administrators in their respective geographic areas informed of the activities of the RTWG.

Immediate Past Chair -- provides guidance to incoming chair to facilitate a smooth transition between biennial meetings.

Administrative Advisor (one from each category) (3):

State Agricultural Experiment Station
State Agricultural Extension Service
USDA - Agricultural Research Service

Publication Coordinator -- serves to handle matters related to the publication of the RTWG Proceedings.

Industry Representative -- to be elected by industry personnel participating in the biennial meeting of the RTWG; represents all aspects of the U.S. rice industry and serves as liaison with other rice industry personnel; and is responsible for keeping all interested rice industry personnel informed of the activities of the RTWG.

The Officers, Geographic Representatives, and the Publication Coordinator of the Executive Committee shall be elected on the first day of each biennial meeting to serve through the close of the next regular biennial meeting.

A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the active subject matter panels. Such election shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the panel program in close cooperation with the Secretary-Program Chair and for seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective panel sessions.

Participation in the panel discussions, including presentation of rice research findings by rice industry representatives and by representatives from National or International Institutes, is encouraged.

At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund,' established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

This type of memorandum among the interested state and federal agencies provides for voluntary cooperation of the seven interested states and agencies.

III. Description of Committees, Positions, Duties, and Operating Procedures

A. Executive Committee

The Executive Committee conducts the business of the RTWG, appoints standing committees, organizes and conducts the biennial meetings and presents the awards. Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (Chair and Secretary), subject to consultation with the remainder of the Executive Committee. A quorum (i.e., eight members, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. A simple majority vote is needed to pass any motion and the Chair only votes in the case of a tie. The Executive Committee is composed of the following 15 members: i) three officers—Chair, Secretary/Program Chair, and Immediate Past Chair; ii) seven Geographical Representatives from each major rice producing state; iii) three administrative advisors from the major agencies of Agriculture Experiment Stations, State Agricultural Extension Services, and the USDA; iv) a Publication Coordinator; and v) a Rice Industry Representative. The Officers, Geographical Representatives, and the Publication Coordinator shall be elected to the Executive Committee at the Opening Business meeting of each biennial meeting to serve through the close of the next regular biennial meeting. Industry personnel participating in the biennial meeting elect the Industry Representative.

1. **Chair**
   The Chair provides leadership to the RTWG by organizing the agenda and presiding over the Business and Executive Committee meetings, presiding over the Awards process, appointing temporary or ad hoc committees to explore and address RTWG interests, and being the official spokesperson for the RTWG during his/her period of office. If the nomination process for selecting geographical representatives and members of the Nominations committee fails to produce a candidate, then it the responsibility of the Chair to work with the state delegation in selecting a candidate from that state. The Secretary/Program Chair is usually nominated by the Nomination Committee to be Chair at the next biennial meeting. If the Chair nominated cannot serve or complete the full term of office, it is the responsibility of the Executive Committee to appoint a new Chair.

2. **Secretary/Program Chair**
   The Secretary/Program Chair serves a two-year term and is responsible for organizing, conducting and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair appoints a Local Arrangements Committee and Chair from their home state to help with organizing and conducting the biennial meeting. The Secretary/Program Chair is responsible for the minutes of all Business and Executive Committee meetings, the publishing of the minutes of these and other committees (i.e., Rice Crop Germplasm, Rice Variety Acreage, and Nominations) at the RTWG in the Proceedings and ensuring the Panel Chairs correctly publish their minutes and abstracts in the Proceedings. The Secretary/Program Chair is responsible setting up the RTWG website. The Secretary/Program Chair is responsible for the resolutions pertaining to the biennial meeting and for the Necrology Report when appropriate. The Secretary/Program Chair authors the Resolutions section of the RTWG Proceedings that expresses appreciation to individuals and organizations that contributed to making the biennial RTWG meeting a success. The Secretary/Program Chair is a member of the Executive Committee and usually resides in the state the biennial meeting is conducted. The Secretary is usually chosen by active rice workers from the meeting host state and the candidate identified to the Nominations Committee for election. If the Secretary/Program Chair nominated cannot serve or complete the full term of office, it is the responsibility of the member on the Nominations Committee of the hosting state to appoint a new Secretary/Program Chair.

3. **Immediate Past Chair**
   Provides guidance to the incoming Chair to facilitate a smooth transition and lend continuity between biennial meetings. The Immediate Past Chair assists the Publication Coordinator in editing the nontechnical sections of the proceedings and revises the MOP as required. The Chair is nominated by the Nominations Committee to be the Immediate Past Chair at the next biennial meeting. The Immediate Past Chair will incorporate the changes approved by the Executive Committee in the MOP.

4. **Geographical Representatives**
   There are currently seven geographical representatives representing each of the major rice producing states, Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, on the Executive Committee. Each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to serve a two-year term on the Executive Committee. If the Geographical Representative nominated cannot serve or complete the full term of office, it is the responsibility of the delegate on the Nominations Committee from that state to appoint a new Geographical Representative.

5. **Administrative Advisors**
   The Administrative Advisors provide advice and lend continuity to the Executive Committee. A minimum of three Administrative Advisors will be appointed to the RTWG to represent the major agencies involved. They shall consist of: i) a Director of an Agriculture Experiment Station from a rice-growing state elected by the Station Directors of the rice-growing states; ii) a Director of a State Cooperative Extension Service from a rice-growing state elected by the Extension Directors of the rice-growing states; and a USDA Administrative Advisor from the ARS named by the Administrator of the Agricultural Research Service. No term limit is established.

6. **Publication Coordinator(s)**
The Publication Coordinator is responsible for assembling, editing, and publishing of the RTWG Proceedings from the biennial meeting. The Coordinator is assisted in the editing the nontechnical session portions of the proceedings by the Immediate Past Chair. The Coordinator serves on the Executive Committee to handle all matters related to the publication of the RTWG Proceedings. Currently, one publication coordinator serves this position. This is a voluntary position requiring the approval of the RTWG Executive Committee to serve. No term limit is established.

7. **Industry Representative**
The Industry Representative represents all aspects of the U.S. rice industry to the Executive Committee and serves as liaison with other rice industry personnel. Responsibilities include keeping all interested rice industry personnel informed of the activities of the RTWG. Industry personnel participating in the biennial meeting elect the Industry Representative. If the Industry Representative nominated cannot serve or complete the full term of office, it is the responsibility of the Industry members of the RTWG to appoint a replacement.

B. Standing Committees

The Executive Committee has appointed the following Standing Committees.

1. **Nominations Committee**
The purpose of the Nominations Committee is to nominate the Secretary/Program Chair, Chair, Immediate Past Chair, and Geographical Representatives to the Executive Committee, and the members or delegates to the Nominations Committee. The Nominations Committee is composed of eight members. Seven of the members represent each of the seven major rice-producing states and one delegate is from the U.S. Rice Industry. As with the Executive Committee, each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to be their delegate on the Nominations Committee and the Rice Industry is responsible for designating who their delegate is on the committee. The Chair of the Nominations Committee is from the next state to hold the RTWG biennial meeting. If a delegate on the Nominations Committee cannot serve or complete the term of office, it is the responsibility of the Geographical Representative from that state to appoint a replacement. Each delegate is responsible for polling the active rice workers in their state or industry to determine who their Geographical Representative is on the Executive Committee and who their delegate is on the Nominations Committee. The Chair of the Nominations Committee is responsible for obtaining the results from each delegate on the Nominations Committee, compiling the results, and reporting the results to the RTWG at the Opening Business meeting for a vote. When a state is next in line to host a biennial meeting, it is the responsibility of the delegate from that state to nominate the Secretary/Program Chair. Since the Secretary/Program Chair moves up to RTWG Chair and the RTWG Chair to Past Chair, it is the responsibility of the Chair of the Nominations Committee to nominate them to the RTWG members.

2. **Rice Crop Germplasm Committee**
The Rice Crop Germplasm Committee functions not only as an RTWG committee but also as the Rice Crop Germplasm Committee for the National Plant Germplasm System. In this capacity, it is part of a specific national working group of specialists providing analysis, data and recommendations on genetic resources for rice and often-related crops of present or future economic importance. This committee represents the user community, and membership consists of representation from federal, state, and private sectors; representation from various scientific disciplines; and geographical representation for rice. There are also ex-officio members on the committee from the National Plant Germplasm System. The Rice Crop Germplasm Committee, along with the other Crop Germplasm Committees, is concerned with critical issues facing the NPGS including: i) identifying gaps in U.S. collections and developing proposals to fill these gaps through exchange and collaborative collecting trips; ii) assisting the crop curators in identifying duplications in the collections, and in evaluating the potential benefits and problems associated with the development and use of core subsets; iii) prioritizing traits for evaluation and developing proposals to implement these evaluations; iv) assisting crop curators and GRIN personnel in correcting passport data and ensuring that standardized, accurate, and useful information is entered into the GRIN database; v) assisting in germplasm regeneration and

in identifying closed out programs and other germplasm collections in danger of being lost and developing plans to rescue the important material in these programs; vi) working with quarantine officials to identify and ensure new techniques for pathogen identification that will assist in the expeditious release of plant germplasm; and vii) maintaining reports on the status of rice for Congress, ARS National Program Staff and Administrators, State administrators, and other key individuals involved with the NPGS. The Committee members serve six-year terms. They rotate off of the Committee in two-year intervals. The Rice Crop Germplasm Committee Chair appoints a committee who nominates a slate of members. This committee maintains the diversity of the membership. Nominations also are requested from the floor and elections take place among the voting members to fill the six-year terms of office. A Chair is then elected from the voting membership for a two-year term. The Chair can only be elected to two consecutive terms of office unless completing the term of a previous Chair.

3. **Rice Variety Acreage Committee**
The purpose of the Rice Variety Acreage Committee is to collect and summarize data on varieties by acreage for each state and publish the summary in the RTWG Proceedings. The Committee consists of the rice specialists from each of the seven major rice-producing states and one other representative, usually a breeder or a director of an experiment station. No more than two members can represent any one state. The Chair of the Rice Variety Acreage Committee solicits information from each of the states then compiles it for the Committee report published in the RTWG Proceedings. Members of the Rice Variety Acreage Committee solicit their own members, first based on state and then on knowledge and interest expressed by active members of the RTWG to be part of the Rice Variety Acreage Committee. The Chair of the Rice Variety Acreage Committee is elected by the members of the Committee and may serve more than one term. No term limits have been established for members of the Rice Variety Acreage Committee. English units of measure should be used for the acreage tables for continuity.

4. **Awards Committee**
The Awards Committee is composed of the Executive Committee. See section IV. C., 'Guidelines for RTWG Awards' for details regarding responsibilities and duties of the Awards Committee.

5. **Location and Time Committee**
The Location and Time Committee is made up of three individuals, two from the state next to hold the biennial meeting and one from the state following the next host state. This Committee explores when and where the next biennial RTWG meeting will be held. The incoming Chair appoints the Location and Time Committee members.

C. Website Coordinator
A third-party website host and developer will be used to maintain a permanent RTWG website. A permanent (100 years from 2010) address (www.rtwg.net) has been purchased through www.networksolutions.com. The Chair and Secretary Program Chair are to meet and transfer responsibilities no later than one year after the preceeding meetings to ensure a smooth transition from one host state to the next.

D. Revisions to the Manual of Operating Procedures
The Executive Committee with a majority vote has approved this 'Manual of Operating Procedures' for use by the Rice Technical Working Group. This 'Manual of Operating Procedures' is a working document that should be amended or modified to meet the needs of the Rice Technical Working Group. Amendments or modification to this 'Manual of Operating Procedures' can only be made by a quorum of the Executive Committee with the approval of the majority of the Executive Committee. The RTWG Chair can only vote in the case of a tie. The Immediate Past Chair will incorporate the approved changes in the MOP.

IV. Biennial Meeting Protocols

A. Biennial Meetings

The biennial meetings are hosted by the participating states in the following rotation: Arkansas, Louisiana, Texas, California, Missouri, and Mississippi. A state is allowed to host a biennial meeting if the state is deemed by the Executive Committee to have a sufficient number of rice scientists to properly conduct a biennial meeting. The Secretary/Program Chair is responsible for organizing, conducting, and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair is responsible for setting up the RTWG website. The Chair organizes the agenda and presides over the Business and Executive Committee meetings and the Awards process. Panel Chairs coordinate the oral and poster presentations in their discipline with the Secretary/Program Chair, editing of abstracts with the Publication Coordinator, updating of panel recommendations, and choosing their successor. Detailed information on the business meetings; detailed responsibilities of the Publication Coordinator, Panel Chairs, and the Local Arrangements Committee; timeline of preparation for the biennial meeting; instructions for preparation of abstracts; and guidelines for the RTWG awards are listed in this section.

1. Executive Committee Meetings

The agenda for the Executive Committee meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Executive Committee meetings. Following is a typical agenda.

a. Opening Executive Committee Meeting (held on day prior to start of meeting)

<u>Old Business</u>

i) The Chair opens the meeting
ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

<u>New Business</u>

The Necrology Report read by Chair.
The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.
The Chair leads a discussion of any New Business that has developed since the last RTWG meeting. Several months prior to the RTWG meeting the Chair should solicit any New Business items from the Executive Committee.

b. Closing Executive Committee Meeting (held on last day of meeting)

<u>Old Business</u>

i) The Chair opens meeting
ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. Opening General Session and Business Meetings

The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

a. Opening General Session and Opening Business Meeting (begins the RWTG meeting)
   i) The Chair opens the meeting and thanks the host state delegation for preparing the program.
   ii) The Secretary welcomes the RTWG membership to their state.
   iii) The Chair opens the Business Meeting by asking the Secretary to read the minutes of the Closing Business meeting from the previous RTWG meeting and the Chair then entertains a motion for acceptance of the minutes.
   iv) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.
   v) The Chair reads the Necrology Report and asks for a few moments of silence.
   vi) The Nominations Committee Chair reads the nominations for the Executive Committee and Nominations Committee to the RTWG membership. The RTWG Chair then entertains a motion to accept the nominations.
   vii) The Chair calls on the Chair of the Location and Time Committee of the next biennial meeting to report when and where the next RTWG meeting will be held.
   viii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.
   ix) The Chair asks for a motion to adjourn the Opening Business Meeting.
   x) The General Session usually ends with invited speaker(s).

b. Closing Business Meeting (ends the RTWG meeting)
   i) The Chair opens the meeting and calls for Committee reports from Rice Crop Germplasm, Rice Variety Acreage, Rice Industry, and the Publication Coordinator.
   ii) The Chair thanks the Publication Coordinator(s) for their efforts in coordinating, editing, and publishing the RTWG Proceedings.
   iii) The Chair thanks the host state delegation for hosting the RTWG Meeting.
   iv) The Chair then passes the Chair position to the Secretary/Program Chair. The incoming Chair thanks the Past Chair for service to the RTWG and presents the Past Chair with a plaque acknowledging their dedicated and valuable service to the RTWG as the Chair.
   v) The incoming Secretary/Program Chair informs the membership of the time and place for the next RTWG meeting.
   vi) The incoming Chair invites everyone to attend the next RTWG meeting and asks for a motion to adjourn the RTWG meeting.

3. Publication Coordinator(s)

The Publication Coordinator(s) are responsible for providing instructions for manuscript preparation, collecting abstracts from the Panel Chairs, assembling all pertinent information for inclusion in the Proceedings, final review, and publication of the Proceedings upon the conclusion of each RTWG meeting. The Publication Coordinator(s) solicit input from the Executive Committee, Panel Chairs, and the general membership for changes and/or adjustments to the RTWG Proceedings content, style, format, and timetable. It is, however, the Publication Coordinator(s) responsibility to make the final decision on changes appropriate to insure the Proceedings is a quality product and reflective of the goals and objectives of the organization. This flexibility is needed to insure that publication of this information through their respective institution is done in accordance with university or other agency requirements. The Publication Coordinator(s) are responsible for updating the guidelines for submitting abstracts as needed and including this information in the published Proceedings and also on the RTWG host website once the call for abstracts is made. The Publication Coordinator(s) are responsible for mailing proceedings in CD and hardcopy format to the general membership and also placing the Proceedings on the internet.

4. **Panel Chairs**
A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the six disciplines or Panels. The current Panels are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization, and Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Such elections shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the Panel program in close cooperation with the Secretary-Program Chair. Program development involves scheduling of oral and poster presentations, securing moderators to preside at each panel session, editing of abstracts, seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective Panel sessions, and election of a successor. Since the Secretary is from the RTWG host state, the Panel Chairs elected should also be from the host state if possible to facilitate close cooperation with the Secretary and other Panel Chairs. If an elected Panel Chair cannot serve or fulfill the duties, then it is the Secretary's responsibility to replace the Panel Chair with someone preferably from the same discipline.

   Each Panel Chair is responsible for collecting all of the Panel abstracts prior to the RTWG biennial meetings. The appropriate due date will be identified in the Call for Papers for the RTWG meeting. Each Panel Chair is responsible for assembling the Panel abstracts into one common MS Word file that is consistent with the above guidelines, with the abstracts appearing in the order presented. Paper abstracts will be presented first and poster abstracts second. A Table of Contents should be included with each panel section. Panel Chairs are responsible for editing all abstracts for their panel. A common file should be developed prior to the beginning of the RTWG meeting and submitted to the Publication Coordinator(s) to accommodate preliminary preparation of the Proceedings prior to the meeting. The Panel Chairs are strongly encouraged to edit the abstracts for content clarity and RTWG format to expedite publication of the Proceedings. These materials will be merged in the final Proceedings in the format submitted. Final editing will be performed by the Publication Coordinator(s), Rice Research Station secretarial staff, and the incoming Chair.

   In addition, Panel Chairs are to prepare and submit both a paper copy and MS Word computer file version of the (1) final Panel Recommendations and (2) a list of panel participants by the conclusion of the meeting. A copy of the previous recommendations and panel participants will be provided to each Panel Chair prior to the meeting.

   Panel Chairs are to organize the oral presentations in the concurrent Technical Sessions and the posters for the Poster Sessions with the Secretary/Program Chair.

5. **Local Arrangements**
The Local Arrangements Committee and the Chair of this Committee are typically appointed by the Secretary/Program Chair to help with meeting site selection and organizing and conducting the biennial meeting. Thus, they usually reside in the state the biennial meeting is conducted due to logistics. Typical responsibilities include: a survey of possible meeting sites and establishments; working with the hotels for rooms, meeting space, and food functions; securing visual aids; helping with spouse activities; solicitation of donations; and providing speakers and entertainment.

6. **Financing Biennial Meeting, Start-up Money, and the Contingency Fund**
   a. The biennial RTWG meetings are financed through registration fees and donations from industry and interested parties. The Executive Committee established a base amount of $6,000 that is to be transferred from one host state to the next as start-up money to begin preparations for the RTWG meeting prior to when donations or registration fees can be collected.

b. At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund', established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

c. The Contingency Fund was established as a safety net for states hosting the biennial meetings. It is to be used by the host state when the startup money transferred from the previous state to host the biennial meetings is insufficient or when a state goes into debt hosting the biennial meetings.

   i. If the previous host state is unable to provide any or all of the $6,000 in start-up money for the next host state to initiate meeting preparations, the current Chair should be informed of this situation as soon as possible (as the Chair will normally have served as Secretary of the previous meeting, he/she will probably be aware of this situation). The Chair should then communicate to the Executive Committee how much money will be needed from the Contingency Fund to provide the next host state the full $6,000 in start-up funds. The Chair will then ask for approval from the Executive Committee to make arrangements to have the appropriate funds transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the next host state. Providing the next host state adequate ($6,000) start-up funds will be the highest priority for the use of contingency funds.

   ii. If a host state has gone into debt as a result of hosting the annual meeting and will request the use of contingency funds to cover all or part of that debt (over and above the inability to provide the $6,000 in start-up funds to the next host state), it must submit a detailed request for approval of the use of these funds to the Chair, who will than make this request available to the Executive Committee. The request should include a detailed accounting of all financial aspects of the hosted meeting, including all funds received and sources thereof, as well as a detailed accounting of all expenses incurred as a result of hosting the meeting. The Chair will have discretion on how to proceed with polling the Executive Committee (e.g., email or conference call) on approval of the use of contingency funds to cover all or part of the incurred debt. The Executive will then decide through parliamentary procedure whether to use contingency funds to cover all or part of the incurred debt. The Chair will then make arrangements to have the amount of any funds approved by the Executive Committee for this purpose transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the host state. No repayment of these funds will be required.

7. Complementary Rooms, Travel Reimbursements, and Registration Fee Waivers

Complementary rooms (Suite) are provided during the meeting for the Chairman and Secretary. Typically, the hotel will provide rooms free of charge in association with a certain number of booked nights. Invited speakers may be provided travel funds, free room, or registration, depending on meeting finances. The Local Arrangement Committee usually does not provide any travel assistance for attendees. Registration can be waived or refunds given on the discretion of the Local Arrangement Committee based on their financial situation. Possibly, a certain amount should be specified non-refundable before registration is begun. Distinguished Service Award recipients usually have their registration fee waived for the day of the Award Banquet if they are not already registered.

8. Biennial Meeting Preparation Timeline

May 1, 2016	Secure Hotel
May 1, 2017	Pre-RTWG planning meeting
June 15, 2017	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 2017	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 2017	First call for papers and a call for award nominations
Sept. 15, 2017	Second call for papers (Reminder; e-mail only)
Oct. 15, 2017	Titles and interpretive summaries due
Dec. 1, 2017	Abstracts due
Dec. 1, 2017	Award nominations due to Chair
Dec. 1, 2017	Registration and housing packet sent
Jan. 3, 2018	Reminder for registration and hotel (e-mail only)
Jan. 29, 2018	Last day for hotel reservations
Jan. 30, 2018	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 2018	Registration due without late fee
Feb. 18, 2018	RTWG Meeting

9. Program Itinerary

The biennial meetings begin on Sunday afternoon with committee meetings followed by a social mixer in the evening. The meetings end on Wednesday morning with the Closing Business meeting. The Awards presentations are made at dinner Monday or Tuesday evening or at a luncheon on Tuesday. See programs from previous RTWG meetings for more details.

<u>Sunday:</u> Registration usually begins Sunday afternoon and standing committees and ad hoc committees meet Sunday afternoon. A Sunday evening social mixer is hosted by the RTWG.

<u>Monday</u>: Registration continues Monday morning and posters are usually setup prior to the Opening General Session. The Opening General Session starts the biennial meeting with opening remarks from the Chair, a welcome from the Secretary/Program Chair, the opening business meeting, and ends with invited speakers. The concurrent technical sessions (i.e., oral presentations) of the six Panels begins after the Opening General Session on Monday. Posters are on display throughout the meeting or removed Monday evening and new ones placed on display Tuesday morning and removed Tuesday evening, depending on the number of posters and poster sessions.

<u>Tuesday:</u> The concurrent technical sessions continue on Tuesday and extend through Tuesday afternoon, depending on the number of papers. Each concurrent technical session ends with the review of the panel recommendations. If there are a sufficient number of posters, a second poster session is held on Tuesday.

<u>Wednesday:</u> The biennial meeting usually ends on Wednesday with the Closing Executive meeting and then the Closing Business meeting.

10. Symposia

Symposia are welcomed in conjunction with the RTWG biennial meetings. Symposia must not interfere with the RTWG biennial meetings and are to be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting.

11. Functions by Industry and Other Groups

Functions held in conjunction with the RTWG biennial meetings are welcomed as long as they do not interfere with the RTWG biennial meetings. Thus, these functions must be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting. Exceptions are informal, brief functions held at the meal breaks of breakfast, lunch, or dinner.

B. Instructions for Preparation of Abstracts for Biennial Meetings

Beginning with the Proceedings for the 24th Rice Technical Working Group meeting, Desktop Publishing software was chosen for expediting the post-meeting publication process using Microsoft Word (Windows). If individuals do not have access to MS Word, submission of materials in ASCII format (DOS compatibility is essential) is acceptable. Each electronic file should include: i) title of materials, ii) corresponding RTWG Panel, iii) corresponding author's name, daytime telephone number, e-mail address, and iv) computer format (i.e., MS Word and version number). These criteria apply uniformly to i) presented paper abstracts, ii) poster abstracts, iii) symposia abstracts, iv) panel recommendations, and v) list of panel participants. More details with respect to each of these items follow below.

As soon as a web page is established by the host state, a link will be provided to the RTWG web page where current submission instructions will be maintained.

1. Presented Paper, Poster, and Symposia Abstracts

To be published in the printed Proceedings, presented paper, poster, and symposia abstracts for the RTWG meetings must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the Proceedings.

a. Both a paper copy and an electronic file are required. Hard copy and electronic file are to be submitted to the respective Panel Chairs 2 ½ months prior to the RTWG meeting, or earlier as stated in the Call for Papers issued by the RTWG meeting Chair and/or Panel Chairs. Please e-mail the abstract to the Panel Chair by the deadline and mail the hard copy thereafter. If e-mail is not available, mail the electronic file to the panel chair on a IBM compatible CD or floppy disk.

The respective Panel Chairs for each RTWG meeting and their e-mail and mailing addresses are presented in the 'Instructions for Preparation of Abstracts" in each Proceedings. In case of other questions or if unable to access the Call for Papers, contact:

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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 Chairman reserves the right to pass the responsibilities of award elections to the immediate past chair, the secretary, or an executive committee member who does not have a conflict of interest.

c. To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority vote once a quorum is mustered. A quorum for the Awards Committee is when at least eight members vote, excluding the Chair. The Awards Committee Chair (RTWG Chair) can only vote in the case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

d. The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting. The Chair of the RTWG shall present the awards by speaking briefly about the accomplishments of the award recipient(s) and after presenting the award allow the recipient(s) an opportunity to express their appreciation.

e. The Awards Committee shall select appropriate certificates for presentation to the recipients of the awards.

4. Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three recommendation letters, pertinent biographies of each nominee, and a concise but complete explanation of the accomplishments. Fifteen complete copies of each nomination must be submitted. A one-page summary of accomplishments should also be included with each nomination. This summary will be published in the RTWG Proceedings if the award is granted.

a. Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

b. A member of an organization, described in 4.a, may nominate or co-nominate two persons.

c. Nominations are to be sent to the Awards Committee for appropriate consideration.

d. The deadline for receipt of nominations shall be three months preceding the biennial meeting. The executive committee reserves the right to entertain Distinguished Service Award packets at the opening executive committee meeting.

e. Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

D. Off-Year Executive Committee Business Meeting

The Executive Committee of the 2004 RTWG Meeting voted to have an Off-Year Executive Committee Business Meeting to add continuity, indoctrinate new Executive Committee members, and discuss pertinent topics more timely. The time and place of the Off-Year meeting is flexible and the possibility of conducting the meeting through distance education is a viable alternative to meeting at a designated location. The best time for the meeting is from February to August in the off-year, and it can be held in conjunction with such meetings as the Breeders' Conference or the organizational meeting for the next RTWG. The meeting can also be held independently at a central location or at the next RTWG meeting site to allow the Executive Committee to become familiar with the hotel and available facilities. A quorum (i.e., eight members are present, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. It is the responsibility of the RTWG Chair and the Secretary/Program Chair to call this meeting and set the agenda in concert with the other members of the Executive Committee.

Drafted by Richard J. Norman and approved by the 31st RTWG Executive Committee on March 1, 2006; revised by Garry McCauley and approved by the 32nd RTWG Executive Committee on February 21, 2008; revised by Cass Mutters and approved by the 33rd RTWG Executive Committee on February 25, 2010; revised by Tim Walker and approved by the 34th RTWG Executive Committee on March 1, 2012.

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