Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Ninth Rice Technical Working Group

Hot Springs, AR: February 20 – 23, 2023

Edited by: Michael Salassi, Jarrod Hardke, and Jason Bond

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

2023 RTWG HOT SPRINGS ARKANSAS 39th RICE TECHNICAL WORKING GROUP

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 2023 Meeting

The 39th RTWG meeting was hosted by Arkansas and held at the Hot Springs Convention Center in Hot Springs, AR, from February 20 – 23, 2023. The Executive Committee, which coordinated the plans for the meeting, included Jason Bond, Chair; Jarrod Hardke, Secretary; and Bruce Linquist, Immediate Past Chair. Geographic Representatives were Trent Roberts (Arkansas), Ian Grettenberger (California), Matthew VanWeelden (Florida), Adam Famoso (Louisiana), Tom Allen (Mississippi), Justin Chlapecka (Missouri), Ted Wilson (Texas), and Mallory Everett (Industry). Administrative Advisors were Michael Salassi (Experiment Station), Steve Martin (Extension Service), and Anna McClung (USDA-ARS). Publication Coordinator was Michael Salassi (Louisiana). The Industry Representative was Mallory Everett (Valent USA). The Local Arrangements Coordinators for Arkansas were Nick Bateman (Chair), Tommy Butts (Vice Chair), Trent Roberts, Jarrod Hardke, Donna Frizzell, and Tara Clayton.

Location and Time of the 2025 Meeting

The 2025 RTWG Meeting Location Committee recommended that the 40th RTWG meeting be held by the host state Louisiana. The meeting will be held in February 2025 in Louisiana.

2023 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 Dustin Harrell. The team award was presented to the Arkansas Weed Science Rice Team of Jason Norsworthy, Tom Barber, and Thomas Butts.

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 an RTWG meeting, it is our fairest award granted to all worthy of such distinction. This award was presented to Ming-Hsuan Chen, Gus Lorenz, Zhongli Pan, Bob Scott, and Eric Webster.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 39th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2023 proceedings. The 2023 proceedings was edited by Michael Salassi, Jason Bond (Chair), and Jarrod Harke (Secretary). They were assisted in the publication of these proceedings by Darlene Regan (LSU AgCenter Southwest Region) and the panel chairs.

Instructions to be closely followed in preparing abstracts for publication in the 40th RTWG (2025 meeting) proceedings are included in these proceedings.

Committees for 2025

Executive:

Chair:	Jarrod Hardke	Arkansas
Secretary:	Adam Famoso	Louisiana

Geographical Representatives:

Nick Bateman	Arkansas
Luis Espino	California
Matthew VanWeelden	Florida
Connor Webster	Louisiana
Tom Allen	Mississippi
Justin Chlapecka	Missouri
Ted Wilson	Texas

Immediate Past Chair:

Jason Bond	Mississippi

Administrative Advisors:

Michael Salassi	Experiment Station
Steve Martin	Extension Service
Michele Reba	USDA-ARS

Publication Coordinator:

Michael Salassi	Louisiana

Web Page Coordinator:

Jarrod Hardke	Arkansas

Industry Representative:

Mallory Everett	Valent USA

2025 Local Arrangements:

Kurt Guidry (Chair)	Louisiana
Brijesh Angira (Vice Chair)	Louisiana
Manoch Kongchum	Louisiana
Ronnie Levy	Louisiana
Kim Guidry	Louisiana

Nominations

Tommy Butts	Arkansas
Ian Grettenberger	California
Matthew VanWeelden	Florida
Brijesh Angira	Louisiana
Tom Allen	Mississippi
Chase Floyd	Missouri
Fugen Dou	Texas
Mallory Everett	Industry-Valent USA

Rice Crop Germplasm:

Georgia Eizenga, Chair	USDA-ARS
Nick Bateman	Arkansas
Gretchen Zaunbrecher	California
Brijesh Angira	Louisiana
Ed Redoña	Mississippi
Stanley (Omar) Samonte	Texas
Christian De Guzman	Arkansas
Qiming Shao	Nutrien Ag Solutions
Xin-Gen (Shane) Zhou	Texas

Ex Officio:

Bishwo Adhikari	USDA-ARS
Harold Bockleman	USDA-ARS
Peter Bretting	USDA-ARS
Travis Huggins	USDA-ARS
Yulin Jia	USDA-ARS
Gary Kinard	USDA-ARS
Jack Okamuro	USDA-ARS

National Germplasm Resources Laboratory:

Gary Kinard	USDA-ARS

Rice Variety Acreage:

Dustin Harrell, Chair	California
Jarrod Hardke	Arkansas
Ron Levy	Louisiana
Hunter Bowman	Mississippi
Justin Chlapecka	Missouri
Ted Wilson	Texas
Matthew VanWeelden	Florida

2025 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:	
Roberto Fritsche Neto	Louisiana
Economics and Marketing:	
Michael Deliberto	Louisiana
Plant Protection:	
Blake Wilson	Louisiana
Postharvest Quality, Utilization and Nutrition:	
Griffiths Atungulu	Arkansas
Rice Culture:	
Manoch Kongchum	Louisiana
Rice Weed Control and Growth Regulation:	
Connor Webster	Louisiana
Student Contest Panel:	
Felipe Dalla Lana	Louisiana

RESOLUTIONS
39th RTWG – 2023

The 39th meeting of the RTWG, held in Hot Springs, Arkansas, February 20 to 23, 2023, provided an opportunity for information exchange among rice research and Extension scientists, rice growers, rice industry representatives, and users of rice products in the United States and abroad. Therefore, the Executive Committee, on behalf of the RTWG, expresses its appreciation to the listed individuals and organizations that contributed to the success of the 39th meeting.

1. Jason Bond, RTWG Chair, and all other members of the Executive Committee who organized and conducted this successful meeting. We recognize Jarrod Hardke and his cooperating staff for the timely completion of organizational details to include notification correspondence, program preparation, specific paper presentation standards, and all other tasks involved with the RTWG.

2. The staff of the Hot Springs Convention Center, Hot Springs, Arkansas, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The staff of Embassey Suites, Hot Springs, Arkansas, for their assistance in arranging lodging and services before and during the RTWG meeting.

4. The Local Arrangements Committee led by Nick Bateman, Tommy Butts, and Trent Roberts, Arkansas, for the site selection and overseeing arrangements.

5. The faculty and staff of the University of Arkansas System Division of Agriculture for their time and assistance in conducting all aspects of pre-meeting and on-site logistics and other conference planning and operational details.

6. Karen Watts-DiCiccio, Chris Meux, Oliver Williams, Gretchen Skinner, and their staffs of the University of Arkansas System Division of Agriculture Cooperative Extension Service departments of Information Technology and Communications who contributed time and effort for developing and maintaining the conference website and coordinated conference registration.

7. The Panel Chairs, Xueyan Sha, Brad Watkins, Nick Bateman, Griffiths Utungula, Trent Roberts, and Tom Barber, and moderators for planning, arranging, and supervising the technical sessions. The Student Contest Chair, Tommy Butts, for planning, arranging, and supervising those special sessions.

8. The paper/poster presenters for sharing research results and new ideas.

9. The Symposia, General Session, and Industry Luncheon speakers, Bob Scott, Deacue Fields, and Dustin Harrell, for sharing their knowledge and wisdom.

10. Michael Salassi, Louisiana Agricultural Experiment Station, and Darlene Regan, H. Rouse Caffey Rice Research Station, LSU AgCenter, for editing and publishing the RTWG proceedings.

11. We gratefully recognize our many generous sponsors that made the 39th Rice Technical Working Group meeting successful.

2023 RTWG Conference Sponsorship

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Distinguished Rice Research and Education Award

Dustin Harrell

Dr. Dustin Harrell, currently the Director of the California Cooperative Rice Research Foundation – Rice Experiment Station, began his scientific career in 2006 when he accepted the leadership responsibility of the Rice Fertility and Agronomy Project at the Rice Research Station in Crowley, Louisiana. Dr. Harrell conducted both applied and basic research focused on rice fertilization and cultural management practices. The overriding objective of his research was to provide an immediate impact on the productivity, profitability, and sustainability of Louisiana rice production and the Midsouthern U.S. rice industry as a whole. Over the next decade and a half, he would serve in additional roles with the LSU AgCenter, including as the state Extension rice specialist from 2014 to 2021 and as the Resident Coordinator of the LSU AgCenter's H. Rouse Caffey Rice Research Station in 2021.

During this time, Dr. Harrell was able to gain a highly regarded reputation with the rice industry, crop consulting, and scientific communities. As a testament to his research and Extension impact, Dr. Harrell received many honors over the years, including the Mosaic Rice Fertility Endowed Professorship in 2009. He received the Rice Technical Working Group's Distinguished Rice Research and Education Team Awards in 2012, again in 2016, and one additional time in 2018. He received Cotton and Rice Tillage Conference's Rice Researcher of the Year Award in 2014, the Louisiana Agriculture Distinguished Service Award in 2015, and the G&H Seed Research Excellence Award in 2015. In 2017, he won the American Society of Agronomy's Extension Educational Materials Program Award in the Newsletters category for his Louisiana Rice Notes. Most recently, he received the Louisiana Rice Research Board Chair of Excellence in Rice Research in 2021.

Dr. Harrell's tenure with the Louisiana Agricultural Experiment Station left footprints all over the rice industry. Four areas where his research impacted the way rice is grown in Louisiana include: identifying zinc deficiency and defining zinc fertilizer recommendations in rice; reducing seeding rate recommendations in drill-seeded, delayed flood rice production systems; improving nitrogen (N) use efficiency in Louisiana rice production with the use of enhanced efficiency fertilizers, improved research-based best management practices, and improving ratoon rice production by providing new research-based recommendations for ratoon fertility and post-harvest stubble management.

Distinguished Rice Research and Education Team Award

Jason Norsworthy, Tom Barber, and Thomas Butts

The Arkansas Weed Science Rice Team includes Drs. Jason K. Norsworthy, Tom Barber, and Thomas R. Butts. The team has published 91 peer reviewed articles related to rice production and management and 113 technical research articles. Their research covers the spectrum from basic science identifying the fundamental causes of weed resistance to applied science focused on developing control strategies that Midsouth rice producers can implement to increase yield and profitability. This research includes evaluation of harvest weed seed control tactics, identification and evaluation of weed control strategies for new problematic weed species, and elucidation of herbicide resistance mechanisms in weeds. The team has screened >3,000 weed samples from rice fields for herbicide resistance.

The team has published 91 peer-reviewed manuscripts, 113 research summaries, >300 abstracts, >300 popular press articles, and 47 Extension publications. Over 10,000 printed copies of the MP-44 weed control guide are distributed annually. Their publications have been cited over 10,000 times in literature, demonstrating how the research is influencing the future direction of scientific inquiry. More importantly, their work impacts stakeholders directly, with 93% of stakeholders surveyed indicating that the resistance screening information provided by this team helped them make more informed decisions regarding rice weed control.

In addition to research, the Arkansas Weed Science Rice Team is innovative in Extension programming. They effectively use multiple delivery mechanisms from podcasts to Twitter to MP-44 printed weed control guides to reach stakeholders regardless of their preferred communication method. Their use of mass text messaging further ensures that rice farmers have the information they need and have it quickly enough to be proactive in their management strategies. These efforts are in addition to the team's train-the-trainer events and popular press articles and make sure that the basic and applied research activities of the team result in action and impact in the rice industry.

Distinguished Service Award

Ming-Hsuan Chen

Dr. Ming-Hsuan Chen worked for the USDA, Agricultural Research Service (ARS) for 21 years as a Research Chemist, starting with the Rice Research Unit in Beaumont, Texas, in 2001 and after that unit's closure in 2012, continued at Dale Bumpers National Rice Research Center in Stuttgart, Arkansas. Dr. Chen devoted her time with ARS to two aspects of rice grain quality research: rice grain functional properties and health beneficial quality of whole grain (brown) rice. She played a leading role in identifying genetic variants in starch synthesis genes associated with critical functional properties and developed genetic markers linked to those traits. Those markers were the foundation for establishing marker-assisted-selection technology in U.S. rice breeding programs and have been broadly used for accelerating the development of new varieties for conventional and specialty uses. She endeavored to improve the health beneficial quality of whole grain rice to combat the rising incidence of chronic diseases impacted by diet. She explored diverse global rice varieties and identified those that have superior health beneficial properties and extend market shelf life. These are now used as parents for creating new rice varieties with health benefits.

Dr. Chen and her collaborators discovered that pigmented red and purple rice possess anti-cancer, anti-diabetic, and gut-health promoting properties and determined the major flavonoids attributing to these effects and their underlying mechanisms. Two of these varieties were recently commercialized in the U.S. and, in 2021, were part of the first export of rice products from the southern United States to China. She launched research that is the basis for developing rice varieties high in resistant starch, a dietary fiber, that lowers glycemic index, improves colon health, and benefits consumers monitoring weight control and glucose metabolism.

Dr. Chen received numerous awards and was a co-recipient of the Distinguished Rice Research and Education Team Award at the 38th Rice Technical Working Group meeting in 2020. Her research and service to the rice research community has helped to sustain and enhance grain quality for the U.S. rice industry.

Distinguished Service Award

Gus Lorenz

Dr. Gus Lorenz began working for the University of Arkansas Extension Service in 1985 as a county agent in Jefferson County. Over the next 10 years he would fulfill multiple roles in Extension. During this time, he completed his Ph.D. and took on the role as Extension entomologist in 1995.

As an Extension entomologist, Dr. Lorenz initially worked in soybean and cotton redefining thresholds and management strategies for multiple insect pests. At the end of the 2007 growing season, he was approached about several problematic insects causing issues for rice growers. Grape colaspis was a major issue occurring across a large portion of the rice-growing region of Arkansas. At the time, neonicotinoid and diamide seed treatments were new and their fit in rice was unknown. Dr. Lorenz's work rapidly determined that these products would be the future of soil insect management in rice. During his career, Dr. Lorenz was integral in redefining thresholds and management strategies for the two biggest pests of rice in the Midsouth, rice stink bug and rice water weevil. He also laid the foundation for the current rice defoliation thresholds used in Arkansas. His impact on rice production in Arkansas has saved growers well over $100 million in insect losses.

Dr. Lorenz has co-authored over 75 peer-reviewed publications in rice, soybean, cotton, corn, and grain sorghum. He has also mentored 17 graduate students and served on many other committees. All these students are still involved in the agriculture industry, and many are making major impacts on the rice industry. He received over 20 awards during his career from state, regional, and national organizations, including the RTWG The Distinguished Rice Research and Education Team Award in 2014.

Dr. Lorenz has a passion for entomology and always strives to do his best for the growers. His proudest accomplishments are seeing the people that he has helped mentor throughout his career continue to help growers with his same passion. While Dr. Lorenz has had a major impact on insect management in all crops grown in the Midsouth, his foresight in rice has helped the industry thrive in Arkansas.

Distinguished Service Award

Zhongli Pan

Dr. Zhongli Pan is an Adjunct Professor in the Department of Biological and Agricultural Engineering at the University of California at Davis where he has been since 2000. Prior to that, he worked as a Research Engineer for 15 years with USDA-ARS Western Regional Research Center, Healthy Processed Foods Research Unit. Dr. Pan had a distinguished career of over 30 years in food engineering. He made exceptional contributions in rice postharvest and processing research. His research and technology development covered insect pest detection, harvest loss, drying, milling, quality and disinfestation. He served as a Panel Chair of Postharvest Quality, Utilization, and Nutrition of RTWG meetings in 2016, 2018, and 2020.

Dr. Pan showed extraordinary creativity and productivity in solving problems and generating new scientific knowledge of importance to the rice industry and academia. Dr. Pan mentored more than 100 graduate students, post-docs, project scientists, and visiting professors from 20 countries. His research results and discoveries related to rice postharvest, processing, and utilization are well documented in the three books: Advances in Science and Engineering of Rice, Infrared Heating for Food and Agricultural Processing, and Integrated Processing Technologies for Food and Agricultural By-products. His publications included 258 peer-reviewed journal publications, 49 conference papers and proceedings, 18 patent applications (6 granted), and 31 book chapters.

Dr. Pan has made significant contributions to food science and engineering by developing and applying new food processing technologies, particularly in rice postharvest and processing, infrared (IR) heating technologies for food and agricultural product processing, and value-added utilization of byproducts. He led a large, innovative research team, including USDA ARS researchers, UC Davis project scientists, graduate students, visiting professors, and industrial collaborators. Dr. Pan is an internationally recognized food engineer and his research has focused on IR heating for rice, rice milling and smart technology for insect pest detection and environmental monitoring. The technologies developed by Dr. Pan and his team have been commercialized and widely reported through the media via TV, magazines, newspapers, and internet.

Distinguished Service Award

Bob Scott

Dr. Bob Scott began working in rice in 1997 as a Technical Service Representative with BASF (American Cyanamid). In that role, Dr. Scott participated in commercialization of the Clearfield technology for rice. In 2002, Dr. Scott became the Extension Weed Specialist with the University of Arkansas Division of Agriculture. His research and Extension duties included statewide responsibilities in rice weed management, and he was an author for the MP-44 Recommended Chemicals for Weed and Brush Control. Dr. Scott published over 200 publications as senior or co-author. He published 50 refereed journal articles, 190 professional abstracts, 91 research reports, and 135 popular press articles. He was also active in professional societies and served as President of the Southern Weed Science Society in 2018.

As the Extension Weed Specialist, Dr. Scott not only directly influenced stakeholders in the rice industry throughout the Midsouth, he also formally and informally mentored numerous graduate students who went on to build strong careers in the rice industry. Dr. Scott continued his service to the rice industry as Director of the Rice Research and Extension Center in Stuttgart, Arkansas, from 2018 to 2020 where he led a group of scientists focused on basic and applied research to advance the rice industry.

Dr. Scott currently serves as Senior Associate Vice President for Agriculture and Director, Arkansas Cooperative Extension Service. He is tasked with serving a broad group of stakeholders from 4-H youth to family and consumer sciences. However, rice remains important to him. He is a very strong supporter of the rice Extension team and works diligently to ensure they have the resources they need to support rice stakeholders in Arkansas.

Distinguished Service Award

Eric Webster

Dr. Eric Webster began doing rice weed management research in 1996 as an Extension Weed Specialist with the University of Arkansas. In 1997, Dr. Webster moved to Louisiana State University with a Research, Teaching, and Extension appointment. His research and Extension duties included statewide responsibilities in rice weed management. Dr. Webster's teaching responsibilities included Plant-Herbicide Physiology and Weed Biology and Ecology. Dr. Webster published over 470 publications as senior or co-author. He published 77 refereed journal articles and semi-technical publications, 53 research reports, 42 Extension publications, and 27 popular press articles. He was also active in professional societies, presented numerous scientific presentations, and given many invited seminars.

In 2012, Dr. Webster became the Secretary for RTWG. In 2014, the 35th RTWG meeting was held in New Orleans, Louisiana, and was attended by 396 participants with 158 oral presentations and 70 posters. Dr. Webster was responsible for the meeting program, local arrangements, meeting organization, and securing invited speakers. In 2014, he became the Chair of the RTWG for the 2016 meeting held in Galveston, TX.

Dr. Webster's rice weed research and Extension programs were highly visible across the United States and internationally. The weed management project helped Louisiana producers select the best weed control program for their specific needs to increase quality and yield at the most economical price. During his tenure, the program brought in over $4 million in grant-in-aid. He conducted cooperative research and Extension programs with everyone at the LSU AgCenter Rice Research Station and conducted cooperative work with researchers and Extension specialist in Arkansas, Mississippi, Missouri, and Texas. During his time with the LSU AgCenter, rice yields improved from a statewide average of 4,530 to 7,500 lb/A.

Dr. Eric Webster is an excellent example of a hardworking, dedicated, and respected research and Extension scientist. He was extremely deserving of the recognition of his accomplishments that accompanies the prestigious Rice Technical Working Group Distinguished Service Award.

Minutes of the 39th RTWG Meeting

Opening Executive Committee Meeting

In Attendance: Jason Bond, Mississippi State University, Chair; Ted Wilson, Texas A&M; Matt VanWeelden, University of Florida; Anna McClung, USDA-ARS; Bruce Linquist, UC Davis, Past Chair; Mallory Everett, Valent USA; Michael Salassi, LSU AgCenter; Adam Famoso, LSU AgCenter; Kurt Guidry, LSU AgCenter; Jarrod Hardke, University of Arkansas Division Agriculture, Secretary; Justin Chlapecka, University of Missouri; Tom Allen, Mississippi State University.

Bond called meeting to order at 7:05 a.m., Monday, February 20, 2023.

Hardke and Bond presented details about the most recent meetings in Long Beach, Orange Beach, and Hot Springs.
Long Beach: 285 attendees; 126 papers, 67 posters.
Orange Beach: 280 attendees; 131 papers, 95 posters.
Hot Springs: 330 attendees (preregistered); 128 papers, 103 posters.

Bond and Hardke discussed financials. MOP states minimum of $6,000 should be transferred to next host. MSU transferred $10,000 to UADA for 2023 meeting. Hardke indicated the financial situation should permit a transfer of $10,000 or more to LSU for 2025 meeting.

Hardke reviewed minutes for the 38th RTWG Closing Executive Committee Meeting.

- Meeting scheduling conflicts continue between RTWG and other meetings.
- RTWG website now permanent as www.RTWG.org. All proceedings past and present will be placed on this website.
- Registration payments will be processed thru FormStack on the site for future meetings; universities not utilizing FormStack will have the option of funds transfers.
- A suggestion was made in Orange Beach to create an award similar to the Distinguished Service Award but for support staff. Wilson, Hardke, and Bond thought this was an idea worth pursuing – need to develop award wording and criteria for award needs further development. McClung suggested the award be geared toward recognition of long-term service and open ended in number of candidates eligible. Wilson and Bond agreed.
- Off Year Meeting of Executive Committee was first proposed continuing to meet at Rice Outlook Conference with off-site participants to be included by Zoom. Wilson suggested strictly a Zoom meeting in off years and continue scheduling around the time of Rice Outlook.
- Suggestions were made to streamline awards presentation.
    - For Research and Service Awards, Linquist suggested to change the nomination packet to include a 250-word bio of nominee.
    - Wilson suggested formal discussion of candidates by Executive Committee instead of just yes/no vote.
    - Famoso suggested a standardized nomination form.
- Lengthy discussion of student awards and moving portions of the awards presentation separate from Awards Luncheon. It was agreed to continue presenting student awards during the Awards Luncheon, but awardees would stand when their name is called and be asked to come up after the luncheon to receive plaques and take pictures.

Point of Order by Wilson to close old business.

Bond read Necrology Report, which included Charles Bollich (June 16, 2022), Albert Fischer (November 22, 2022), Ben Jackson (September 23, 2021), Gabriel Sciumbato (June 1, 2022), and John Scott (April 22, 2021).

Bond announced awards recipients.

There were five Distinguished Service Awards.
Ming Chen
Gus Lorenz
Zhongli Pan
Bob Scott
Eric Webster

Rice Research and Education Team Award
Arkansas Weed Science Rice Team
Tom Barber
Tommy Butts
Jason Norsworthy

Only a single nomination was received for the individual and team Research and Education Awards. Participants should be encouraged to apply for these awards in the future.

Famoso gave a report of the nominations for the Nominations Committee and Geographical Representatives.

Salassi gave a Publications Report. Proceedings will be uploaded to the website to avoid the use of USB drives or CDs. Currently in search of someone for the Publications Coordinator position.

Salassi gave an update on status of RTWG group. Current term for SERA 18 (Southern Extension Research Activity 18) ends September 2023. Bond is working on new term language. RTWG information can be viewed on NIMSS.org. Wilson suggested changing from SERA 18 to a multi-state research project to be eligible for HATCH funding. Makes motion of discussion from going from a working group SERA18 to a multi-state project group.

Other business. None discussed.

Famoso provided an update on the 40th RTWG. Location will be New Orleans, Louisiana. Likely at the Sheraton New Orleans. The dates will tentatively be the week of February 10, 2025.

Meeting was adjourned at 8:40 a.m.

Opening Business Meeting

Secretary Jarrod Hardke welcomed the membership to the 39th RTWG and to Hot Springs, Arkansas.

Hardke recognized meeting sponsors. A presentation roll played throughout the business meeting displaying meeting sponsors and contribution levels.

Chair Jason Bond called the meeting to order at 8:05 a.m. on February 21, 2023, at the Hot Springs Convention Center, Hot Springs, Arkansas.

Bond asked Hardke to read the minutes from RTWG 2020. Tom Allen moved to dispense with the reading of the minutes. Adam Famoso seconded.

Bond gave highlights from Opening Executive Committee Meeting. Beginning in 2023, RTWG will be in odd years (e.g., 2023, 2025, 2027). Staff Award to be awarded in Distinguished category beginning at the 40th RTWG in 2025.

Bond read Necrology Report, which included Charlie Bollich, Albert Fischer, Ben Jackson, Gabe Sciumbato, and John Scott. Details were provided about the contributions of each to the U.S. rice industry and RTWG. A moment of silence was observed by the membership.

As acting Chair of the Nominations Committee, Famoso announced the following nominations for the 40th RTWG meeting:

Jarrod Hardke, Chair
Adam Famoso, Secretary
Jason Bond, Past Chair

Geographical Representatives:
Nick Bateman, Arkansas
Ted Wilson, Texas
Tom Allen, Mississippi
Luis Espino, California
Matthew VanWeelden, Florida
Connor Webster, Louisiana
Justin Chlapecka, Missouri
Mallory Scott, Industry

Nominations Committee:
Tommy Butts, Arkansas
Fugen Dou, Texas
Tom Allen, Mississippi
Ian Grettenberger, California
Matthew VanWeelden, Florida
Brijesh Angira, Louisiana
Chase Floyd, Missouri
Mallory Scott, Industry

Xueyan Sha moved and Dustin Harrell seconded to accept these nominations.

Famoso announced the location of the 2025 40th RTWG hosted by Louisiana State University Agricultural Center to be in New Orleans either February 10 or February 3.

Meeting was adjourned at 8:30 a.m.

Closing Executive Committee Meeting

In attendance: Jason Bond, Mississippi State, Chair; Anna McClung, USDA-ARS; Michele Reba, USDA-ARS; Jarrod Hardke, UofA Division of Agriculture, Secretary; Donna Frizzell, UofA Division of Agriculture; Tom Allen, Mississippi State; Ted Wilson, Texas A&M; Trent Roberts, UofA Division of Agriculture; Matt VanWeelden, University of Florida; Bruce Linquist, UC Davis, Past Chair; Ian Grettenberger, UC Davis; Adam Famoso, LSU AgCenter; Mallory Scott, Valent USA; Justin Chlapecka, University of Missouri.

Jason Bond, Chair called the meeting to order at 8:15 a.m. on Thursday, February 23, 2023.

Hardke provided report on the program.
- He reported final meeting attendance of 340-350: 318 paid and 29 spouse registrations; 28 sponsor registrations.
- The program included 128 papers and 103 posters.
- Three posters were not exhibited due to issues.

Hardke discussed the student competition.
- The Student Paper Contest has expanded.

- The four concurrent student sessions were overlapped with two technical sessions of Breeding and Rice Culture.
- There were issues with this overlap and discussions were made to streamline this.
- There was a lengthy discussion of possible adjustments to student paper competitions, including moving to Monday afternoon in place of Symposium, and moving Symposium to another time/day. Consider further shortening the time/length of student papers.

Reba commented that moderators made an excellent effort to keep technical talks on time.

Bond commented that changes voted on Opening Executive Committee Meeting concerning streamlining the Awards Luncheon went well. He would like to give awardees an opportunity to comment during the presentation of their award.

Famoso and Guidry presented plans for the 40th RTWG to be held during February 2025 in New Orleans, LA, at either the Sheraton or Marriott Hotel.

Bond asked Wilson to provide further information concerning a change from RTWG being a SERA-18 project to a multi-state HATCH project. Wilson offered to gather more information. HATCH requires an annual report. RTWG states would be eligible to compete within their state for available multi-state money. Geographic Representatives are to find out how this type of project works in their individual states and provide this information during the fall 2023 committee meeting.

Registration procedures were discussed.
- McClung asked was there any exception to be made to substitute another person for someone not able to attend at the last minute.
- Wilson asked that the committee vote on this during the fall 2023 meeting.
- Hardke commented to Famoso to move registration cutoff or refund to first week of January instead of first week of December.

McClung suggested that meeting attendees traveling from international locations be given time slots toward the end of the meeting to allow for potential travel plan disruptions.

Bond thanked Grettenberger, McClung, Wilson, and Linquist for their input and work to streamline the awards guidelines.

Bond provided a report on the Staff Service Award. There is not a need to create another award; faculty, staff and industry are eligible for the current Service Award. Guideline wording will be clarified to include "faculty, staff and industry personnel" to better highlight the ability to award this. Discussion of wording of award criteria.

Bond commented that panels may need to be adjusted. A Water Management panel could be created by pulling some talks from Rice Culture and from Breeding and Genetics. Discussion by entire committee. There was concern for shrinking small sessions.

Bond asked for future topics.
- Linquist asked for diversity in the committees.
- Reba suggested a symposium topic for Women in Agriculture.
- Wilson suggested to target List Serves to increase meeting attendees from other countries and new faculty from the member universities.
- Hardke suggested the use of Constant Contact in the place of List Serve for this purpose.
- Hardke reviewed the use of FormStack for RTWG payments with the ability to automatic transfers from U of A to host university every month or semi-monthly if the host university does not support FormStack.
- Scott asked was RTWG being promoted at Rice Outlook Conference.

Meeting was adjourned at 10:00 a.m.

Closing Business Meeting

Chair Jason Bond called the meeting to order at 10:00 a.m. on February 23, 2023, at the Hot Springs Convention Center in Hot Springs, AR.

Georgia Eizenga presented a report from the Rice Germplasm Committee.
- Rice Germplasm Committee met Monday, February 20, 2023, at 10:00 a.m.
- Seven of nine current members attended or sent a representative. Six of seven ex-officio members attended either in-person or via Zoom.
- Review of the collection in National Small Grains Collection totals 19,130 *Oryza* accessions with 18,918 being *O. sativa*. Other accessions were mentioned as having gone through quarantine.
- A suggestion was made to add "leaf color" descriptor and decrease panicle type descriptors from 9 to 3 in the GRIN-global database for rice.
- Committee membership approvals included Nick Bateman and Brijesh Angira re-elected and Gretchen Zaunbrecher elected to 6-year terms; Stan De Guzman to complete 6-year

- term of Xueyan Sha; Georgia Eizenga re-elected to 2-year term as Committee Chair.
- Meeting adjourned at 12:30 p.m.

Dustin Harrell presented the report from the Rice Acreage Committee.

- Rice Acreage Committee met Monday, February 20, 2023, at 3:00 p.m.
- State reports were given by a representative from each of the seven states.
- Attendees reported on what cultivars were grown in each state in 2020, 2021, and 2022, how the data were collected, new cultivars in each state, and estimates of acreage for 2023.
- Meeting adjourned at 5:10 p.m.

Bond presented report of Executive Committee.

- Growth of the meeting has continued; interest in the student competition has continued as well, therefore student competition was at the same time as two technical sessions. Committee is aware of time constraints and is looking to streamline all things.
- Proposed establishment of the Staff Distinguished Service Award – No need to establish a new award for this. Ted Wilson had made certain that the language did not restrict the award to only faculty and the description will be further clarified to include that the award is open to faculty, staff and industry personnel.
- Editing will be done to the language in all awards criteria to make clear the required submission documents.

Bond passed the gavel to Hardke as incoming RTWG Chair.

Hardke presented Bond with a plaque acknowledging his dedication as Chair of the 39th RTWG meeting.

Hardke acknowledged the retirement of Yeshi Wamishe as rice Extension pathologist at UofA Division of Agriculture.

Meeting was adjourned at 11:30 a.m.

SPECIAL COMMITTEE REPORTS

Nominations Committee

The Nominations Committee proposed the following individuals for membership on the 2025 RTWG Executive Committee and Nominations Committee:

Executive Committee:

Jarrod Hardke	Chair
Adam Famoso	Secretary
Jason Bond	Immediate Past Chair

Geographical Representatives:

Arkansas	Nick Bateman
California	Luis Espino
Florida	Matthew VanWeelden
Louisiana	Connor Webster
Mississippi	Tom Allen
Missouri	Justin Chlapecka
Texas	Ted Wilson
Industry	Mallory Everett

Nominations Committee:

Arkansas	Tommy Butts
California	Ian Grettenberger
Florida	Matthew VanWeelden
Louisiana	Brijesh Angira
Mississippi	Tom Allen
Missouri	Chase Floyd
Texas	Fugen Dou
Industry	Mallory Everett

Rice Crop Germplasm Committee

The 42nd Rice Crop Germplasm Committee (CGC) meeting was held on Monday, February 20, 2023, in Hot Springs, Arkansas. Members in attendance were Georgia Eizenga (Chair), Brijesh Angira, Teresa DeLeon, Omar Samonte, Qiming Shao, Shane Zhou, Bishwo Adhikari, Trevis Huggins, Yulin Jia, and Jack Okamuro. Members Harold Bockelman and Peter Bretting attended virtually. Members Nick Bateman, Ed Redoña, Xueyan Sha, and Gary Kinard were unable to attend. Stan De Guzman attended to represent Xueyan Sha. Guests in attendance were NanYen Chou, Adam Famoso, Dustin Harrell, Aaron Jackson, Melissa Jia, Frank Maulana, Anna McClung, Kent McKenzie, Shannon Pinson, Nirmal Sharma, and Gretchen Zaunbrecher.

The minutes of 41st Rice CGC, held virtually on February 24, 2021, due to Covid 19 travel restrictions, and subsequent addendum items were presented. Brijesh moved to approve the minutes and addendum items. The move was seconded by Omar and approved by committee members in attendance.

The report provided by Gary Kinard, USDA/ARS National Germplasm Resources Lab, was reviewed by Georgia since Gary could not attend. Personnel changes included Karen Williams, Botanist, retiring and the Plant Pathologist vacancy being advertised, and hopefully filled by summer 2023. Plant Exploration and Exchange Program guidelines for 2024 were sent to CGC chairs and are due July 3l, 2023. Several proposals approved in previous years were postponed because of the pandemic. Some of these have been rescheduled for 2023. GRIN Taxonomy, available through GRIN-Global, now represents about 16,300 taxa and includes a broad range of economically important plants, as well as thorough coverage of wild relatives of all major and minor crops. Distribution of germplasm from the NPGS to foreign scientists and international genebanks through collaboration with USDA-APHIS remains challenging, due to limited APHIS inspection personnel and global shipping issues. The GRIN-Global plant database currently includes 605,446 active accessions representing 2,565 plant genera.

Harold Bockelman, Curator of the National Small Grains Collection (NSGC), reported there are currently 150,019 accessions in the NSGC which represents the global diversity of wheat (*Triticum*), barley (*Hordeum*), oat (*Avena*), rice (*Oryza*), rye (*Secale*), triticale (*X Triticosecale*), and various wild relatives. As a point of history, the NSGC was established in 1948 and officially moved from Beltsville, MD, to Aberdeen, ID, in 1988 which took about four weeks to move about 120,000 accessions, including 15,000-16,000 *Oryza* accessions. Currently, there are 19,130 *Oryza* accessions with 18 new *O. sativa* accessions added since February 2021. Since January 1, 2021, 2,130 *Oryza* accessions have been distributed across 182 separate requests with about 1/3 distributed internationally and 2/3 to domestic customers. Kent McKenzie commented that accessions covered by a PVP certificate can be distributed once the PVP expires.

Bishwo Adhikari, USDA/APHIS Plant Germplasm Quarantine Program (PGQP), Team Lead for the *Poaceae* Quarantine Program joined in June 2021. In 2021, 37 accessions were processed through the quarantine grow-out and 12 accessions in 2022. All but one accession were imported by Trevis as detailed in his report. Due to the high sensitivity of the High-Throughput Sequencing (HTS) technology recently implemented at PGQP, several viruses have been detected to date, including endornaviruses in rice, but these are not known to be pathogenic, nor have pathogenic symptoms been observed. Endornaviruses in rice are double-stranded RNA viruses that are transmitted through seeds with no transmission to adjacent plants reported. The HTS results indicated these viruses genetically cluster by the country the rice seed was imported from and have only been found in *japonica* cultivars. Currently, PGQP is working with the APHIS policy group to summarize their findings and based on these findings it appears there is no need for regulation.

Trevis Huggins, USDA/ARS Dale Bumpers National Rice Research Center (DBNRRC), reported the Genetic Stocks-*Oryza* (GSOR) collection currently holds 38,371 accessions. Recently, a weedy red rice population, and five of the six Chromosome Segment Substitution Line (CSSL) populations with three different wild *Oryza* spp. donors in either the Cybonnet or IR64 (*O. sativa*) background were made available for distribution. The sixth CSSL population and the *Tropical Japonica* Core collection will be available soon. From January 2020 to February 2023, 35,670 accessions were distributed in 288 orders. Recently, 36 *O. australiensis* accessions were imported from the International Rice Research Institute (IRRI), brought through PGQP quarantine, and are now growing at the DBNRRC. A total of 18 NERICA (New Rice for Africa) accessions were imported from AfricaRice of which 12 are currently growing at the DBNRRC and six remain in quarantine due to endornaviruses. The program continues to rejuvenate and characterize about 1,000 accessions from the GRIN rice collection each year. Accessions are validated as true-to-type using GRIN-Global, the IRRI database and notes from Ted Johnson who evaluated the rice collection in the 1980s. If needed, seed in long-term storage at Ft. Collins is requested to verify the current seed matches the original imported sample. This is the fourth year that seed being rejuvenated is also characterized with 11 fingerprint and 18 trait specific markers. The marker data will soon be included in GRIN-Global and will serve as another basis for true to type identify as well as provide important information for end users based on the marker determination for linked traits that would otherwise not be phenotyped. Accessions that are "Redundant by Name (RBN)" continue to be evaluated to identify those accessions that can be archived and not be included in the active collection. The evaluation of the accessions that are repeated in duplicate were completed in 2021, triplicate names in 2022, and those with four or five redundant names are planned for 2023. For accessions with the same genotype and phenotype, one accession is selected for distribution and the others are archived. Lorie Bernhardt, technician in the GSOR lab, retired in December 2021, and Jonathan Moser is now in that position.

Trevis proposed adding "Leaf Blade Color" as a descriptor with six categories as done at IRRI. Brijesh motioned to approve adding this descriptor, it was seconded by Q. Shao, and supported by all committee members. Secondly, Trevis proposed using three panicle type categories (compact, intermediate, open) rather than nine categories to improve data consistency. Currently, with nine categories, the category often varies depending on the rater, as well as when the rating is done. (Harold mentioned this same issue was reported by those classifying wheat spike architecture.) According to records from Ted Johnson (1980s), there were only three categories which later was expanded to nine. After a lengthy discussion of the pros and cons of three versus nine panicle type categories, which involve both members and guests, many of whom collect panicle type as part of their breeding programs, Teresa moved to decrease the number of categories to three so the data would be more consistent. This motion was seconded by Stan and supported by the committee members. Of note, the current data with nine categories will remain part of the GRIN-Global database.

Peter Bretting USDA/ARS Office of National Programs, reported on the status of the National Plant Germplasm System (NPGS) which highlighted NPGS locations, total no. of accessions (605,000+ in 2022) with 233,00 accessions distributed in 2022. Even with various funding increases, the overall funding has stayed nearly level when adjusted for inflation. Most recently, pecan, coffee and pulse crops received funding increases. The top priorities for NPGS are maintenance, regeneration, documentation, acquisition (especially crop wild relatives), and distribution. Procedures for managing gene edited products are under development. New informational and educational resources include the development of a 3-credit course on Plant Genetic Resources (PGR) being offered through Colorado State University, and there are numerous PGR educational and training materials freely available through GRIN-University at https://grin-u.org/, as well as "Infographic posters available in six languages at http://genebanktraining.colostate.edu/trainingmaterials.html.

Minor edits were suggested to the "Rice Crop Vulnerability" slide. These edits were made by Georgia and the revised slide sent to Peter, Jack, Harold, and Gary.

Votes regarding committee membership changes included:

1) A motion by Q. Shao to have Nick Bateman and Brijesh Angira serve another six-year term, ending in 2029, which was seconded by Bishwo and supported by the committee membership.

2) A motion by Georgia that Stan De Guzman complete X. Sha's term ending in 2027, as recommended by Sha. This was seconded by Brijesh and supported by the committee membership.

3) A motion by Teresa for Gretchen Zaunbrecher (Director Genetics Lab, CCRRF) as a committee member replacing Paul Sanchez. This was seconded by Shane and supported by the committee membership.

4) A motion by Q. Shao that Georgia continue another 2-year term as committee chair. This was seconded by Shane and supported by the committee membership.

Teresa made a motion to adjourn the 42nd Rice Crop Germplasm Committee meeting. This motion was supported by Trevis and supported by the committee membership.

Rice Germplasm Committee members as of February 21, 2023 business meeting with year term ends in parentheses:

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Dr. Stanley (Omar) Samonte (2025)
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Dr. Christian (Stan) De Guzman (2027)
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Publication Coordinator/Panel Chair Committee

Publication Coordinator Michael Salassi communicated by email with the panel chairs before the 2023 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 2025 proceedings. Proceedings will be made available in electronic format on the RTWG web page when finalized.

Submitted by
Michael Salassi

Rice Variety Acreage Committee

The 42nd meeting of the Rice Technical Working Group (RTWG) Acreage Committee was called to order by Dustin Harrell at 3:30 p.m. on February 24, 2023, in Room 201 of the Hot Springs Convention Center in Hot Springs, Arkansas.

In attendance were committee members: Jarrod Hardke, University of Arkansas; Dustin Harrell of California Cooperative Rice Research Foundation; Ron Levy of Louisiana State University Agricultural Center; Hunter Bowman of Mississippi State University; Ted Wilson of Texas A&M Agrilife, Matthew VanWeelden of University of Florida; and Justin Chlapecka of University of Missouri. Guests in attendance included Yeshi Wamishe of the University of Arkansas and others.

Harrell distributed and presented the minutes of the February 24, 2020, Acreage Committee meeting and asked for a motion to accept. The motion carried.

The Louisiana report for 2021 and 2022 was given by Ron Levy. Rice acres in 2021 and 2022 were approximately 411,000 and 415,000 acres, respectively. The rice variety PVL03 represented 21% of the acres in 2022. Cercospora came in late in 2022 and reduced yields and approximately 30% of ratoon fields were not harvested. New upcoming varieties include Avant, which is a conventional long grain expected to take over Cheniere acres; Addie Joe, a high amylose line; CLL19 a Clearfield long grain; and PVL04 a new Provisia long grain. Mediun-grain acres are expected to increase in 2023.

The Arkansas report for rice acres in 2020 and 2021 was given by Jarrod Hardke. 2022 was a down year in acres with about 1.1 million acres. FullPage 7521 was the largest planted acres in Arkansas. DynaGro 263L was planted on approximately 70,000 acres. Diamond represented approximately 50,000 acres. MaxAce represented about 40,000 acres. Medium grain is expected to increase dramatically in 2023 to about 150,000 to 175,000 acres, however, there will be a medium-grain seed shortage. A new medium grain, Taurus, shows an improvement in yield. A new long grain will be released in 2023 called Ozark. A new Clearfield medium grain will be released in the near future, possibly in 2024. Arkansas is expected to have 1.25-1.3 million acres in 2023.

The California report was presented by Dustin Harrell. He reported that the California estimates are based on foundation seed sales and acres enrolled in the California Crop Improvement Association's registered and certified seed production program. In 2021, approximately 405,000 acres were planted. Medium grain accounted for 363,000 acres, short grain 35,000 acres, and long grain 7,000 acres. M-206 and M-209 were the two most widely grown varieties. In 2022, approximately 255,000 acres were grown. The reduction in acres was due to the unavailability of water because of the drought. Medium grain accounted for 218,000 acres, short grain 30,000 acres, and long grain 7,000 acres. M-206 and M-209 were the most widely grown varieties. New varieties include the release of M-521 in 2023 which is the first ROXY medium-grain variety and Calhikari-203 a new premium quality short grain.

The Texas report was presented by Ted Wilson. Data was determined by a survey respondents and USDA-FSA certified acres. Texas planted rice acres for 2021 and 2022 were approximately 186,641 and 191,648 acres, respectively. Average yields were approximately 7,241 and 7,138 in 2021 and 2022, respectively. About 70% of the acres were in RiceTec hybrids. Two new releases are expected in the near future but are currently unnamed. Both are long grains. Acres for 2023 are expected to be between 130,000 and 160,000.

The Mississippi report was given by Hunter Bowman. The rice acres were approximately 99,504 and 84,525 in 2021 and 2022, respectively. Rice acres for 2023 were projected to increase with over 110,000 acres of seed sold already at the time of the meeting. New varieties include Leeland, a conventional long grain similar to Diamond, and CLHA02, a high amylose long grain.

The Florida report was given by Matthew VanWeelden. Crop consultants with the Florida Crystals provided the estimates. 2021 and 2022 acres were approximately 23,000 and 22,000, respectively. Approximately 95 percent of the acres are long grain.

There being no further business, a motion to adjourn was passed and the meeting was adjourned at 5:10 pm.

Submitted by
Dustin Harrell

Industry Committee

The Rice Technical Working Group Industry Committee held a successful luncheon at the 39th RTWG meeting in Hot Springs, Arkansas, on Tuesday, February 21, 2023. 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 one another. Since the luncheon is open to all attendees of the Rice Technical Working Group meeting, it naturally encourages 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 2023 Industry luncheon met all these goals. The luncheon was attended by nearly 300 guests who heard Dr. Dustin Harrell, Director of the California Cooperative Rice Research Foundation – Rice Experiment, speak on 'The US Rice Industry – Our beginning, innovations, regional differences, and future challenges.' Dr. Harrell began by giving us all a well-researched history lesson on the origins of U.S. rice production. His presentation talked through many advances in production as well as regional differences between the South and the West coast. Due to his unique experiences as director of the station at both LSU and California, Dustin was able to discuss future challenges for both unique areas of rice production. Dr. Harrell presented today's challenges in rice from a national standpoint. Having current and future researchers of rice in the room for Dr. Harrell's talk was a rewarding experience for all.

The Industry Committee would like to thank Dr. Jason Bond and Dr. Jarrod Hardke for their assistance in coordinating the luncheon. The Industry Committee looks forward to hosting the next luncheon at the 40th RTWG meetings hosted by Louisiana in 2025.

Submitted by
Mallory Scott

2020 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2019 Acreage	2020 Acreage	MEDIUM GRAIN			LONG GRAIN								
			Jupiter	Titan	Others[2]	CLL15	Diamond	RT 7301	RT 7321 FP	RT 7521 FP	RT CLXL745	RT Gemini 214 CL	RT XP753	Others[2]
Arkansas	74,687	88,601	422	1,238	2,779	403	6,126	6,733	3,921	7,544	2,089	22,902	28,520	5,922
Ashley	5,409	12,420	0	0	0	0	0	0	0	0	381	3,049	731	8,259
Chicot	17,880	27,929	0	0	0	7	28	0	0	14,821	7	4,341	6,310	2,417
Clark	1,860	3,764	0	0	0	0	0	0	0	0	683	0	3,081	0
Clay	64,931	75,751	3,553	293	151	5,293	5,930	5,462	4,379	5,933	4,129	12,892	11,929	15,807
Craighead	53,183	60,812	4,590	2,573	823	5,974	5,638	3,549	2,879	4,542	3,009	13,871	8,412	4,952
Crittenden	43,743	58,763	95	5,107	0	0	1,293	8,026	2,841	4,501	549	5,954	28,924	1,474
Cross	71,600	86,464	6,658	3,008	2,313	3,836	11,602	830	2,901	15,272	2,000	24,531	10,031	3,483
Desha	20,399	38,783	0	2,764	0	458	1,255	988	6,360	3,995	1,933	5,165	2,804	13,060
Drew	9,137	16,352	0	0	0	0	0	2,665	1,390	3,427	1,315	3,826	967	2,762
Greene	58,606	61,313	2,577	863	0	3,069	4,789	5,274	1,918	7,106	0	13,770	18,166	3,780
Independence	5,311	10,977	526	526	0	3,308	0	6,617	0	0	0	0	0	0
Jackson	66,127	98,580	5,300	4,531	1,454	6,701	11,684	12,384	1,898	4,978	2,175	26,531	14,134	6,810
Jefferson	51,730	75,827	1,939	1,410	176	16,953	8,490	80	0	12,038	7,090	5,691	9,119	12,841
Lafayette	3,456	4,030	0	0	0	0	1,539	0	0	0	0	0	2,490	0
Lawrence	76,188	81,514	4,359	8,269	156	2,892	9,499	8,201	1,723	6,220	4,663	7,044	24,097	4,391
Lee	16,670	24,294	816	0	0	768	15,779	615	0	0	0	3,914	1,552	849
Lincoln	17,466	30,177	0	0	0	0	0	1,698	2,463	0	12,447	13,568	0	0
Lonoke	65,728	92,448	3,891	0	0	237	2,264	8,640	2,785	9,547	2,116	34,822	21,461	6,684
Mississippi	56,313	67,237	1,963	0	656	2,389	11,955	5,181	1,923	1,277	1,262	19,375	14,660	6,595
Monroe	39,999	54,818	1,576	1,424	0	4,307	13,523	1,414	0	2,198	600	18,637	6,729	4,410
Phillips	26,920	37,301	726	0	0	0	11,234	10,381	0	2,275	4,608	0	8,077	0
Poinsett	94,753	116,444	20,357	1,710	4,790	7,474	24,820	22	3,102	19,821	6,083	7,080	6,450	14,736
Pope	1,898	4,320	0	0	0	254	0	0	0	0	0	0	0	4,066
Prairie	53,623	58,605	3,235	594	0	2,273	3,179	1,091	6,077	7,961	4,815	15,006	13,403	969
Pulaski	2,894	6,709	453	453	0	0	0	0	0	0	0	5,803	0	0
Randolph	27,582	33,990	4,679	2,730	390	0	0	735	0	6,920	3,568	10,304	4,665	0
St. Francis	34,508	38,979	295	487	694	994	3,655	246	2,916	12,933	1,714	972	13,804	268
White	7,871	6,726	113	0	0	0	2,080	759	774	873	137	1,533	455	0
Woodruff	49,495	52,163	1,718	144	0	1,608	6,007	567	2,641	7,131	0	20,985	7,160	4,201
Others[3]	2,855	9,373	155	0	0	973	1,423	0	0	0	878	1,253	3,418	1,273
Unaccounted[4]	3,179	5,538												5,538
2020 Total		1,441,000	69,997	38,124	14,384	70,173	163,792	92,158	52,891	161,312	68,253	302,820	271,549	135,547
2020 Percent		100.00	4.86	2.65	1.00	4.87	11.37	6.40	3.67	11.19	4.74	21.01	18.84	9.41
2019 Total	1,126,000		106,892	73,490	6,665	715	122,922	0	0	0	108,791	168,302	288,046	250,177
2019 Percent	100.00		9.49	6.53	0.59	0.06	10.92	0.00	0.00	0.00	9.66	14.95	25.58	22.22

[1] Harvested acreage. Source: USDA-NASS, 2021.
[2] Other varieties: PVL01, PVL02, CL153, CL151, CLM04, CL111, RT 7801, LaKast, AB647, ARoma 17, RT CLXP756, RT 7501, CL163, Roy J, Cheniere, CLL16, Jazzman-2, Lynx, Jewel, Jazzman, and Wells.
[3] Other counties: Conway, Faulkner, Franklin, Hot Springs, Little River, Logan, Miller, Perry, and Yell.
[4] Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and estimates obtained from each county FSA.

2021 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2020 Acreage	2021 Acreage	MEDIUM GRAIN Jupiter	MEDIUM GRAIN Titan	MEDIUM GRAIN Others[2]	LONG GRAIN CLL15	LONG GRAIN CLL16	LONG GRAIN DG263L	LONG GRAIN Diamond	LONG GRAIN RT 7301	LONG GRAIN RT 7321 FP	LONG GRAIN RT 7521 FP	LONG GRAIN RT XP753	LONG GRAIN Others[2]
Arkansas	88,601	70,089	652	179	502	762	2,403	1,962	3,035	137	21,693	14,805	17,405	6,553
Ashley	12,420	7,968	0	0	0	0	890	0	0	0	5,997	0	540	540
Chicot	27,929	18,314	0	0	0	0	0	0	0	0	5,409	5,091	2,706	5,107
Clay	75,751	69,757	4,744	105	313	3,079	3,347	4,239	4,527	0	16,288	14,316	10,035	8,766
Craighead	60,812	61,454	4,191	1,601	1,827	1,560	3,349	2,317	2,999	0	21,513	5,166	9,828	7,103
Crittenden	58,763	37,723	1,858	619	0	0	0	1,703	705	3,208	6,912	8,369	14,325	24
Cross	86,464	69,404	1,987	1,913	3,413	1,261	4,507	2,529	5,525	665	18,808	14,505	12,051	2,239
Desha	38,783	18,616	0	0	0	11	197	0	123	0	8,592	6,127	891	2,674
Drew	16,352	8,866	0	0	0	0	0	0	768	0	3,334	2,850	1,859	54
Greene	61,313	68,721	4,092	0	0	0	2,430	14,420	810	655	20,665	0	24,992	655
Independence	10,977	9,071	793	264	0	0	0	0	2,565	0	0	5,450	0	0
Jackson	98,580	93,444	5,861	10,304	17	2,115	1,733	443	12,408	663	14,589	12,899	19,692	12,719
Jefferson	75,827	48,426	1,369	456	0	0	1,307	8,473	808	0	14,927	18,465	32	2,587
Lawrence	81,514	102,192	6,243	11,661	0	5,587	2,458	6,507	10,131	4,362	22,209	4,955	27,693	386
Lee	24,294	11,527	84	0	0	0	0	394	914	1,109	1,977	1,318	5,731	0
Lincoln	30,177	17,129	0	0	0	0	0	0	358	0	10,348	5,552	872	0
Lonoke	92,448	75,811	2,969	0	692	3,066	744	458	0	6,640	15,951	18,608	23,873	2,809
Mississippi	67,237	56,771	1,009	0	0	0	0	2,129	2,398	56	9,256	13,806	27,556	560
Monroe	54,818	39,304	994	331	0	1,450	1,729	1,119	1,857	4,148	7,803	8,858	9,784	1,231
Phillips	37,301	15,613	0	0	0	0	0	0	1,849	4,520	0	0	9,244	0
Poinsett	116,444	95,617	14,436	2,114	4,803	2,133	8,651	2,757	11,453	0	11,048	19,159	10,783	8,280
Prairie	58,605	52,027	709	410	0	911	1,900	1,009	1,397	530	19,199	14,474	10,778	711
Pulaski	6,709	3,351	0	0	0	0	0	0	0	1,060	1,175	0	0	1,116
Randolph	33,990	37,409	35	11,159	0	0	600	2,348	2,113	1,174	5,811	2,994	7,090	4,086
St. Francis	38,979	30,244	503	205	0	22	636	1,413	4,139	777	5,288	8,652	8,089	518
White	6,726	4,756	135	0	0	0	0	0	1,768	0	1,486	624	743	0
Woodruff	52,163	48,912	1,734	438	0	593	1,935	3,093	458	383	15,352	20,528	4,153	244
Others[3]	21,486	19,896	0	0	0	124	3,161	0	1,585	0	1,268	1,500	7,045	5,214
Unaccounted[4]	5,538	1,586												1,586
2021 Total		1,194,000	54,400	41,761	11,567	22,674	41,978	57,313	74,693	30,088	286,902	229,071	267,792	75,763
2021 Percent		100.00	4.56	3.50	0.97	1.90	3.52	4.80	6.26	2.52	24.03	19.19	22.43	6.35
2020 Total	1,441,000		69,997	38,124	14,384	70,173	1,151	0	163,792	92,158	52,891	161,312	271,549	505,469
2020 Percent	100.00		4.86	2.65	1.00	4.87	0.08	0.00	11.37	6.40	3.67	11.19	18.84	35.08

[1] Harvested acreage. Source: USDA-NASS, 2022.
[2] Other varieties: ARoma17, CL111, CL151, CL153, CLL17, CLM04, Jazzman-2, Jewel, LaKast, Lynx, ProGold1, ProGold2, PVL02, PVL03, Roy J, RT 7401, RT 7501, RT 7801, RT CLXL745, and RT Gemini 214 CL.
[3] Other counties: Clark, Conway, Faulkner, Franklin, Hot Springs, Lafayette, Little River, Logan, Miller, Perry, Pope, and Yell.
[4] Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and estimates obtained from each county FSA.

2022 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2021 Acreage	2022 Acreage	MEDIUM GRAIN			LONG GRAIN						
			Jupiter	Titan	Others[2]	CLL16	DG263L	Diamond	RT 7321 FP	RT 7521 FP	RT XP753	Others[2]
Arkansas	70,089	65,448	2,197	1,071	0	1,188	4,902	303	7,402	30,633	13,872	3,880
Ashley	7,968	4,563	0	0	0	913	0	0	0	2,282	1,369	0
Chicot	18,314	18,186	0	0	0	0	0	0	11,075	4,814	2,296	0
Clay	69,757	62,298	225	2,127	0	3,277	3,503	1,460	9,746	23,391	1,977	16,592
Craighead	61,454	50,276	6,890	0	380	11,844	1,266	0	10,868	15,285	1,615	2,127
Crittenden	37,723	29,139	1,738	0	0	0	4,405	6	3,060	7,141	10,765	2,024
Cross	69,404	54,413	758	2,221	2,477	1,814	4,871	1,954	8,055	22,755	5,812	3,696
Desha	18,616	18,447	0	186	0	5	392	8	659	1,818	14,069	1,310
Drew	8,866	10,267	0	0	0	0	1,794	5	0	1,290	6,870	308
Greene	68,721	55,281	2,269	685	0	1,345	20,163	8,590	1,966	897	10,948	8,417
Independence	9,071	8,904	650	325	325	1,521	760	0	1,521	1,521	2,281	0
Jackson	93,444	84,101	15,496	748	954	1,653	3,040	13,194	8,796	8,278	18,738	13,205
Jefferson	48,426	54,861	0	2,301	0	0	2,813	8,242	15,470	25,642	33	360
Lawrence	102,192	75,582	0	8,652	1,688	0	5,838	24	13,263	7,171	34,387	4,559
Lee	11,527	12,749	323	0	0	0	6,955	1,199	0	3,373	0	899
Lincoln	17,129	20,060	0	0	0	0	6,070	0	7,731	5,457	0	802
Lonoke	75,811	84,168	7,782	1,342	0	1,037	379	0	2,573	35,842	26,098	9,115
Mississippi	56,771	43,194	1,465	0	0	0	5,755	492	13,660	18,994	2,828	0
Monroe	39,304	40,834	0	632	0	7,167	7,300	0	3,061	13,941	5,570	3,163
Phillips	15,613	19,955	271	0	271	0	11,296	4,351	0	3,765	0	0
Poinsett	95,617	81,464	5,082	3,557	3,767	13,792	6,507	13,009	8,120	17,768	3,266	6,597
Prairie	52,027	50,771	871	213	720	2,105	5,408	1,315	9,385	20,111	8,053	2,590
Pulaski	3,351	5,219	261	0	261	0	0	0	0	2,966	0	1,732
Randolph	37,409	28,629	1,719	5,221	244	0	6,575	0	5,108	4,064	5,091	608
St. Francis	30,244	26,630	257	257	0	647	2,023	801	5,247	11,026	5,254	1,117
White	4,756	6,086	0	0	0	0	734	0	1,928	3,424	0	0
Woodruff	48,912	46,662	691	166	0	4,660	4,874	1,053	9,397	24,452	0	1,369
Others[3]	19,896	24,306	201	0	0	591	0	3,512	331	4,633	12,053	2,985
Unaccounted[4]	1,586	1,505										1,505
2022 Total		1,084,000	49,146	29,702	11,088	53,560	117,623	59,516	158,421	322,737	193,247	88,959
2022 Percent		100.00	4.53	2.74	1.02	4.94	10.85	5.49	14.61	29.77	17.83	8.21
2021 Total	1,194,000		54,400	41,761	11,567	41,978	57,313	74,693	286,902	229,071	267,792	128,525
2021 Percent	100.00		4.56	3.50	0.97	3.52	4.80	6.26	24.03	19.19	22.43	10.76

[1] Harvested acreage. Source: USDA-NASS, 2023.
[2] Other varieties: ARoma17, ARoma22, CL151, CLL15, CLL17, CLM04, Jazzman-2, Jewel, Lynx, ProGold1, ProGold2, PVL03, RTv7231 MA, RT 7301, RT 7331 MA, RT 7401, RT 7501, and RT 7801.
[3] Other counties: Clark, Conway, Faulkner, Franklin, Hot Springs, Johnson, Lafayette, Little River, Logan, Miller, Perry, Pope, and Yell.
[4] Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and estimates obtained from each county FSA.

2021 and 2022 California Rice Acreage Summary.

Variety	2021			2022		
	Seed Acres†	Percentage	Estimated Acres‡	Seed Acres†	Percentage	Estimated Acres‡
Medium Grain						
M-105	2,945	12.1	48,808	2,645	13.8	35,279
M-206	8,172	32.4	131,382	5,332	27.9	71,119
M-209	4,665	20.5	82,957	2,506	13.1	33,429
M-210	2,053	8.4	33,944	1,725	9.0	23,013
M-211	1,542	6.5	26,232	2,729	14.3	36,401
M-401	1,136	4.6	18,790	407	2.1	5,428
Total RES-Medium	20,513	84.5	342,113	15,343	80.3	204,669
Non-RES Medium	1,400	5.2	20,887	999	5.2	13,331
Total Medium Grain	21,913	89.6	363,000	16,343	85.5	218,000
Short Grain						
CA-201	1	0.04	143	7	0.1	170
CH-201	50	0.2	707	46	0.4	1,126
CH-202	145	0.5	2,067	232	2.2	5,622
CM-101	484	1.9	7,525	106	1.0	2,569
CM-203	346	1.5	5,889	193	1.8	4,689
S-102	198	0.7	2,816	256	2.4	6,206
S-202	16	0.1	221	2	0.02	54
Total RES -Short	1,238	4.8	19,368	842	8.0	20,436
Non-RES Short	613	3.9	15,632	394	3.8	9,564
Total Short Grain	1,851	8.6	35,000	1,236	11.8	30,000
Long Grain						
A-201	241	0.5	1,987	206	0.6	1,476
A-202	220	0.4	1,814	214	0.6	1,540
CJ-201	79	0.2	652	276	0.8	1,984
CT-202	17	0.0	140	18	0.1	129
L-205	20	0.0	167	46	0.1	331
L-207	207	0.4	1,707	155	0.4	1,114
L-208	10	0.0	78	19	0.1	134
Total RES -Long	794	1.6	6,545	934	2.6	6,710
Non-RES Long	1	0.0	455	40	0.1	290
Total Long Grain	795	1.7	7,000	974	2.7	7,000
USDA-NASS Acres						
Medium			363,000			218,000
Short			35,000			30,000
Long			7,000			7,000
TOTAL			405,000			255,000

† Seed acres represent the number of approved seed acres in the California Crop Improvement seed certification program.

‡ Estimated acres were determined by using the percent acres in seed production and the total reported USDA-NASS acres.

Florida Rice Acreage Report, 2021 and 2022

Variety	2021		2022	
	Acreage	Percentage	Acreage	Percentage
Medium Grain				
Titan	839	4	1,387	6
Total Medium Grain	839	4	1,387	6
Long Grain				
Cheniere	1,125	5	1,760	8
DG263L	642	3	549	2
Diamond	7,189	31	8,136	36
Jewel	758	3	9,355	41
LaKast	7,601	33	0	0
Mermentau	1,232	5	0	0
Mixed	221	1	0	0
Rex	2,269	10	0	0
RT7323	0	0	137	1
RT7401	42	<1	34	<1
XP754	1,139	5	1,376	6
Total Long Grain	22,218	96	21,347	94
TOTAL	**23,057**		**22,734**	

Louisiana Rice Varieties and Acres

Rice Varieties 2021		
Milagro	530	0.14
Cheinere	57434	15.39
Cocodrie	1149	0.31
Diamond	3640	0.98
DG 263 L	5337	1.43
Mermentau	36559	9.80
Thad	166	0.04
Blanca Isabel	7	0.00
CLJ01	2161	0.58
CL111	13760	3.69
CL151	6590	1.77
CL153	20195	5.41
CL163	2355	0.63
CL172	0	0.00
CLL15	251	0.07
CLL16	40	0.01
CLL17	31981	8.57
PVL02	44144	11.83
PVL03	3370	0.90
RT7301	6373	1.71
RT7501	12855	3.44
XL723	1620	0.43
XP753	28665	7.68
CLXL745	69505	18.63
Gemini214 CL	5904	1.58
RT7321 FP	19964	5.35
RT7521 FP	11436	3.06
Hybrid Seed Prod.	4073	1.09
Total Long Grain	373154	0.90
Jupiter	29449	76.42
Titan	7386	19.17
CLM04	1701	4.41
Total Medium Grain	38536	0.10
Total Acres	411690	

Rice Varieties 2022		
Milagro	235	0.06
Cheinere	48083	13.08
Diamond	2085	0.57
DG 263 L	25288	6.88
Mermentau	31688	8.62
Della2	512	0.14
Jazzman	1749	0.48
CLJ01	3130	0.85
CL111	4234	1.15
CL151	7604	2.07
CL153	2019	0.55
CLL16	4758	1.29
CLL17	40630	11.05
RTv7231 MA	18967	5.16
PVL02	2769	0.75
PVL03	78971	21.48
RT7301	11042	3.00
RT7501	1250	0.34
RT7801	1242	0.34
XP753	17291	4.70
RT7421	1497	0.41
RT7523	7766	2.11
RT7321	36563	9.94
RT7521	12762	3.47
RT7331 MA	1837	0.50
Della2	512	0.14
Jazzman	1749	0.48
CLJ01	3130	0.85
Total Long Grain	366670	88.24
Jupiter	25204	51.56
Titan	22220	45.45
CLM04	1464	2.99
Total Medium Grain	48886	11.76
Total Acres	415556	

Mississippi – 2021 and 2022 Rice Summary Table.

Certified Acreage All Rice

County	Acreage 2021	Acreage 2022
Bolivar	27,698	23,500
Coahoma	7,257	4,482
DeSoto	585	770
Grenada	197	233
Holmes	0	154
Humphreys	2,478	398
Issaquena	101	271
Leflore	4,105	4,793
Panola	5,147	5,759
Quitman	4,293	6,807
Sharkey	186	0
Sunflower	10,816	8,179
Tallahatchie	5,564	4,967
Tate	682	948
Tunica	22,126	18,596
Washington	8,272	4,669
Total	99,504	84,525

Variety	Acreage 2022	Acreage Projected 2023
CLL15	3800	2,000
CLL16	5400	8,000
PVLO3	400	920
Other Horizon	405	6,670
RT 7321 FP	11,900	16,100
RT 7521 FP	17,700	24,150
XL 753	20,575	28,175
Other RiceTec	8,850	12,075
DG263L	12,500	17,250
Diamond	1,500	1800
Other public	1,495	1,500

2021-2022 Missouri Rice Acreage Report					
	2021			2022	
Variety	Percentage	Acres		Percentage	Acres
Long Grain	98.0	190,120		98.0	146,015
Hybrids	68.0	131,920		65.5	97,595
Conventional					
XP753	18.0	34,920		15.8	23,542
RT7401	2.0	3,880		2.1	3,129
RT7301	2.0	3,880		1.4	2,086
FullPage					
RT7521 FP	22.0	42,680		22.4	33,376
RT7321 FP	24.0	46,560		21.7	32,333
RT7421 FP	-	-		0.7	1,043
RT7523 FP	-	-		0.7	1,043
MaxAce					
RT7331 MA	-	-		0.7	1,043
Varieties	30.0	58,200		32.5	48,420
Conventional	14.7	28,547		21.8	32,467
DG263L	3.1	6,014		16.0	23,840
Diamond	7.0	13,580		4.5	6,705
Others	4.6	8,943		1.3	1,922
Clearfield	12.1	23,538		7.5	11,152
CLL15	3.1	6,019		0.8	1,125
CLL16	7.1	13,747		5.6	8,273
CLL17	0.4	734		0.1	203
CL111	0.3	531		0.1	96
CL151	0.4	743		0.4	552
CL153	0.1	111		-	-
CL163	0.9	1,653		0.3	510
CLHA02	-	-		0.3	393
Provisia/MA	1.2	2,235		1.2	1,821
PVL02	0.8	1,459		-	-
PVL03		0		0.5	778
RTv7231 MA	0.4	776		0.7	1,043
Specialty	2.0	3,880		2.0	2,980
Jazzman-2	2.0	3,880		2.0	2,980
Medium Grain	2.0	3,880		2.0	2,980
Jupiter	1.5	2,910		1.5	2,235
CLM04	0.1	111		-	-
Titan	0.4	854		0.5	745
Total Acreage	100.0	194,000		100.0	149,000

2022 Texas Rice Acreage by Variety

[Combined]

Update:11/10/2022

Percent Variety Acres By County

COUNTY	2021 ACREAGE	2022* ACREAGE	ACREAGE Change	% MC Ratooned	LONG GRAIN																						MEDIUM	OTHER*
					XL73	XL723	XL753	CL153	RT73	RTV7	JASM	XL74	PRES	DG26	CL151	CHEN	RT75	XL75	DIXI	CLL17	RT75	Dina	PVL03	TEXM	RT73	RT75	JUPI	
East Zone																												
Brazoria	18452	16172	-12.4%	8																								
Chambers	27921	27514	-1.5%	11	5.6		36.6				21.8	14.1															21.8	
Galveston	777	1653	112.7%																									
Hardin	571	642	12.4%																									
Jefferson	24689	26916	9.0%	50	81.1					18.9																		
Liberty	6921	7510	8.5%	33	31.1		16.4			52.5																		
Orange																												
East	**79331**	**80407**	**1.4%**	**26**	**41.5**		**18.3**			**14.6**	**9.7**	**6.3**															**9.7**	
Northwest Zone																												
Austin	1532	1341	-12.5%	0		100																						
Colorado	33413	36990	10.7%	49		54.6	12.3		24.4			2.3					6.1									0.2		
Fort Bend	2415	1995	-17.4%	70	39.7								25.3						25.9					9.2				
Harris	267	73	-72.7%	0			100																					
Lavaca	3700	3668	-0.9%	67		100																						
Robertson	176																											
Waller	3796	3808	0.3%	81	74.7		14.8			7.2															3.4			
Wharton	36700	39176	6.7%	65	20.2	4.8	11.8	23.7	11.8			3		1.9	8.1		0.7	6.2	1.2	0.6	1.2	1.1	0.6					3.1
Lamar																												
Brazos	97	58	-40.2%																									
NorthWest	**82096**	**87109**	**6.1%**	**58**	**13.3**	**31.1**	**11.3**	**10.7**	**15.7**	**0.3**		**2.3**	**0.6**	**0.8**	**3.6**		**2.9**	**2.8**	**1.1**	**0.3**	**0.6**	**0.5**	**0.3**	**0.2**	**0.1**	**0.1**		**1.4**
Southwest Zone																												
Calhoun	2800	4220	50.7%																									
Jackson	8992	8902	-1.0%	82		20.9		43.4				4.2	18.3			7.4				5.8								
Matagorda	10795	9643	-10.7%	45	6.2	11.6	40.4							26.5		15.4												
Victoria	1498	1272	-15.1%	100									100															
Cameron	139																											
SouthWest	**24224**	**24038**	**-0.8%**	**65**	**3**	**15**	**19.6**	**19.5**				**1.9**	**14.7**	**12.9**		**10.8**				**2.6**								
Northeast Zone																												
Bowie	990	95	-90.4%																									
Hopkins																												
Red River																												
Northeast	**990**	**95**	**-90.4%**																									
State	**186641**	**191648**	**2.7%**	**45**	**23.9**	**16**	**15.3**	**7.3**	**7.1**	**6.3**	**4.1**	**3.9**	**2.1**	**2**	**1.7**	**1.4**	**1.3**	**1.3**	**0.5**	**0.5**	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0**	**4.1**	**0.6**

*Acreage Source: USDA/CFSA Certified Acreage

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2022 Texas Main Crop Combined Yields by Variety (State)

[Main Crop]

[Combined]

[State]

Variety	Variety Type	2022						2021					
		Number Of Fields Report	Reported Acreaged	Yield lbs./Acre	Milling Yield %H	Milling Yield %T	Grade	Number Of Fields Report	Reported Acreaged	Yield lbs./Acre	Milling Yield %H	Milling Yield %T	Grade
RT7321FP	Hybrid	120	13125	8405	53.0	70.7	2.0	86	7556	8472	56.0	72.5	2.0
XL723	Hybrid	102	8697	4439	51.7	69.0	2.4	96	9374	4721	57.4	70.6	2.0
XL753	Hybrid	64	7123	7371	54.0	70.4	2.0	93	8780	8129	56.9	72.7	2.0
CL153	Inbred	43	3981	7234	57.3	69.7	2.1	46	4949	7117	60.1	70.4	2.0
CLXL745	Hybrid	27	2803	8016	59.7	72.9	2.0	76	7718	7848	59.7	72.6	2.0
CL151	Inbred	14	1299	7710	55.2	70.0	2.0	13	1289	8134	58.8	71.1	2.0
RT7521FP	Hybrid	16	1203	8461	49.9	68.6	2.2	14	1207	8767	58.4	72.3	2.0
RT7401	Hybrid	9	824	5779	50.5	69.4	2.3	6	520	9152	58.3	72.1	2.0
CLL17	Inbred	5	645	7206	56.5	68.4	2.0	11	828	7244	59.0	69.2	2.0
RT7523FP	Hybrid	5	583	8466	50.8	70.1	2.0						
DG263L	Inbred	8	535	8276	58.6	68.4	2.0	12	712	8268	58.0	69.4	2.0
RTv7231MA	Inbred	10	529	6685	52.7	70.2	2.0	1	47	6979	58.0	70.0	3.0
Cheniere	Inbred	5	400	4948	61.0	71.3	2.7	10	743	6700	63.5	72.2	2.1
RT7331MA	Hybrid	6	354	9118	57.0	72.0	2.0	1	35	9694	59.0	73.0	2.0
PVL03	Inbred	3	285	6498	58.6	70.8	2.0						
Gemini 214CL	Hybrid	4	260	6312	53.5	69.3	2.0	3	220	8629	57.3	69.5	2.0
RT7301	Hybrid	3	245	8198	46.9	69.2	2.4						
CLL16	Inbred	2	130	7655	50.6	67.5	2.0	2	160	7324	50.7	70.0	2.7
Presidio	Inbred	1	110	6334	35.0	69.0	2.0	13	1217	5904	56.4	69.9	2.3
Trinity	Inbred	1	100	7797	63.0	70.0	2.0						
PVL02	Inbred							4	262	5789	62.6	70.8	2.0
Texmati	Inbred							1	70	2966	56.0	72.0	2.0
CL163	Inbred							1	22	9369	62.0	73.0	2.0
Total		448	43230	7133	53.8	70.1	2.1	489	45708	7241	57.9	71.6	2.0

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RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

X. SHA, Chair; A. FAMOSO and C. DE GUZMAN, Moderators; B. ANGIRA, E. BELLIS, A. BORJAS, P. COUNCE, T. DE LEON, J. EDWARDS, G. EIZENGA, R. FRITSCHE-NETO, X. GU, T. HUGGINS, Y. JIA, J. KEPIRO, A. MCCLUNG, K.S. MCKENZIE, P. MOSQUERA, D. NORTH, S. PINSON, A. RIVERA, J. RICHARDS, J. ROHILA, S. SAMONTE, D. SANCHEZ, Q. SHAO, N. SHARMA, G. SINGH, P. SUBUDHI, T. TAI, M. THOMSON, R. UNAN, and G. ZAUNBRECHER, Participants.

Issues/Recommendations:

1. The Puerto Rico winter nursery is critical for Southern U.S. rice breeding programs for generation advancement, fast-track seed increase and purification of new variety releases. Due to decreased discretionary funding resulting from declining rice acreage and the accompanied decline in check-off funds, as well as increased costs due to inflation, the panel recommends acquiring long-term support and maintaining open access to the winter nursery facilities in Puerto Rico.

2. The rice research community in the USA is small relative to other cereal grains and to other major rice producing countries. In order to assure sustainability of USA rice production, the panel recommends additional funding to support a coordinated multi-state genetic improvement project using molecular breeding techniques that will increase the speed of development of varieties that meet the demands of domestic and international markets (e.g. conventional rice, aromatics, premium medium grain, etc.).

3. The current USA regulatory framework for genome editing is causing gene editing research in the USA to not keep pace with global research and breeding progress by imposing undue constraints, such as limiting editing to one mutation at a time. The panel recommends regulatory agencies adjust current restrictions to incorporate feedback from the scientific community. Moreover, the APHIS Biotechnology Regulatory Services website needs to be streamlined and updated in a timely manner to provide clear guidance to researchers and breeders who are working with gene edited products. Federal funding should also be made available to support a public education component to encourage acceptance of gene editing in the USA and worldwide for both growers and consumers, as this will be needed for future commercialization and export of gene-edited rice commodities.

4. The rice research community in the USA needs greater support for translating basic knowledge and new discoveries into applied solutions. The identification of genes and gene interactions (biochemical pathways, physiology) that influence traits with economic significance is a crucial first step in this effort. Such traits include, but are not limited to, resistance to biotic and abiotic stresses that constrain present and future U.S. rice production scenarios (such as climatic changes and consumer/processor demands). Databases are essential to help bridge the gap between gene discovery and application for varietal improvement. Specifically, breeder friendly databases are needed that link genes and their associated sequence variants/haplotypes with (predicted or experimentally determined) effects on economically important traits, and selection for molecular markers linked to desirable gene haplotypes would accelerate and enhance rice breeding programs.

ECONOMICS AND MARKETING

B. WATKINS, Chair; A. DURAND-MORAT, L NALLEY, R. MANE, K. GUIDRY, and G. ATUNGULU, Participants.

Supply/Production Research

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

Economic investigation of arsenic and/or other heavy metals in rice production.

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

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

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

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

Analyze the feasibility of U.S. rice producers to adopt varieties of rice that are imported.

Explore the impact of lost premium due to losing identity preservation.

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

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

Analyze consumer preferences for different rice varieties. See how these preferences change across demographics.

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

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

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

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

PLANT PROTECTION

N. BATEMAN, Chair; F. DALLA LANA, Chair-Elect (2023); T.W. ALLEN, X.-G. ZHOU, Y. JIA, Y. WAMISHE, and L. ESPINO.

The main recommendations for each of the groups that comprise the plant protection panel (entomology (insects and other animal pests) and plant pathology (diseases) are listed below by discipline. In addition, a single statement was made by the entirety of the group regarding the future of our combined disciplines.

Diseases
The principal objectives of basic and applied rice disease research in the United States include a more comprehensive understanding of the biology and epidemiology of diseases and the molecular mechanisms involved in the host pathogen relationship, determining specifics regarding pathogenesis within each pathogen system, and host resistance to rice pathogens. In addition, continuing to monitor for fungicide resistance as well as developing new management strategies in those areas where resistance is detected. Consequently, an effective and integrated disease management program relying on disease-resistant germplasm, cultural practices, and chemical control based on cooperative research with scientists in agronomy, entomology, weed science, and molecular biology should be the main goal of the group. If advances are made in the understanding and application in biological, microbiome manipulation, or molecular-genetic control aspects, these factors should be developed and incorporated into the program.

Major yield and quality reducing diseases occurring in the U.S. causing damage to the rice crop on an annual basis currently includes 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); rice blast, caused by *Pyricularia oryzae* Cavara = *P. grisea* Sacc. (teleomorph: *Magnaporthe grisea* (Hebert) Barr); and kernel smut, caused by *Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc. = *Neovossia horrida* (Takah.) Padwick & A. Khan. Seed rot and seedling diseases continue to cause major stand establishment problems in both water- and dry-seeded systems and in organic production systems, especially with the trend towards earlier planting dates. In water-seeded systems, *Achlya* and *Pythium* spp. are important while *Pythium*, *Rhizoctonia, Fusarium,* and possibly *Bipolaris*, and additional fungi have been considered important in dry-seeded rice in the southern U.S. Straighthead, a physiological disease, remains a major problem in certain geographic areas.

Rice diseases that are more locally important or may occur more infrequently 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.), and and bacterial panicle blight, caused by *Burkholderia glumae* Kurita & Tabei and *B. gladioli* Saddler. White tip, a nematode disease of rice caused by *Aphelenchoides besseyi*

Christie, remains an economic constraint to rice exports in the southern U.S. although direct yield and quality losses in the field remain minor. Peck of rice, caused by a poorly defined complex of fungi and possibly additional microbes in concert with rice stinkbug feeding, remains a problem in certain areas and years.

Currently, the minor diseases of rice 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. In addition, limited information exists on some of the "newer" observations of specific organisms including: *Athelia rolfsii,* and *Marasmius graminum* (sterile white basidiomycetes fungus) which to date has only been observed in a limited geography. In the 1990s, a minor and confusing strain of *Xanthomonas* was observed causing symptoms on rice in parts of Louisiana and Texas. Originally identified as a weakly virulent strain of *Xanthomonas oryzae* Ishiyama pv. *oryzae* Swings (*Xoo*), the cause of bacterial leaf blight in other parts of the world, recent information suggests this strain differs from *Xoo*. In 2021 and 2022, rice bacterial blight disease, caused by *Pantoea ananatis*, was identified in research plots in Arkansas. The disease was characterized by spreading and coalescing lesions on leaves, panicle sterility and reduced yield in highly susceptible, mature rice germplasm. No spread of the disease to nearby plants was observed. *P. ananatis* was also recovered from several similarly diseased rice breeding lines.

Three recently identified foliar diseases, brown leaf spot caused by *Curvularia hawaiiensis*, leaf spot caused by *Epicoccum sorghum*, and Fusarium sheath rot caused by *Fusarium incarnatum-equiseti*, have been identified to be present in Texas. However, their distribution and economic importance need to be investigated throughout the rice growing region. Miscellaneous diseases and problems of currently unknown causal organisms are scattered in the rice growing regions of the U.S. 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 issues.

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

1. Cooperation with breeding programs should be continued for improved disease resistance within rice varieties and hybrids to be released. Screening programs should use coordinated efforts to include evaluations in the field and greenhouse and integrate the current molecular techniques in the laboratory as well as considering the use of genetic markers to identify and incorporate resistance genes. Diseases to be given significant priorities include rice blast, sheath blight, bacterial panicle blight, narrow brown leaf spot, kernel smut, stem rot, aggregate sheath spot, and false smut. Novel sources of resistance should be identified and developed for incorporation into rice germplasm and hybrids/varieties.

2. Research must be initiated and continued to develop biological strategies to manage rice diseases and continue efforts at reducing the dependency on chemical control options.

Other specific priority areas should include:

1. Systematic and coordinated field monitoring and diagnostics should be established and continued on a long-term basis within rice-producing states to detect new pathogens or potential changes within the existing pathogen complex. Yearly surveys on the genetic makeup of blast, including the composition of blast avirulence genes in blast nurseries and commercial fields in each state, should be conducted to support existing and future research and Extension programs, including breeding for improved resistance using the identified major resistance genes.

2. A comprehensive testing program focused on new and existing chemical management options should be continued with regional coordination where available. A better understanding of chemical efficacy and economic return under realistic field conditions should be emphasized, in addition to inoculated efficacy trials where possible. The discovery and development of improved scouting and detection methods and decision thresholds should be continued. Measurement of crop losses associated with the current diseases identified under different conditions should be encouraged.

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

4. Chemical, cultural and biological management options for bacterial panicle blight need more research. Intensive screening for greater 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 to the epidemic potential of the disease.

5. Research on the molecular genetics of host/parasite interactions, including molecular characterization of the pathogen isolates, and their interaction mechanisms with U.S. rice and the use of molecular genetics and biotechnology, including genetic engineering, molecular-assisted breeding, genomic prediction, and biotechnology-based tools including CRISPR-CAS9 and deep machine learning to improve disease control should be a high priority. Research using simple sequence repeat (SSR) markers for *M. oryzae* and PCR based on rDNA for other pathogens, and pathogen critical pathogenicity factors and their interacting genes should be explored.

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

7. Molecular characterization of virulent blast races IE1k and IC1 in commercial fields and on the weakly virulent bacterial strains, originally reported as Xoo in Louisiana and Texas, should be conducted to characterize and identify them. An international rice blast differential system or monogenic lines or near isogenic lines with major blast resistance genes and user-friendly high throughput scoring system should be established to provide effective screening for useful blast resistance genes.

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

9. Encourage and assist in monitoring the potential development of fungicide resistance in the pathogen populations of sheath blight, narrow brown leaf spot, blast, and kernel smut across the rice-producing region.

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

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

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

13. Research on alternate irrigation (alternate wetting and drying, mid-summer drainage, furrow irrigation, and overhead (pivot) irrigation) and its effect on rice disease incidence and severity should be encouraged since these cultural strategies continue to increase as methods to conserve natural resources.

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

15. Research is encouraged on the development and application of UAV (drone)-based technologies, artificial intelligence for the detection and management of rice diseases.

Insects and Other Animal Pests

The major insect pests that damage the seed or rice plants between planting and harvesting are the rice water weevil, Lissorhoptrus oryzophilus Kuschel; rice stink bug, Oebalus pugnax (Fabricius); grape colaspis, Colaspis brunnea (Fabricius), and Colaspis louisianae; stem borers, Diatraea saccharalis (Fabricius), Eoreuma loftini (Dyar), and Chilo plejadellus Zincken; rice leaf miner, Hydrellia griseola (Fallen); South American rice miner, Hydrellia wirthi Korytkowski; armyworm, Mythimna unipuncta (Haworth); western yellowstriped armyworm, Spodoptera praefica (Grote); fall armyworm, Spodoptera *frugiperda* (JE Smith); chinch bug, *Blissus leucopterus* (Say); various species of leaf and plant hoppers; numerous grasshopper species (Locustidae and Tettigoniidae); midge larvae (Chironomidae); greenbug, *Schizaphis graminum* (Rondani); bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus.); rice root aphid, *Rhopalosiphum rufiabdominalis* Sasaki; yellow sugarcane aphid, *Sipha flava* (Forbes); an exotic stink bug, *Oebalus ypsilongriseus* (DeGeer), found in Florida; sugarcane beetles, *Eutheola rugiceps* (LeConte); billbugs, *Sphenopherous* spp.; and thrips (various species). In 2015, the rice delphacid, *Tagosodes orizicolus* (Muir), was found attacking ratoon rice in Texas. After several years of no detections, the delphacid is now causing damage in some fields in Texas.

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

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

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

2. Monitor rice for possible introduction of exotic pests. In addition, continue to monitor for Hoja blanca virus as it relates to the rice delphacid.

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

4. Understanding how water conservation practices, such as row rice and alternate wetting and drying, may influence the biology, ecology, and management of arthropod pests of rice in the U.S.

As a combined group of scientists, the group would like to make an overarching statement regarding the continued efforts to train graduate students in the disciplines of entomology and plant pathology. As a group of scientists working for the rice industry, we feel that students should be encouraged to enroll in the plant protection disciplines and embrace the field-level aspects of these two important disciplines. Moreover, students should be encouraged to learn how to properly conduct field-level research trials in rice systems to address the continued management concerns we face within our respective disciplines as rice researchers.

POSTHARVEST QUALITY, UTILIZATION, AND NUTRITION

G. ATUNGULUZ, Chair; P. ARMSTRONG, S. PINSON, and Z. PAN, Participants.

Recommended Research Priorities:

1. Develop technologies, sensors, electronic systems and database for improving production efficiency, food safety, product quality and processing quality of rice, such as real-time monitoring and detection devices/systems for rice grain quality during harvest, insect occurrence during storage and grain quality during milling.

2. Study the rice quality (such as chalkiness) and safety (such as arsenic) from genetic, physiological, environmental and production management aspects to improve the rice quality.

3. Develop technologies for producing value added products, and reducing losses and increasing values in harvest, storage and processing.

Specific Recommendations:

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

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

Awareness of Postharvest Quality, Utilization and Nutrition.

Increase the awareness of work related to postharvest quality, utilization and nutrition through cosponsoring meeting and marketing.

Rice Harvesting, Drying, Storage, and Handling
Correlate environmental factors (temperature, humidity) at harvest to physical, chemical, and functional properties of the rice kernel.

Develop new and/or improved rice drying, storage, and handling systems to impart desirable functional properties, improve efficiency, and reduce energy use.

Incorporate economic factors into post-harvest models and guidelines for harvesting, drying, storage, and insect management recommendations.

Develop sensors to rapidly and objectively monitor rice properties.

Evaluate alternatives to chemical fumigants for grain and facility treatment.

Develop resistance management program for phosphine gas, a fumigant.

Determine mechanisms for head rice loss when rice is transferred.

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

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

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

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

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

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

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

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

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

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

Improve inspection methods for measuring chemical constituents and quality factors.

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

Develop effective, cost-efficient methods for fractionating rice components (e.g., starch, protein, oil, and fiber).

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

Identify applications for rice components (i.e. starch, protein, bran) in native and modified forms.

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

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

Measure the amount of these bioactive components in various varieties.

Develop non-food uses for rice, rice hulls and ash, straw, bran, and protein.

Nutrition and Food Safety
Promote the health benefits of rice and develop rice products and constituents that promote human and animal health.

Evaluate the bioavailability of rice components of nutritional importance, and investigate the levels required to generate responses in humans and animals.

Investigate the effects of processing, and storage conditions on microbial loads in rice for improved food safety.

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

Other Considerations

- One member proposed that we reconsider the name of our panel due to concerns that the term "postharvest" may be unclear to some individuals, resulting in presentations being assigned to other panels. However, others suggested that the panel chair could work more closely with other chairs to redirect relevant presentations and increase participation in our panel.

- We discussed the need for more campaigns to encourage student participation in both poster and oral presentations.

- It was recommended that the next program be intentional in inviting industry speakers to provide presentations, define quality needs, and share industry-related information.

RICE CULTURE

T. ROBERTS, Chair; L. TARPLEY, D. FRIZZELL, A. SMARTT, K. HOEGENAUER, E. RANDS, H. VICKMARK, C. SCOTT, S. WILLIAMSON, J. CHLAPECKA, G. DRESCHER, M. REBA, M. KONGCHUM, D. HARRELL, F. DOU, and G. BESSA DE LIMA; Participants.

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

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

Cultural Practices
Evaluate rotation systems that involve rice.

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

Determine the influence of irrigation management strategy (i.e. furrow irrigated, Alternate Wetting and Drying, and Traditional) on biotic stresses to the delayed-flood rice production system.

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 and nutritional value.

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 and redox potential.

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 and identify potential mitigation strategies.

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 macroenvironment 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, nutritional value 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.

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 technology and equipment for effective rice management.

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 Geospatial systems and related sensor technologies 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

T. BARBER, Chair; C. SANDOSKI, C. WEBSTER, L. SCHMIDT, E. WEBSTER, T. BUTTS, J. BOND, and L. PRIESS; 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.

It was mentioned that very little if any "Growth Regulation" topics or research existed and discussion to remove "Growth Regulation" form the panel name was proposed. However, due to low attendance, no vote was officially taken

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

Investigate 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.

Research Priorities
Weed management under new water management strategies.

Chemical and non-chemical management of herbicide resistant weeds.

Weed biology and competition studies.

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

Extension priorities
Online training for Extension and interactive tools.

Abstracts of Papers from the Student Oral Contest Panel-Plant Protection, Breeding, Genetics, and Genomics
Moderator: Nick Bateman

Molecular Characterization of Propiconazole Resistant *Tilletia horrida* Isolates

Khanal, S., Antony-Babu, S., and Zhou, X.G.

Rice kernel smut, caused by *Tilletia horrida,* is currently one of the most important rice diseases in the United States. Kernel smut management relies on employing various management strategies to reduce the disease-damage to an acceptable level. Current management practice heavily depends on the use of fungicides to manage kernel smut. Especially, midseason preventive applications of propiconazole based fungicides is recommended. Regardless, recent years have seen reports of reduced efficacy, or even failures of propiconazole fungicides to control kernel smut across the US. Propiconazole is a demethylation inhibitor (DMI) class of fungicide, which inhibits fungal sterol synthesis by preventing demethylation of lanosterol. Decreases in propiconazole control efficacy may indicate the development of propiconazole resistant *T. horrida* populations*.* There are no studies have been conducted to evaluate the genetic basis of propiconazole resistance in *Tilletia*. Thus, the objectives of this study were to first establish a baseline for propiconazole baseline sensitivity, second to characterize the resistance of the *T. horrida* isolates to propiconazole, and finally identify the molecular basis of propiconazole resistance.

A total of 63 *T. horrida* isolates were collected from across the U.S. rice-growing regions. Three of the isolates were from an organic rice farm, where no fungicides had been used, were used to establish the propiconazole baseline sensitivity. We established the baseline sensitivity of 0.2 µl/ml concentration of propiconazole. Then, the remaining 60 *T. horrida* isolates were screened for resistance to propiconazole at the concentration ranging from 0.2 to 50 µl/ml. Out of the 60 isolates, 52 grew on potato dextrose agar (PDA) amended with 0.2 µl/ml of propiconazole. The number of isolates that could grow in the concentration of 0.5 µl/ml, 1 µl/ml, 5 µl/ml, 10 µl/ml, 25 µl/ml, and 50 µl/ml was 52, 52, 43, 39, 14, and 1, respectively. Variations in the *CYP51* gene, the target gene for propiconazole resistance, in the resistant and sensitive isolates were further characterized and found that mutations were present at different amino acid sites in *CYP51* gene. The results show, for the first time, that propiconazole resistance has developed in the US *T. horrida* populations and that the mutations at different amino acid sites in *CYP51* gene contribute towards the propiconazole resistance.

Management of Rice Stink Bug in Mississippi

Lytle, M.J., Gore, J., Crow, W.D., Cook, D.R., Catchot, A.L., and Bond, J.A.

The rice stink bug (*Oebalus pugnax*) is a key late season insect pest in Mississippi and Mid-South rice (*Oryza sativa* L.) production. Historically, Mississippi rice producers have been dependent on pyrethroids to effectively control rice stink bug because they are more cost effective than other insecticide classes. The damage associated with rice stink bug feeding has the potential to result in yield loss, which can be attributed to rice grain development being restricted and profit loss due to decreased grain quality (e.g., peck) and subsequent milling damage. Currently labeled insecticides for use in Mississippi rice production include dinotefuran (Tenchu), gamma-cyhalothrin (Declare), lambda-cyhalothrin (Warrior II), malathion (Malathion 57EC, Malathion 5EC), and zeta-cypermethrin (Mustang Maxx), but failed pyrethroid applications have been reported across the rice producing region of Mississippi. Reductions in efficacy potentially indicate an increased tolerance and ultimately, resistance to the pyrethroid class. These control issues may be the result of overreliance on pyrethroids, due to the cost effectiveness of the insecticides. In 2021 and 2022, laboratory bioassay experiments evaluating the efficacy of pyrethroids on Mississippi rice stink bug populations were conducted at the Delta Research and Extension Center in Stoneville, MS. The study consisted of liquid scintillation vials each treated with technical grade lambda-cyhalothrin at various concentrations and a nontreated control. Technical grade lambda-cyhalothrin was diluted in acetone and 0.5 milliliters was pipetted into each vial. The vials were placed onto a commercial hot dog roller with the heating element disabled and allowed to roll until the acetone had evaporated, leaving only the appropriate lambda-cyhalothrin dose in each vial. Lambda-cyhalothrin was chosen as a representative of the pyrethroid class due to the popularity with Mississippi rice producers.

Rice stink bug populations were collected throughout the Mississippi Delta and one rice stink bug was placed in each vial. The experiment was set up as a two-factor factorial completely randomized design, with the first factor being year and the second factor being concentration. Twenty-four hours following vial infestation, mortality ratings were taken. In 2022, the 5 µg/ml (microgram per milliliter) and 10 µg/ml concentrations resulted in lower percent mortality than in 2021. Percent mortality data suggests that some populations of rice stink bug exhibit increased tolerance to pyrethroids at previously lethal doses. With an already limited number of chemical options for rice stink bug control, the loss of an economical insecticide may be challenging for Mississippi rice producers to protect yields.

Impact of Insecticide Seed Treatments and Water Management on Selected Insect Pests of Furrow-Irrigated Rice (Oryza sativa L.)

Musgrove, T., Landry, K., and Wilson, B.

With the emergence of furrow-irrigated rice, 'row-rice,' throughout the Midsouth, efforts to improve insect pest management have focused on the role of irrigation methodology and insecticide seed treatments (ISTs). In traditional flood irrigation, ISTs primarily provide protection against the rice water weevil (RWW) (*Lissorhoptrus oryzophilus* Kuschel), the most damaging insect pest of immature rice. However, this insect's lifecycle is negatively impacted when removing a flood under furrow irrigation. This raises the question of whether ISTs are justified when the primary target pest is no longer a threat. Alternatively, changing irrigation methods may alter the overall pest complex and give rise to other pests not previously considered important, such as the rice billbug (*Sphenophorus pertinax*). Therefore, a field trial was conducted in Crowley, Louisiana, to characterize the role of ISTs in row-rice using two furrow-irrigation methods (tail-water release, end-blocking) and several ISTs, alone and in combination compared to an untreated control. Larval densities of RWW and billbug were quantified per soil core and m^2, respectively. Number of whiteheads due to billbug or stem borer (Family: Crambidae) injury were quantified per m^2. Rice was harvested to determine whether ISTs improve yields in row-rice. Results indicate ISTs had little impact on pests nor did they protect rice yields under either irrigation method. Alternatively, differences in whiteheads and yield between irrigation methods were significant. Early signs point to irrigation strategy receiving greater emphasis in row-rice pest management than ISTs and additional growing seasons are needed to solidify this hypothesis.

Examining Pyrethroid Resistance in Arkansas Rice Stink Bug, *Oebalus pugnax,* Populations

Newkirk, T., Bateman, N.R., Lorenz, G.M., Thrash, B.C., Joshi, N.K., Felts, S.G., Plummer, W.A., Floyd, C., Whitfield, A., Murray, Z., and Davis, T.

Rice stink bug (RSB), *Oebalus pugnax,* is the most damaging pest to heading rice, feeding on developing kernels. Limited number of labeled insecticides are accessible to rice growers for RSB control options. Lambda-cyhalothrin (Lambda) is the most widely used insecticides applied for RSB management, providing sufficient control at a low cost. Lambda is applied to over 90% of Arkansas rice acres on a yearly basis, intended for RSB control. Alternative options, namely, Tenchu (Dinotefuran), are efficacious for control but not at an aggressive price rate. The reliance on Lambda for RSB management, and control matters observed in Louisiana and Texas, creates concern for RSB resistance in Arkansas. New insecticides for RSB control need to be assessed in preparation for resistance to Lambda. Efficacy field trials were performed in 2020, 2021, and 2022 to compare insecticides for efficacy and residual control of RSB. Sweep net samples were performed at 3, 7, 10, and 14 DAT to monitor RSB efficacy. Additionally, assays were carried out over various RSB populations in 2022 throughout the growing season. RSB adults were collected, Lambda was applied to petri dishes at five different rates with an untreated check for comparison purposes and replicated 10 times. After Lambda application, dishes were allowed to dry before inserting five RSBs to each dish. Mortality ratings were recorded at 24 hours post infestation. Throughout the growing season, 80% mortality was never achieved with any rate. On average, over the sampled locations the 4X rate achieved 70% mortality. The 1X and 2X rates reached 66% and 67% mortality. Results from these studies suggest resistance to Lambda is becoming an issue in Arkansas. Resistance issues are concerning, increasing awareness of this developing issue, and educating growers and consultants in respective management tactics.

Characterization of Grain Quality in U.S. and Latin American Rice and Implications for Breeding

Guerra, R., Angira, B., Kongchum, M., and Famoso, A.

Latin America is the largest importer of U.S. milled rice, receiving 40% of total exports in 2020. Since 2010, concerns have been voiced from Latin American importers about the quality of U.S. rice, mainly regarding the high chalk content of milled rice and the stickiness of cooked rice. The objectives of this work were to 1) understand the differences in grain quality between U.S. long and Latin American rice samples and 2) to investigate the most effective strategy to breed germplasm for the Latin American export market. A panel of 88 Southern U.S. varieties was characterized for components of visual quality—grain length and width and chalk content—and cooking quality—amylose content, gelatinization temperature, and pasting properties—and compared to 21 popular samples from Latin America. Amylose content was the primary component differentiating U.S. and Latin American rice and it explained many of the differences in cooking characteristics. Genotypic characterization of the waxy and ALK genes demonstrated a strong association to amylose and gelatinization temperature phenotypes and clearly distinguished U.S. and Latin American rice. Based on the observed phenotypic differences between the U.S. and Latin American rice and the accuracy of the DNA markers, a breeding strategy was deployed crossing U.S. germplasm to develop new U.S. germplasm with unique grain quality similar to the desired Latin American quality profile. This research defined the key quality differences between U.S. long-grain and Latin American rice necessary for developing target product profiles for the Latin American market.

Sheath Blight Evaluation of Elite Breeding Materials and Future Breeding Strategies

Manangkil, J.M., Cerioli, T., Angira, B., Montiel, M., Amores, J., Richards, J., and Famoso, A.N.

Sheath blight, caused by *Rhizoctonia solani*, is an important rice (*Oryza sativa* L.) disease. There are no known sources of complete resistance to sheath blight and generally U.S. rice is susceptible to this disease. The quantitative nature of sheath blight resistance limits the progress made in genetic studies and in applied breeding. This study aimed to identify additional sources of resistance and to develop future breeding strategies for sheath blight. A total of 838 elite breeding materials with three replications was evaluated under field condition. These elite breeding materials were derived from a cross between six to eight founders representing the elite diversity of U.S. rice varieties and genotyped with 14,028 SNPs. The materials were inoculated using rice hull and paddy substrate and two scoring methods, Horizontal Progression Top (HPT) and Horizontal Progression Bottom (HPB), were used to evaluate sheath blight resistance scores. A wide phenotypic distribution was also observed among the population. A Genome Wide Association study was also conducted to identify loci associated with the disease and number of significant and clearly defined peaks were observed, however, the variance explained from these loci was relatively small. The small effect of the detected peaks suggests that marker assisted selection on specific loci will not be an effective breeding approach for sheath blight. Due to the quantitative nature of the trait, genomic selection was explored by conducting cross-validation. Preliminary results produced a cross-validation accuracy of 0.41. These observations suggest genomic selection is the most effective molecular breeding approach for improving the efficiency of sheath blight breeding.

Comparison Backward and Forward Genomic Selection Accuracy in Multiparent Populations in Rice (*Oryza sativa* L.)

Montiel, M.G., Amores, J., Angira, B., Cerioli, T., Hernandez, C., Robbins, K., McCouch, S., Famoso, A., Fritsche-Neto, R., and Sha, X.

Genomic selection (GS) enables information encoded in the genotype to be combined with phenotypic data into a mixed model to predict the genomic estimated breeding values (GEBVs) of lines that could be potentially selected. This technique relies on the genetic relatedness of individuals between the training and the validation population. There are numerous schemes to implement GS in breeding programs. Overall, there are two main strategies forward and backward prediction. The former uses historical data as a training set to predict new genotypes in later generations. Conversely, the second strategy develops "MAGIC" populations with high haplotype resolution and genetic variability to predict genotypes in bi-parental crosses (BP). Each strategy represents different generations of recombination, genetic variability, and haplotype resolution; thus, they might provide different selection accuracies. Therefore, we aim to compare the backward and forward genomic selection accuracy in multiparent rice populations. For that, we developed a multi-parent population (MPP) derived from eight elite Southern U.S. rice varieties. There were 220 lines from BP populations and 318 genotypes from MPP that have been tested across two years and two environments in yield tests and genotyped with 550 genome-wide markers. We estimated that the correlation between observed and predicted values of yield is 0.36 when using as a training set a BP to predict an MPP (forward prediction), and it increases up to 0.45 when using an MPP to predict a BP (backward). Therefore, we observed a higher accuracy when using a MPP to predict simple crosses, which can be a very efficient way of conducting selection in a breeding program.

Abstracts of Papers from the Student Oral Contest Panel – Rice Culture
Moderator: Trent Roberts

Influence of Rice Production Systems on Soil Health Parameters

Aziz, A., Kongchum, M., Wang, J.J., Harrell, D.L., Adotey, N., and Ali, M.H.

Furrow-irrigated rice system has gained increasing interest in southern USA for its production flexibility. Currently, there is no information as to how furrow-irrigated rice practice is compared to delayed-flooded rice farming in affecting soil health parameters that control nutrient cycling. In this study, soil health chemical and biological indicators of delayed-flooded and furrow-irrigated rice systems were measured, compared, and related to rice yield. Pre-plant and end-season surface soil samples were taken from delay-flooded and furrow-irrigated rice field trials at the Louisiana State University Agricultural Center Rice Research Station and farmers' fields in Louisiana and were analyzed for total carbon, nitrogen (N), permanganate oxidizable carbon (POXC) known as active carbon, 24-hr CO_2-burst, Solvita Labile-Amino nitrogen (SLAN), and soil enzymes including β-glucosidase, β-glucosaminidase, phosphatase, and arylsulfatase activities.

The results showed that a relationship can be established between rice yields and pre-plant soil 24 hr CO_2 burst results. An inverse relationship is observed between 24 hr CO_2 burst and relative yield increase at application rate of 134 kg ha^{-1} of N as urea. These findings indicate the potential of using 24 hr CO_2 burst results to predict N mineralization to calibrate N fertilization. In addition, the flooded rice system showed higher soil active carbon as measured by POXC than furrow-irrigated system, while there was no significant difference in soil CO_2-burst and labile amino-N results between the two systems. Moreover, further analysis showed that furrow-irrigated rice system had generally higher β-glucosaminidase, Phosphomonoesterase, and Arylsulfatase, but lower β-glucosidase activities than delayed flooded rice system. There was a positive relation between β-glucosidase activity and rice yield for flooded rice system but a negative for furrow-irrigated system. Further research trials in different geographical locations need to be evaluated to better understand these production system differences on soil health and sustainability.

Does Furrow Irrigated Rice Have the Same Phosphorus and Potassium Requirements as Flooded Rice?

Hoegenauer, K.A., Roberts, T.L., Drescher, G.L., Smartt, A.D., Ortel, C.C., and Followell, C.A.

Adoption of furrow irrigation in place of traditional continuous flood irrigation in rice (*Oryza sativa*) production has grown significantly in the last five years. As with any new system, there are challenges to overcome and questions to be answered. Nitrogen was the first nutrient that received widespread attention in furrow irrigated rice systems as it is often the most limiting nutrient in rice production and the nutrient most impacted by alternative water management. Fertilizer-N rates for furrow irrigated rice have been established and the focus has shifted more to phosphorus (P) and potassium (K) as these are also macronutrients that can limit rice yield in many Mid-south rice fields. One of the primary differences between these two irrigation management practices is the degree to which the soil is saturated and ultimately the aerobic vs. anaerobic nature of the soil throughout the season. Previous research has identified the impact of sustained anaerobic conditions on the solubility of soil P and the P available for plant uptake. Little work has been done on the effects of water management on K uptake in rice. A study was designed to identify the P and K rates required to maximize yield under a furrow irrigated system as opposed to a traditional continuous flood system. The study was conducted over the course of 2 years on a soil representative of rice production in Arkansas. Fertilizer treatments were applied preplant and consisted of six rates of P (0-168 kg P_2O_5 ha^{-1}) applied as triple super phosphate (46% P_2O_5) and six rates of K (0-168 kg K_2O ha^{-1}) applied as muriate of potash (60% K_2O). The irrigation treatments consisted of a full season continuous flood treatment and furrow irrigation treatment. Grain yield was collected at the end of the season and used to calculate the rate of K and P required to achieve 95% relative grain yield under each irrigation system. Although the number of trials on hand is limited, it appears that no adjustments to the current fertilizer-K rates based on soil test K levels are needed. However, preliminary results for P suggest that rice grown in aerobic systems such as furrow irrigation water management may require 17-34 kg P_2O_5 ha^{-1} more than is currently recommended for flood irrigated rice based on soil test P levels.

Soil Biochemical and Greenhouse Gas Emission Dynamics Response to Nitrogen Application Rates in Organic Rice Management

Lasar, H.G.W., Gentry, T., Dou, F., Lamichhane, S., and Zhou, X.G.

Inappropriate nitrogen (N) management remains “a grand challenge” not only limiting rice production but also threatening the global climate and environments. Greenhouse and field experiments were conducted to assess the effects of different N rates from organic amendments on soil biochemical properties and greenhouse gas (GHG) emissions at Texas A&M AgriLife Research Center, Beaumont, TX. Three levels of N (0, 50, and 150 kg N ha^{-1}) from organic soil amendments (chicken litter pellet and nature safe) are arranged in a complete randomized design (greenhouse) and a complete randomized block design (field) with four replications. This study hypothesized that application N rates from organic amendments expected to significantly affect soil total microbial biomass (TMB), inorganic N (NH_4^+, NO_3^-), and CH_4, CO_2, and N_2O emissions. This research is convinced to provide an empirical evidence of how different N rates of organic amendments affect TMB, soil N dynamics, and GHG emissions.

Impacts of Rice Husk Amendments on Plant Silicon Uptake, Soil Carbon, and Methane Emissions

Linam, F.A., Limmer, M.A., and Seyfferth, A.L.

Rice is unique among crops in that it hyperaccumulates silicon (Si). Silicon increases disease, pest, and abiotic stress resistance and is a beneficial nutrient for rice. It can also increase yield in some situations. In plants, Si is primarily found as amorphous SiO_2 opaline minerals, which dissolve much more rapidly than soil minerals. This results in plant Si being intensively recycled in surface soils. Rice husk has the highest concentration of Si (5-10%) in the plant, but it is currently an underutilized waste product which accumulates at rice mills where it is sometimes burned to decrease its mass. Returning this Si-rich residue to rice fields could help maintain adequate Si levels for rice.

Amending soils with plant residues greatly impacts the soil carbon © cycle. This is especially true in rice paddies, where the flooded conditions can preserve C for long periods of time but can also increase emissions of methane (CH_4), a potent greenhouse gas. Rice straw is known to greatly increase CH_4 emissions when incorporated in the field, while burning the straw can decrease these emissions. Rice husk is also C-rich and, therefore, will impact soil organic matter (SOM) and CH_4 emissions if returned to the field.

We conducted small-scale and greenhouse studies to examine how rice husk residue incorporation affects the soil C and Si cycles. Our objective was to determine whether unaltered husk (“Husk”), low-temperature husk biochar (“Biochar”), or burned husk (“CharSil”) amendments maximized plant Si uptake and SOM gains while minimizing CH_4 emissions relative to an unamended treatment (“Control”).

Amendments were added in triplicate to the paddy mesocosms at the University of Delaware farm. The soil is a highly-weathered Ultisol silt loam which had been cultivated in rice for one year prior. Husk, Biochar, or CharSil was added at 1 Mg/ha Si rate, which is equivalent to ~7 years’ worth of rice production; Control received no amendment. Alternate wetting and drying (AWD) water management was practiced. We monitored greenhouse gas emissions, porewater dissolved organic carbon concentration, SOM concentration, porewater Si concentration, and plant Si content for three years after amending. We also conducted a greenhouse pot experiment with the same amendments but with added water treatments of nonflooded (NF), AWD, and flooded (F). The same parameters were measured in this study, but rice was grown only for one growth cycle.

Our results show that none of the amendments significantly affected grain or biomass yield in both experiments. In the first year of the paddy experiment, Husk and Biochar increased straw Si by 117% and 72% and Husk Si by 76% and 48%, respectively. In the second year, they increased straw Si by 39% and 41%, respectively. In year 3, there were no significant differences in plant Si. Similarly, Husk and Biochar amendment increased straw and Husk Si in the pot study, and F water management also increased plant Si. Despite its high Si content, CharSil did not impact plant Si uptake.

Husk amendment significantly increased SOM over Control in the paddies. Biochar and CharSil also increased SOM but the results were not statistically significant. Similar values were obtained in the pot study, but none of the values were statistically significant. Emissions of CH_4 from Husk amendment were significantly increased in year 1 and year

2 of the paddy study, resulting in a 54% cumulative increase compared to Control. Biochar and CharSil did not impact CH_4 emissions. In the pot study, F water management increased CH_4 emissions compared to NF. Considering the amount of C lost during production, amendments of Biochar and CharSil shows that CharSil increased CO_2 release by 25-100%. On a CO_2-equivalent basis, Husk stored a net 0.15 t C ha^{-1} y^{-1}. Biochar had a similar 0.14 t C ha^{-1} y^{-1} storage value, though these values are more uncertain. Finally, the large emission of CO_2 during CharSil production negates its C storage potential.

In summary, both Husk and Biochar are seen to provide available Si to rice crops and to store net C in the soil, despite increased CH_4 emissions from Husk amendment. Burning husk at high temperature to produce CharSil greatly limits its ability to provide Si for plants and also releases CO_2. We conclude that for highly-weathered paddy soils, unaltered or low-temperature pyrolyzed rice husk amendments maximize Si available to rice plants while also storing net C in the soil.

Rice Yield Following Winter Cover Crops

Followell, C.A., Roberts, T.L., Pessotto, M., Drescher, G.L., Hurst, B., Hoegenauer, K., Ortel, C., and Smartt, A.

With the increased interest in the use of cover crops, reaching a high of 15.4 million acres in the United States in 2017, it is vital to explore their impact on soil health, agronomic practices, and yield of common row crops. This includes the impact of cover crops on the growth and yield of rice, (*Oryza sativa* L.) which poses unique challenges as it relates to successful cover crop implementation and rice establishment following cover crops. Rice is typically produced in poorly drained soils that can significantly limit winter annual plant growth especially in years with above average precipitation. A study was developed to look at the impact of various winter cover crop species on rough rice grain yield when compared to a traditional winter fallow. Cover crops included in the trial were crimson clover (*Trifolium incarnatum),* balansa clover (*Trifolium michelianum*), Austrian winter pea (*Pisum sativum*), hairy vetch (*Vicia villosa*), and common vetch (*Vicia sativa*) all planted at the recommended seeding rates based on current University of Arkansas System Division of Agriculture recommendations. Other than the winter cover crop treatments, rice was produced used standard agronomic practices for direct-seeded, delayed flood rice using a randomized complete block design with four replications. The rice cultivar CLL 15 was established into chemically terminated cover crop residue using a no-till drill and stands were adequate for optimal rice yields across all winter cover crop treatments. Overall, rice yields were slightly less than the state average, but were not statistically different amongst the various winter cover crop treatments. The winter fallow treatment resulted in a rough rice yield of 8,265 kg/ha. The rough rice yields following winter cover crops ranged from 7,812-8,820 kg/ha. The results of this trial suggest that there is little to no penalty in rough rice yield following a winter cover crop and that this management practice should be explored further to determine if other benefits associated with cover crop planting can be realized in a rice production rotation.

Field-Based High Night Air Temperature Stress Imposition Reduced Rice Stem Non-Structural Carbohydrates

Mendez, K., Larazo, W., Quiñones, C., Lorence, A., Walia, H., and Adviento-Borbe, M.A.

Carbohydrate partitioning in rice under high night air temperature (HNT) stress is not fully elucidated, specifically under field condition. Plants with a higher capacity to store non-structural carbohydrates (NSC) in the stem can better tolerate changes in climatic conditions, including HNT stress. This finding was proven in Nagina 22, a heat-tolerant variety grown under greenhouse and field conditions. A field experiment was conducted to understand the effect of HNT stress on a rice diversity panel. Six high-tunnel greenhouses were used as a heating infrastructure. The facility imposed a +4°C difference between the two treatments: ambient and heated. HNT stress was imposed when approximately 50% of the rice diversity panel reached the flowering stage. The non-structural carbohydrate (NSC) contents of the selected 12 rice lines were quantified using anthrone colorimetric method. NSC was computed by summing all soluble sugar and starch concentrations. Two main tillers were collected during the flowering and dough growth stages. Samples were separated into leaves, stems, and panicles. Among the plant parts of selected rice accessions, NSC significantly lessened in the stem exposed to HNT stress. When heated, mean stem NSC at flowering stage was reduced from 109.98±10.62 $mg.g^{-1}$ to 91.228±91.22 $mg.g^{-1}$. Similarly, mean NSC content at dough stage was lower under heat stress (78.66±19.31 $mg.g^{-1}$) compared with ambient condition (93.64±8.49 $mg.g^{-1}$). These findings provide a novel phenotypic marker through quantification of carbohydrate reserves and can be used in the development of high-yielding, HNT-tolerant rice cultivars.

High Night Air Temperature Stress Affects Rice Yield and Yield Components

Quiñones, C., Larazo, W., Mendez, K., Cunningham, S., Adviento-Borbe, M.A.A., Walia, H., and Lorence, A.

High night air temperature (HNT) stress can reduce rice grain yield by 10% in every degree increase in nighttime temperature. HNT studies have been conducted in greenhouses, growth chambers, and field conditions but with fewer genotypes and under constant elevated nighttime air temperature. Field phenotyping using large rice germplasm using computer-based HNT imposition is needed to further understand the underlying processes involved in the response of crops under heat stress. In this study, six field-based infrastructures were built in an experimental field in Harrisburg, AR, and were coupled with cyber-physical system to impose HNT of ~4°C temperature increase relative to ambient temperature at reproductive stage during 2019 cropping season. The movable infrastructures accommodated 310 rice accessions from Rice Diversity Panel 1 (RDP1) and 10 commercial hybrid cultivars, arranged in a randomized complete block design with three replications for each ambient control and HNT treatments. To assess the impact of HNT stress, several U.S. rice cultivars were selected and found that HNT significantly affected harvest index (HI) and reduced grain yield by an average of 24%. Although not statistically significant, there was an average increase of 4.25% of unfilled grains weight ($g\ m^{-2}$), and a decrease of 12.6% of aboveground biomass ($g\ m^{-2}$) under HNT compared to ambient control conditions. Seed dimensions analyses are on-going to further assess the impacts of HNT to rice grains. One of the many outcomes of this study is to identify potential traits for HNT resilience that will help plant breeders improve rice for changing climate.

Determining an Irrigation Management Plan in a Furrow-Irrigated Rice Production System

Smyly, A.C., Gholson, D.M., Bond, J.A., Bowman, H.D., Bryant, C.J., and Golden, B.R.

Rice *(Oryza sativa L.)* in Mississippi is typically grown using a continuous flood production system that requires large inputs of water throughout the growing season. Irrigation water for rice production in the Mississippi Delta is extensively drawn from the Mississippi River Valley alluvial aquifer (MRVAA) and the aquifer is beginning to deplete. Determining a more efficient rice irrigation approach is vital to the sustainability of the aquifer for agricultural needs. Research in Mississippi has shown furrow-irrigated rice (FIR) to produce rice with less water, but there is limited information on how to efficiently irrigate and fertilize FIR. This study was conducted to determine an irrigation management plan in FIR by evaluating rice response to different irrigation frequencies.

Research was conducted at the Delta Research and Extension Center in Stoneville, MS, on Sharkey clay soil in 2021 and 2022. The experimental design was arranged as randomized complete block with four irrigation frequencies (irrigating every day, every 3, every 5, and every 7 days) each replicated three times. Soil moisture, water depth levels, and water usage were recorded using WaterMark® Soil Moisture Sensors®, Pani-Pipes®, Precision King AgSense Sensors®, and flowmeters. Rice grain yield was determined for each treatment plot and each zone within treatment plots. Plots irrigated every day in 2021 and 2022 produced numerically greater average yields (10,222 and 10,894 kg ha^{-1}) compared to all other irrigation frequencies. On average, irrigation treatment plots in 2021 resulted in a greater average yield for plots irrigated every day, no difference in the average yield for plots irrigated every 3 and 5 days, and a lower average yield for plots irrigated every 7 days. However, in 2022 plots, there was no difference in yield across treatments. There was no difference in the combined averaged yield for all treatments between top, middle, and bottom one-thirds in 2021. In 2022, the average yield of all treatments combined in the bottom one-third was greater than the middle and top one-thirds but was only significantly different from the top one-thirds average yield. The research study will be repeated again in 2023.

Nutrient Uptake and Accumulation in Rice Cultivars in the Arkansas Delta

Bessa de Lima, G.H., Roberts, T.L., Drescher, G.L., Ortel, C.C., Followell, C.A., Hoegenauer, K.A., and Smart, A.

Rice (Oryza sativa L.) is a major crop for the state of Arkansas and at the same time represents the major food source for more than half of the global population. Nutrient management represents one of the highest input costs for successful rice cultivation and being economically efficient is crucial for reaching optimum profit. Modern rice cultivars paired with improved agronomic practices may have affected the accumulation of nutrient uptake since the last broad studies were published. The objective of this research is to investigate nutrient uptake among different modern rice cultivars. The experimental design utilized was an RCBD with a 2 x 4 factorial arrangement. Factor A being fertilizer rate and factor B as rice cultivars, respectively, with four replications. The trial locations were situated on silt loam soils at the Pine Tree and Rohwer Research Stations located in the Arkansas delta. The fertilizer recommendations were 100% and 125% of the soil test-based rate recommendations, respectively, and the rates applied were N (135 or 163 kg N/ha); P (0 or 50 kg P_2O_5/ha); and K (0 or 67 kg K_2O/ha). The rice varieties used were Diamond, RT 7521, Titan, and CLL 16. Plants were sampled at two growth stages (V3 and V5/6 immediately preflood) and the total aboveground nutrient uptake was determined. Following harvest, there were statistical differences in yield among the cultivars at both locations. No statistical differences in nutrient uptake among the fertilizer rates or cultivars were observed. Nutrient analysis of the other rice growth stages is still pending. The results of this research will contribute important data on the nutrient uptake and partitioning of modern rice cultivars to optimize fertilizer rates and timing recommendations for rice production.

Abstracts of Papers from the Student Oral Contest Panel – Weed Control and Growth Regulation I
Moderator: Zach Hill

Effectiveness of Oxyfluorfen for Weedy Rice in Single and Sequential Applications

Arnold, C.H., Norsworthy, J.K., Butts, T.R., Pritchett, S.L., Reed, N.A., and Barber, L.T.

Oxyfluorfen (ALB2023 and ALB2024) is a WSSA group 14 herbicide that can be used both for pre- and postemergence applications. Oxyfluorfen is not currently labeled for use in rice, but research is being conducted to evaluate weedy rice control in the ROXY® Rice Production System. In Arkansas, weedy rice is resistant to WSSA group 2 herbicides, leaving only one option (quizalofop-p) for weedy rice control in field fields other than rotating to a different crop. During the 2021 and 2022 growing seasons, two separate field trials were conducted at the Rice Research and Extension Center in Stuttgart, AR. The first trial was designed to determine if there is a rate response associated with the postemergence applications of oxyfluorfen, and the second trial was designed to determine the optimal rates of oxyfluorfen to apply pre- and postemergence in a sequential program. For all assessments, there was no interaction of treatments with site-year; hence, treatments were combined across years. In the first trial, clomazone was applied preemergence at 336 g ai ha^{-1}, followed by a postemergence application of oxyfluorfen (ALB2024) at 560, 840, 1120, 1400, or 1680 g ai ha^{-1} when the rice reached the 2-leaf growth stage. In the second trial, clomazone in combination with oxyfluorfen (ALB2023) (336 + 560 or 840 or 1120 g ai ha^{-1}) was applied preemergence followed by a postemergence application of oxyfluorfen at 560, 840, or 1120 g ai ha^{-1}, for a season total of 1,680 g ai ha^{-1} of oxyfluorfen. All postemergence applications contained methylated seed oil at 1% v/v, and a clomazone only treatment served as a control. In the first trial, there were differences in weedy rice control among rates at 28 days after treatment (DAT), with control ranging from 61 to 74%. There were no differences in weedy rice control among rates at earlier evaluations. In the second trial, the highest rate of oxyfluorfen (1,120 g ai ha^{-1}) applied preemergence resulted in 70% weedy rice control, which was 24 percentage points higher than the lowest rate of oxyfluorfen (560 g ai ha^{-1}). When preemergence applications were followed by postemergence applications of oxyfluorfen, weedy rice control was similar among all three programs, ranging from 78 to 81% at 14 days after final treatment. Oxyfluorfen could potentially serve as an additional herbicide option for suppression of weedy rice in a drill-seeded ROXY® Rice Production System, but complete control with oxyfluorfen alone is not likely.

Barnyardgrass Control and Rice Tolerance with Acetochlor and a Fenclorim Seed Treatment on a Clay Soil

Avent, T.H., Norsworthy, J.K., Castner, M.C., Arnold, C.T., and Noe, S.C.

Previous research has demonstrated that a fenclorim seed treatment safens rice (*Oryza sativa* L.) to a microencapsulated (ME) formulation of acetochlor applied on silt loam soils. However, no published research presents data on how the fenclorim seed treatment and various rates of ME acetochlor perform with rice on heavy-clay soils. Trials were initiated at the Northeast Research and Extension Center in Keiser, AR, in 2020 and 2021 on a Sharkey-Steele complex with 17, 34, and 49% sand, silt, and clay, respectively. A two-factor factorial randomized complete block design with four replications was implemented to determine the effects of a fenclorim seed treatment with various rates of ME acetochlor on rice tolerance and control of both barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv] and Palmer amaranth (*Amaranthus palmeri* S. Watson). The first factor (herbicide) consisted of four ME acetochlor rates at 0, 1,260; 1,890; and 2,560 g ai ha^{-1}. The second factor included with or without a fenclorim seed treatment at 2.5 g ai kg^{-1} of seed. The cultivar 'Diamond' was planted at 72 seeds m^{-1} of row, and acetochlor was applied delayed-preemergence. Rice injury increased as the acetochlor rate increased at 14 and 28 days after emergence (DAE). The fenclorim seed treatment reduced injury averaged over acetochlor rates by 40 and 32 percentage points, respectively. Rough rice yield was also improved by 1,590 kg ha^{-1} by adding the fenclorim seed treatment, averaged over acetochlor rates. The fenclorim seed treatment did not influence weed control for either species ($P > 0.378$), but weed control improved as the herbicide rate increased. For barnyardgrass control 28 DAE, ME acetochlor at 2,520 and 1,890 g ai ha^{-1} provided better control than 1,260 g ai ha^{-1}, which provided 87, 82, and 56% control, respectively. For Palmer amaranth control 28 DAE, ME acetochlor provided the same trend with 95, 89,

and 78% control, respectively. Results from this study demonstrate the ability of fenclorim to provide enhanced rice tolerance to ME acetochlor without compromising weed control and that ME acetochlor at 1,890 g ai ha^{-1} (4.5 pt A^{-1} of Warrant®) can provide sufficient control of barnyardgrass and Palmer amaranth.

Behavior of Pendimethalin in Water after an Application onto Flooded Rice

Becerra-Alvarez, A., and Al-Khatib, K.

Water-seeded rice, *Oryza sativa* L., is the predominant method for rice production in California's Sacramento and San Joaquin Valley. Pre-germinated rice is air seeded onto fields with a standing flood of 10-12 cm. The field is then continuously flooded throughout the whole season up to about two months before harvest. Water-holding periods after herbicide applications are important in flooded rice to reduce off-target exposure and influence the herbicide activity. Therefore, it is important to understand the behavior of pendimethalin formulations when applied onto a flooded rice field to gain knowledge for the use of pendimethalin in water-seeded rice. Three pendimethalin formulations, a capsule suspension, emulsifiable concentrate, and granular, were applied onto flooded rice field plots at three different rates, 1.12 kg ai ha^{-1}, 2.25 kg ai ha^{-1}, and 3.57 kg ai ha^{-1}. Then, water samples were collected at 1, 3, 5, 10, and 15 days after treatment and analyzed for residue of the pendimethalin parent molecule with high performance liquid chromatography-mass spectrometry. There were differences on the amount of pendimethalin residue observed in the flood water among rate (P=<0.0001) and sampling time (P=<0.0001) but not for formulations (P=0.326). Interaction across formulations and sampling time (P=<0.0001) was observed. Pendimethalin levels in the flood water were below the standard of 17.6 ppb on all treatments by 5 days after treatment. Results may indicate a water-holding period of at least 5 days and variable dissipation rates for each formulation.

The Evaluation of Italian Ryegrass Control Using Fall-Applied Residual Herbicides

Burrell II, T.D., Bond, J.A., Eubank, T.W., Mangialardi, G.A., Bowman, H.D., and Whitt, D.R.

Italian ryegrass (*Lolium perenne*) is one of the most troublesome weeds of rice in Mississippi. Its resistance to multiple modes of action has made it more difficult to control in recent years. Residue remaining following control measures is often present at the time of rice seeding, and this can compromise planting efficiency. The most effective and economical management strategy to control Italian ryegrass is fall-applied residual herbicides; however, the most effective products are not labeled for use in the fall prior to rice seeding. Therefore, research was conducted in Stoneville, MS, to evaluate the effect of fall-applied residual herbicides on rice growth and development.

Treatments were arranged as a factorial of application rate and herbicide treatment within a randomized complete block design and four replications, and the study was repeated in time. Residual herbicides were applied at one and two times (1 and 2x) the labeled rates for control of Italian ryegrass in Mississippi. Herbicide treatments included flumioxazin, acetochlor, acetochlor plus flumioxazin, clomazone, clomazone plus flumioxazin, dimethenamid-p, and dimethenamid-p plus flumioxazin. Labeled (1x) rates for each treatment were flumioxazin at 29 g ai ha^{-1}, acetochlor at 513 g ai ha^{-1}, clomazone at 340 g ai ha^{-1}, and dimethenamid-p at 340 g ai ha^{-1}. Treatments were applied in October or November, and plots were left undisturbed until rice seeding. A nontreated control that received no fall-applied residual herbicide treatment was included for comparison. Visible estimates of rice injury were recorded 7, 14, 21, and 28 d after rice emergence (DAE). Rice seedling density was determined 14 DAE, and rice height was recorded 14 DAE and at maturity. The number of days to 50% heading was recorded as an indication of maturity. At maturity, rough rice grain yields were recorded and adjusted to 12% moisture. All data were subjected to ANOVA and estimates of the last square means were used for mean separation at $p \leq 0.05$.

No main effects or interactions with application rate were detected among the parameters analyzed. Visible rice injury 21 DAE was 37 and 39% with acetochlor and acetochlor plus flumioxazin, respectively; however, no injury was recorded following other herbicide treatments. Rice density was lower in plots receiving treatments containing dimethenamid-p or acetochlor compared with flumioxazin alone or treatments with clomazone. Additionally, acetochlor reduced rice density more than dimethenamid-p. After the beginning of reproductive growth, negative effects of dimethenamid-p were not evident. Maturity and yield were similar in plots treated with dimethenamid-p and those receiving flumioxazin alone or treatments with clomazone. Acetochlor delayed maturity 4 d and reduced rough rice yields 10 to 15% compared with other treatments.

Acetochlor should not be applied in fall targeting Italian ryegrass in fields where rice is scheduled for seeding the following spring. Although maturity and rough rice yield were not reduced in plots receiving dimethenamid-p, early-season growth and development of rice was compromised. Clomazone remains the only viable treatment as a fall-applied residual herbicide in rice areas.

Integration of Rogue into Max-Ace Rice Systems for Improved Weed Control and Reduced Selection for Resistance

Carvalho-Moore, P., Norsworthy, J.K., Schmidt, L., Piveta, L.B., Arnold, C.T., and King, T.

Max-Ace® is the newest herbicide tolerance technology in rice fields. This technology provides resistance to the herbicide Highcard™ (quizalofop-p-ethyl) and adds a new mode of action to the rice weed control portfolio. However, using additional chemistries is essential to ensure the prolonged viability of this technology and avoid weed resistance. Therefore, this study aimed to evaluate how Rogue® (benzobicyclon) fits into Max-Ace rice weed control programs. The experiment was conducted in Stuttgart, Arkansas, and organized in a two-factor randomized complete block with a split-plot setup. The whole-plot factor was with or without Rogue at postflood (POSTF), and sub-plot factor was herbicide programs: 1) no herbicide, 2) Highcard sprayed at early postemergence (EP) and preflood (PREF), 3) Highcard sprayed at EP and POSTF, 4) Highcard sprayed at PREF, and 5) Highcard sprayed at POSTF, respectively. Weedy rice (*Oryza* spp.) and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] control were rated 4 weeks after POSTF treatments. Yield data were obtained at the end of the season. For both weeds evaluated, the lowest control levels were obtained when Highcard was only sprayed at POSTF without Rogue or Rogue applied by itself at POSTF. Barnyardgrass and weedy rice control were above 95% whenever repeated herbicide applications of Highcard were present, independently of Rogue. The lowest yield was obtained in the treatment with a single application of Highcard at POSTF. The highest yields were obtained when Highcard was sprayed twice in the season with or without Rogue or a single application of Highcard PREF followed by Rogue POSTF. Using the same herbicide chemistry consecutively increases risk of resistance and jeopardizes the longevity of its efficacy. The alliance of Max-Ace rice systems with an effective alternative herbicide like Rogue is a potent weed control option to reduce the development of herbicide resistance.

Use of Florpyrauxifen-Benzyl-Coated Urea to Reduce Off-Target Movement to Soybean

Castner, M.C., Norsworthy, J.K., Cotter, B.L., and Butts, T.R.

Following the commercial launch of Loyant® (florpyrauxifen-benzyl) in 2018, occurrences of off-target movement of the herbicide were prevalent onto soybean [*Glycine max* (L.) Merr.] in proximity to rice (*Oryza sativa* L.) from aerial applications. Field experiments were conducted in 2020 and 2021, in Fayetteville, AR, to determine if florpyrauxifen-benzyl-coated urea prills could mitigate damage to soybean from the herbicide in the instance of an off-target movement event in comparison to a simulated spray drift. Seven low-dose rates of florpyrauxifen-benzyl, ranging from 0 to 5.63 g ae ha^{-1}, were applied over-the-top of soybean at V3 as a foliar spray or coated urea and evaluated for visible injury at 7, 14, 21, and 28 days after treatment (DAT). In addition to visible injury, soybean yield was collected at harvest. A Weibull Growth curve was used to model visible injury at 21 DAT, and a Mechanistic Growth curve for yield following harvest. The predicted (α=0.05) florpyrauxifen-benzyl dose needed to elicit 80% visible injury to soybean from a coated or foliar application was 18 and 0.56 g ae ha^{-1}, respectively, which is a 32-fold increase in soybean sensitivity when foliar spray drift occurs (R^2=0.99). At the maximum tested rate of florpyrauxifen-benzyl (5.63 g ae ha^{-1}), soybean yield was protected 33-fold when the herbicide was coated on urea (3,390 kg ha^{-1}) in contrast to simulated spray drift (102 kg ha^{-1}). In areas where soybean is adjacent to rice, aerial applications of florpyrauxifen-benzyl-coated urea will likely mitigate injury to soybean as opposed to spray drift of the herbicide.

Impact of Florpyrauxifen-Benzyl on a Hybrid Rice Cultivar Seeded at Different Densities

Eubank, T.W., Bond, J.A., Mangialardi, G.A., and Burrell, T.D.

Florpyrauxifen-benzyl is a postemergence (POST) herbicide commercialized in 2018. Florpyrauxifen-benzyl applications have reduced rice yield in some situations, and producers are concerned that the impact could be even greater with low rice plant densities. Research was conducted in Stoneville, MS, from 2019 to 2021 to evaluate the effect of florpyrauxifen-benzyl on rice yield when a hybrid cultivar was seeded at reduced densities.

The rice cultivar 'Clearfield XL7521' was seeded at 10, 17, 24, 30, and 37 kg ha^{-1}. The seeding rates were percentages (120, 80, 56.67, and 33.3) based on the recommended seeding rate of 30 kg ha^{-1} for Clearfield XL7521. At the four-leaf to one-tiller growth stage, florpyrauxifen-benzyl was applied at 0 or 59 g ai ha^{-1}. Visible injury was assessed 7, 14, 21, and 28 d after application. Rice plant height was recorded by measuring from the base of the plant to the uppermost leaf of five randomly selected plants on rows two and seven of each plot. Rice maturity was estimated as the number of days to 50% heading and recorded as days after emergence. At maturity, rough rice grain yields were recorded and adjusted to 12% moisture.

Rice injury with florpyrauxifen-benzyl ≤8% across all seeding rates and evaluation intervals. Application of florpyrauxifen-benzyl reduced plant height 14% across all seeding rates. The greatest reduction in rice plant height was between the two florpyrauxifen-benzyl treatments with rice seeded at 37 kg ha^{-1}. Rice seeded at 10 and 17 kg ha^{-1} matured more slowly than that seeded at 24, 30, and 37 kg ha^{-1}. Florpyrauxifen-benzyl reduced rough rice grain yields at the 17 and 37 kg ha^{-1} but not at any other seeding rate. These results indicate application of florpyrauxifen-benzyl at twice the labeled rate can result in a loss of yield due to variation in rice densities.

Rice and Smallflower Umbrella Sedge Responses to Loyant at Different Growth Stages

Inci, D., and Al-Khatib, K.

Smallflower umbrella sedge (SMF), *Cyperus difformis* L., is a troublesome sedge weed in California rice agroecosystem. The repeatedly use of the same modes of action herbicides and the lack of crop rotation have resulted in herbicide resistant SMF. Loyant, florpyrauxifen-benzyl, is a new synthetic auxin type rice herbicide recently registered in California. Two field research experiments were conducted during the 2021 and 2022 growing seasons at the California Rice Experiment Station in Biggs, CA, to study rice and SMF response to Loyant when applied at different growth stages. In the first study, clomazone at 622 g ai/ha was applied to all plots excluding untreated control (UTC). Loyant was applied at 40 g ai/ha to 1-leaf, 10, 15, 20, and 25 cm tall SMF. In the second study, Loyant was applied at 40 and 80 g ai/ha after the rice panicle initiation to determine rice phytotoxicity, including blanking and late-season weed control. All Loyant treatments included methylated seed oil at 584 ml/ha rate. Both studies were conducted as a randomized complete block design, where experimental units were 3X6 m treatment plots. All plots were evaluated for weed control and crop injury at 7, 14, 21, 28, 35, and 42 days after treatments (DAT). Weeds were counted at 28 DAT within two randomly selected areas in each plot, plots were harvested at the end of the season, and the yield was measured. The first study showed that the highest chlorosis, 12%, and the highest necrosis, 10%, were observed at 7 DAT of 1-leaf SMF stage application. Loyant at the 1-leaf stage was the most effective to control SMF and rice field bulrush (BLR) with 98% control at 28 DAT, and watergrass (WTG) with 100% control at 42 DAT. All treatments achieved 100% control of ducksalad (DKS) at 42 DAT. Loyant applied on 15 cm tall SMF achieved 100% redstem (RDS) control at 42 DAT. The highest yield at harvest was achieved as 12,432 kg/ha at 25 cm tall SMF application, which was the latest application timing of this study. In the second study where Loyant applied after rice panicle initiation applications, the highest necrosis of 32% was observed at 7 DAT of Loyant 80 g ai/ha treatment. Rice gradually recovered from all the injuries by the 42 DAT. Loyant at 80 g ai/ha was the most effective treatment. The highest BLR and sprangletop control were observed at 35 DAT at 83% and 95%, respectively. Similarly, the highest SMF and WTG control was observed at 42 DAT at 96% and 93%, respectively. Nevertheless, the highest yield at harvest was achieved as 9,620 kg/ha at Loyant 40 g ai/ha treatment. While 40 and 80 g ai/ha Loyant treatments caused 8% grain blanking of rice panicles, UTC showed 14% blanking. Seeds per panicles were observed as 86, 83, and 82 for Loyant treatments at 40 and 80 g ai/ha and UTC, respectively.

Abstracts of Papers from the Student Oral Contest Panel – Weed Control and Growth Regulation II
Moderator: Leah Collie

Interference of Palmer Amaranth in Furrow-Irrigated Rice: What is the Area of Influence?

King, T.A., Norsworthy, J.K., Woolard, M.C., Pritchett, S.L., Barber L.T., and Butts, T.R.

Arkansas rice producers face a growing concern when transitioning to a furrow-irrigated rice system, which is the lack of a continual flood allowing for weeds to emerge. The lack of a continual flood allows for Palmer amaranth emergence throughout much of the growing season and creates an environment conducive for growth of the weed. Existence of Palmer amaranth in furrow-irrigated rice may cause increased potential for reduced rice yields and a greater need for additional herbicide applications. A field trial was conducted at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR, in 2022 to assess the impact of Palmer amaranth on furrow-irrigated rice. Newly emerged Palmer amaranth plants were marked every 7 days, beginning 1 week prior to rice emergence in a furrow-irrigated rice system through 4 weeks after rice emergence. Palmer amaranth biomass decreased by 1.5 oz., on average, every 7 days that emergence of the weed was delayed relative to rice. At 2 weeks after rice emergence and beyond, most Palmer amaranth plants that emerged failed to survive until rice harvest. Averaged over emergence times, female plants weighed more than male plants, which resulted in greater interference with rice for limited resources. Female Palmer amaranth plants that emerged one week prior to the emergence of the crop produced 270,000 seeds per plant while Palmer amaranth plants that emerged the week after the crop produced 11,000 seeds per plant. Palmer amaranth plants that emerged 1 week prior to the crop reduced rough rice yield by 68% at 6 inches from the weed. These results show that Palmer amaranth time of emergence is a critical factor influencing rough rice yields, Palmer amaranth seed production, and Palmer amaranth biomass. In order to reduce yield loss from Palmer amaranth, herbicide control options should be used to delay Palmer amaranth emergence.

Alternative Herbicide Options for Paraquat in Treatments Targeting Palmer amaranth (*Amaranthus palmeri*)

Mangialardi, G.A., Bond, J.A., Eubank, T.W., and Burrell, T.W.

Paraquat is a non-selective group 22 herbicide inhibiting photosynthesis at photosystem I. Paraquat was applied to U.S. crops in totals of 769,292 kg to cotton, 407,325 kg to corn, and 49,441 kg to rice in 2020. Palmer amaranth has been noted causing more economic damage than all glyphosate-resistant weeds in the southern United States, and paraquat is often utilized at planting for Palmer amaranth control. Uncertainty of paraquat's future due to high mammalian toxicity and few treatments for accidental poisoning provokes the need to study alternative herbicide options for control of Palmer amaranth.

Two studies were conducted at the Delta Research and Extension Center in Stoneville, MS, in 2022 to evaluate control of Palmer amaranth with different herbicides and adjuvants. Both studies were designed to simulate herbicide treatments targeting Palmer amaranth applied immediately following planting. Both studies were conducted in fallow areas and were arranged as a two-factor factorial within a randomized complete block design with four replications. In the Herbicide Treatment Study, Factor A was herbicide treatment and included paraquat at 841 g ai ha^{-1} plus metribuzin at 140 g ai ha^{-1}, glyphosate at 1,121 g ae ha^{-1} plus tiafenacil at 25 g ai ha^{-1}, glyphosate at 1,121 g ha^{-1} plus tiafenacil at 50 g ha^{-1}, glyphosate at 1,121 g ha^{-1} plus dicamba at 560 g ae ha^{-1}, glufosinate at 656 g ai ha^{-1}, glyphosate plus 2,4-D choline at 2,164 g ae ha^{-1}, and 2,4-D choline at 1,065 g ae ha^{-1} plus glufosinate at 656 g ha^{-1}. All treatments containing paraquat or dicamaba included NIS (Non-Ionic Surfactant) at .5% v/v, while treatments containing tiafenacil included MSO (Methylated Seed Oil) at 1% v/v. Factor B was application timing with treatments applied when Palmer amaranth was 7- or 25-cm in height. In the Adjuvant Study, Factor A was herbicide treatment and included paraquat 841 g ha^{-1} plus metribuzin at 280 g ha^{-1}, two different iosopropylamine salts of glyphosate (IPA-1, IPA-2) at 1,121 g ha^{-1} plus tiafenacil at 25 g ha^{-1}. Factor B was adjuvant and included no adjuvant, MSO at 1% v/v, AMS

(Ammonium Sulfate) at 1.25% v/v, COC (Crop Oil Concentrate) at 1% v/v, MSO at 1% v/v plus AMS at 1.25% v/v, and COC at 1% v/v plus AMS at 1.25% v/v. All treatments were applied to 15 cm Palmer amaranth.

In the Herbicide Treatment Study, only paraquat plus metribuzin and 2,4-D choline plus glufosinate controlled 7- and 25-cm Palmer amaranth >90% across all evaluations. Glyphosate plus both rates of tiafenacil, glyphosate plus dicamba, glufosinate, and glyphosate plus 2,4-D choline controlled 7-cm Palmer amaranth similar to paraquat plus metribuzin and 2,4-D choline plus glufosinate. These treatments did not provide comparable control of 25-cm Palmer amaranth. In the Adjuvant Study, paraquat plus metribuzin provided the greatest control of Palmer amaranth (≥97%) regardless of adjuvant. Methylated Seed Oil mixed with IPA-1 and COC mixed with IPA-2 plus tiafenacil were the only treatments to provide Palmer amaranth control similar to paraquat plus metribuzin treatments.

In summary, at planting control of Palmer amaranth with paraquat is still very effective. Preliminary data suggests that three treatments in the Herbicide Treatment Study can provide control of 7-cm Palmer amaranth comparable to that of paraquat. Preliminary data from the Adjuvant study also suggests that adjuvant type and type of isopropylamine salt of glyphosate influences tiafenacil's ability to control Palmer amaranth.

Effect of Rice Cultivar and Row Width on Weed Control in Drill-Seeded, Flooded Rice

Reed, N.H., Butts, T.R., Norsworthy, J.K., Hardke, J.T., Barber, L.T., Bond, J.A., Bowman, H.D., Davis, B.M., Dillon, T.W., Arnold, C.H., and Kouame, K.B.J.

Problematic weeds such as barnyardgrass (BYG) in a rice production system cause complications like yield loss, increased input costs, and difficulty with harvest. The fast evolution of herbicide resistance in BYG and further restrictions on herbicides have emphasized the need for cultural management strategies such as drill row width manipulation and the use of more competitive cultivars. The objective of this research was to document the effect of drill row width and rice cultivar on weed management and crop canopy development. A field experiment was conducted in 2021 and 2022 at Lonoke, Pine Tree, and Rohwer, AR, as a randomized complete block split-plot design. Four rice cultivars (subplot factor) [medium-grain (CLM04), long-grain in-bred (CLL16), and two long-grain hybrids (RT7301 and RT7521 FP)] were drill-seeded in four drill row widths (whole plot factor) (13-, 19-, 25-, and 38-cm). Barnyardgrass density was assessed at the 5- to 6-leaf rice stage (preflood) and preharvest. Aerial imagery from a small unmanned aerial system (sUAS) was also taken at the panicle differentiation rice stage and analyzed using Field Analyzer. All data were analyzed using JMP Pro 16.1 and subjected to ANOVA using Tukey's HSD (P=0.05). No interaction between drill row width and rice cultivar was observed, regardless of the response variable. Across locations and years at the 5- to 6-leaf rice stage, there was a 60% decrease in BYG density for the 19-cm spacing compared to the 38-cm spacing. Across locations and years at the preharvest rice stage, there was a 50% decrease in BYG density for the 19-cm spacing compared to the 38-cm spacing. At the preharvest stage, a 60% decrease in BYG density was observed for the hybrid compared to the conventional cultivars. Based on the sUAS imagery at panicle differentiation, there was a 20% reduction in canopy coverage for the 38-cm spacing compared to the 19-cm. No differences were seen for cultivars. The standard rice row width of 19-cm still shows to be the most optimal drill row spacing for weed control compared to wider widths like the 38-cm. A hybrid rice cultivar may aid in weed management efforts compared to conventional cultivars due to enhanced tillering/growth and increased competitiveness.

Evaluation of Delayed-Preemergence-Applied Metolachlor with and without a Fenclorim Rice Seed Treatment on a Clay Soil

Noe, S.C., Norsworthy, J.K., Piveta, L.B., Arnold, C.T., Smith, D., and Avent, T.H.

Barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] is a highly problematic weed in flooded rice that can result in significant yield losses when left unchecked. To preserve high yields in Arkansas rice production, new methods of barnyardgrass control will be needed. *S*-metolachlor is a chloroacetamide herbicide that targets grasses and small-seeded broadleaf weeds; therefore, an experiment was conducted in Keiser, AR, to evaluate the efficacy of metolachlor in a rice system in conjunction with a fenclorim seed treatment to mitigate crop injury. Three rates of a proprietary metolachlor formulation (560, 1,120, and 1,680 g ai h^{-1}) were applied delayed-preemergence to 'Diamond' rice that was treated with fenclorim at 0 or 2.5 g ai kg-seed. Rice stand counts were taken at 14 and 28 days after treatment (DAT), and all plots were over-sprayed to remove weeds at 28 DAT. Barnyardgrass control was rated in comparison with the nontreated through 28 DAT, and rice injury was evaluated throughout the growing season. Rough rice grain yield was determined at crop maturity. The presence of fenclorim reduced stand loss at every rate of metolachlor, but rice stand was reduced as herbicide rate increased. While rice injury initially was high, 70%, by 35 DAT without fenclorim, the low rate of metolachlor combined with a fenclorim seed treatment caused less than 15% injury. The low rate of metolachlor provided 82% barnyardgrass control 35 DAT. Overall, the presence of fenclorim reduced injury to rice at each rate of *S*-metolachlor, while not having an impact on weed control. At metolachlor rate of 560 g ai ha^{-1} with a fenclorim seed treatment, yield of rice was comparable with the nontreated. However, increasing rates of metolachlor reduced yield. The combination of a low rate of metolachlor with a fenclorim seed treatment provided a high level of barnyardgrass control while not reducing yield compared to the nontreated. If metolachlor becomes labeled for use in rice, this would provide an alternative site of action for weed control without requiring a herbicide-resistance trait.

Optimization of a Clomazone: Oxyfluorfen Mixture for Extended Barnyardgrass Control on a Silt Loam Soil

Smith, T., Norsworthy, J.K., Arnold, C.H., Souza, M.C., and. Butts, T.R.

Oxyfluorfen is a group 14 herbicide that is currently labeled for barnyardgrass control in crops other than rice. Pending commercialization of the Roxy Rice Production System (Roxy rice), which enables use of oxyfluorfen through a non-GMO resistance trait, growers will have an additional control option for this troublesome weed. A field experiment was conducted at the Rice Research and Extension Center near Stuttgart, AR, to evaluate rates of clomazone and oxyfluorfen for residual control of barnyardgrass in Roxy rice. Herbicide treatments included sequential applications of clomazone alone at 0.25 or 0.3 lb ai/A, and oxyfluorfen at 0.6 or 0.75 lb ai/A with the first application applied at planting and the subsequent application at the 2-leaf stage of rice. Additionally, clomazone at 0.25 lb ai/A + oxyfluorfen at 0.75 lb ai/A (1:3 ratio) or clomazone at 0.3 lb ai/A + oxyfluorfen at 0.6 lb ai/A (1:2 ratio) was evaluated. At 3 weeks after the preemergence application, all rates of clomazone and oxyfluorfen provided at least 93% barnyardgrass control. When oxyfluorfen and clomazone were applied in combination, regardless of rate, barnyardgrass control was 100% at 3 weeks after the preemergence application. At 5 weeks after the postemergence applications, all treatments provided at least 94% barnyardgrass control. By 6 weeks after the postemergence applications, differences among treatments began to appear, with the clomazone and oxyfluorfen combinations still providing at least 95% barnyardgrass control. Conversely, when oxyfluorfen was applied alone sequentially regardless of rate, barnyardgrass control had fallen to no more than 79% by 7 weeks after the postemergence application. These results show that oxyfluorfen when used in combination with clomazone provides another effective and unique mode of action for residual barnyardgrass in Roxy rice.

Evaluation of Gambit and Propanil Interactions in Louisiana Rice Production

Williams, J.A., Webster, L.C., and Arcement, M.P.

Competition from many grasses, broadleaves and sedges can be economically detrimental to rice production. The wide variety of problematic weeds has made mixing two or more herbicides a common practice to broaden the control spectrum. Additionally, applying herbicides in mixtures reduces application costs and can aid in preventing or delaying the development of herbicide resistance. Combining two or more herbicides in a single application will result in either syngergistic, additive/neutral, or antagonistic effects, and these effects are often species dependent. Antagonism occurs when the result of mixing two or more herbicides decreases performance when compared to the herbicides applied separately. Reductions in alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.] control have been reported when a prepackaged mixture of halosulfuron plus prosulfuron (Gambit®) is mixed with propanil.

Studies were conducted in 2021 and 2022 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, to evaluate the interaction between a prepackaged mixture of halosulfuron plus prosulfuron and an emulsifiable concentrate formulation of propanil (Stam®). Plot size was 1.5 by 3 m^{-2} with hybrid 'RT7321 FP' rice at 47 kg ha^{-1}. Three alligatorweed and grassy arrowhead [*Sagittaria graminea* Michx.] plants were hand transplanted into separate 30.5 cm in diameter plastic rings at the front of each plot. This study utilized a randomized complete block design with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of an application of propanil at 0 or 3,363 g ai ha^{-1}. Factor B consisted of either no mix partner or a pre-packaged mixture of halosulfuron plus prosulfuron at 55 or 83 g ai ha^{-1}, halosulfuron (Permit®) at 35 or 53 g ai ha^{-1}, or prosulfuron (Peak®) at 20 or 30 g ai ha^{-1}. Herbicides were applied postflood at the 1- to 2-tiller rice growth stage. All applications were applied with a crop oil concentrate at 1% v v^{-1}, except for applications containing propanil. All herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Visual evaluations of percent control of alligatorweed and grassy arrowhead were recorded at 28 and 35 days after treatment (DAT).

Results from both 28 and 35 DAT indicate a reduction in alligatorweed control when halosulfuron plus prosulfuron was mixed with propanil. At 28 DAT, halosulfuron plus prosulfuron applied alone at 55 and 83 g ha^{-1} controlled alligatorweed 78 and 81%, respectively; however, when mixed with propanil control was 32 and 43%, respectively. Similarly, at 35 DAT halosulfuron plus prosulfuron applied alone at 55 and 83 g ha^{-1} controlled alligatorweed 69 and 83%, respectively, but when mixed with propanil control was 39 and 54% at 28 and 35 DAT, respectively. Similar results were observed for grassy arrowhead control.

Evaluating the Use of Fluoridone in a Furrow-Irrigated Rice System

Woolard, M.C., Norsworthy, J.K., King, T.A., Piveta, L.B., Arnold, C.T., and Butts, T.R.

Fluoridone is a WSSA group 12 herbicide widely used as a preemergence (PRE) in cotton (*Gossypium hirsutum* L.) production for control on Palmer amaranth (*Amaranthus palmeri* S. Wats.) and some grass species. Currently, there are limited options for PRE control of Palmer amaranth in furrow-irrigated rice systems due to lack of broadleaf herbicides and a permanent flood. Therefore, fluoridone is being elevated as a Palmer amaranth-focused option in furrow-irrigated rice. Experiments were conducted near Colt and Fayetteville, Arkansas, on silt loam soils. Treatments included fluoridone at 168 g ai/ha plus clomazone at 336 g ai/ha versus clomazone at 336 g ai/ha alone preemergence. The treatments that had fluoridone and clomazone preemergence received an application of florpyrauxifen-benzyl at the tillering growth stage at 0, 14.7, and 29.4 g ai/ha plus 0.42% v/v methylated seed oil. The treatments that received clomazone preemergence were followed with treatments of fluoridone at 0 and 168 g ai/ha plus florpyrauxifen-benzyl 14.7 g ai/ha and 0.42% v/v methylated seed oil at the three-leaf and tillering growth stage. For the trial conducted near Colt, rice injury averaged 46% when treated with fluoridone plus clomazone compared to 42% for clomazone 7 days after emergence (DAE). All treatments provided greater than 95% Palmer amaranth control at 42 DAE, except for fluoridone and clomazone preemergence (<75% control). For the trial in Fayetteville, rice injury from fluoridone plus clomazone 7 DAE averaged 11% compared to clomazone which was 3%. Palmer amaranth control ranged from 76 to 94% with 1) fluoridone plus clomazone followed by the high rate of florpyrauxifen-benzyl and 2) clomazone followed by fluoridone plus florpyrauxifen-benzyl followed by florpyrauxifen-benzyl 35 DAE. Future research should determine if the early season injury has any impact on rice yield. Overall, in a programs approach, fluoridone may be a viable option for control of Palmer amaranth in a furrow-irrigated rice system, but additional research should evaluate rice tolerance in lower portions of furrow-irrigated fields where irrigation water is often held.

Utilizing Benzobicyclon to Control Weedy Rice in Imidazoline-Resistant Rice Systems

Pritchett, S.L., Norsworthy, J.K., Piveta, L.B., Arnold, C.T., Arnold, C.H., Barber, L.T., and Butts, T.R.

An increase of weedy rice (*Oryza sativa* L.) populations resistant to herbicides has heightened the need for alternative modes of action. Benzobicyclon is a 4-hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor, the first of its kind labeled in rice. Preliminary research has displayed that benzobicyclon controls various monocot and broadleaf weed species. This study aims to evaluate the effectiveness of benzobicyclon as a weed control partner in imidazoline-resistant rice weed control systems.

The study was initiated on May 30, 2022, at the Rice Research and Extension Center near Stuttgart, Arkansas. The study was organized as a split-plot in a randomized complete block design with four replications. The whole-plot factor was with or without benzobicyclon at 371 g/ha applied post-flood, and the subplot factor was herbicide treatments that included 1) no additional herbicide, 2) imazethapyr at 87 g/ha applied at 2- to 3-leaf rice followed by imazamox at 44 g/ha applied at 5- to 6-leaf rice, 3) imazethapyr at 87 g/ha applied at 2- to 3-leaf rice followed by imazamox at 44 g/ha applied post-flood, 4) imazamox at 44 g/ha applied at 5- to 6-leaf rice, and 5) imazamox at 44 g/ha applied post-flood. Clomazone at 336 g/ha was applied to the entire test site immediately after drill-seeding FullPage rice. Weedy rice and barnyardgrass control were visibly rated (0-100%), along with rice injury and rice stunting. These ratings were taken at 1, 2, 3, 4, and 6 weeks after the post-flood treatment (WAFT). In addition, rough rice yield was collected at crop maturity.

Injury was minimal at all evaluation timings, with no treatment averaging more than 12% injury. Most of the injury in benzobicyclon-treated plots was a result of slight bleaching, which never exceeded 8% for any specific treatment. The addition of benzobicyclon to each herbicide program resulted in improved weedy rice control in three of five programs at 1 WAFT. The treatments for which weedy rice improved included 1) no additional herbicide, 2) imazamox at 44 g/ha applied at 5- to 6-leaf rice, and 3) imazamox at 44 g/ha applied post-flood. A post-flood application of benzobicyclon following imazethapyr at 87 g/ha applied at 2- to 3-leaf rice followed by imazamox at 44 g/ha applied at 5- to 6-leaf rice resulted in a 10-percentage point increase in weedy rice control at 3 WAFT. At 4 and 6 WAFT, all benzobicyclon-containing herbicide programs had superior weedy rice control compared to the corresponding treatments without benzobicyclon. Rice in all herbicide-containing treatments, including benzobicyclon alone, produced comparable yields, which were at least 4,140 kg/ha greater than the non-treated control. Findings from this research show that the addition of benzobicyclon to weed control programs in FullPage rice will likely improve weedy rice control, which should aid in lowering weedy rice seedbank density in subsequent years.

Influence of Application Timing on Rice Tolerance to Fluridone

Souza, M.C., Norsworthy, J.K., Piveta, L.B., Castner, M.C., Barber, L.T., and Butts, T.R.

Widespread herbicide resistance is an issue in rice, making weed management a challenge for farmers. To avoid weed resistance, it is crucial to implement a varied weed management program that includes different modes of action. Therefore, this study aimed to evaluate the influence of fluridone application timing on rice tolerance. The experiment was conducted at the Rice Research and Extension Center in Stuttgart, AR, in the summer of 2022. The experiment was organized in a randomized complete block design with 10 application timings and four replications. The application timings were: 21 and 14 days preplant, preemergence (PRE), delayed-preemergence (DPRE), 1-leaf, 2-leaf, 3-leaf, 4-leaf, preflood, and post-flood. A nontreated check was included for comparison. Fluridone was applied at 168 g ai/ha in all treatments. Visible injury ratings and rice groundcover were collected at 35 and 70 days after emergence (DAE). Yield was collected at harvest. At 35 DAE prior to establishment of the permanent flood, the highest injury levels were observed for PRE and DPRE treatments, at 13 and 11%, respectively. At 70 DAE, injury was accentuated, reaching 40% for both above-mentioned treatments. The lowest groundcover occurred following PRE, DPRE, and 1-leaf treatments at 91, 95, and 94%, respectively. Rice yields were lower than the non-treated control following the PRE, DPRE, 1-leaf, 2-leaf, and 3-leaf treatments. Rice exhibited a high level of tolerance to the post-flood application of fluridone, with an average yield of 7,270 kg/ha, which was comparable to the non-treated control. Fluridone seems to be a suitable herbicide to be added in the weed control rice portfolio, specifically targeting late postemergence applications.

Abstracts of Papers on Breeding, Genetics, and Genomics
Panel Chair: Xueyan Sha

Comparison of QTL, GWAS, and Genomic Selection Breeding Approaches for the Quantitative Trait of Grain Length

Angira, B., Cerioli, T., Guerra, R., and Famoso, A.

Rice grain shape is a major determinant of rice market value and the end-use. *GS3* is a major grain shape gene that controls grain length trait in U.S. rice germplasm. Recently, *qGL7.1* grain length gene was mapped to chromosome 7, which explained significant grain length variation in U.S. rice germplasm. Both *GS3* and *qGL7.1* genes do not segregate within the long-grain or medium-grain U.S. rice germplasm and no other major genes are reported within each grain class. These genes would be useful in long by medium crosses but it is challenging to make yield gains and achieve the preferred quality for either class from these crosses. Therefore, improvement on grain length within the long grain class would not be possible with marker assisted selection approach on these two major genes.

Grain length in rice is a genetically controlled and highly heritable trait. Thus, an improvement on grain length of long-grain rice can be achieved using other approaches - QTL stacking and genomic selection approaches. We used four bi-parental populations - CL111/RoyJ, CL153/Lakast, CL172/Cypress, and Presidio/Catahoula, developed using elite southern long-grain parents, to map the QTLs for grain length and genomic prediction and two multi-parent populations for the genome-wide association. Our results did not identify any major and consistent QTLs for grain length in the four bi-parental populations. We selected lines having favorable alleles at two QTLs that explained the highest phenotypic variations for one of the populations named MPB and selected 10 lines out of 100 total lines that had favorable alleles for long grain. The average of the selected lines was 7.13 mm. In another approach, we predicted all the lines of the MPB population and selected the top 10 lines for grain length and the average of these lines was 7.24 mm. Similar results were observed in one of the other populations and no significant QTLs were identified in the remaining two bi-parental populations. GWAS in multi-parent did not result in any significant peak for grain length. These results demonstrate that stacking QTLs is less effective in improving grain length within long grain class compared to the genomic selection approach. Moreover, the stacking QTLs approach requires more resources compared to genomic selections.

Towards the Implementation of Genomic Selection (GS) for Grain Yield and Quality-Related Traits in the Arkansas Rice Breeding Program

Borjas, A.H., McCarty, D.L., Northcutt, C.H., Fruge, A., Ellenburg, H.M., and De Guzman, C.T.

Genomic selection (GS) holds great potential to accelerate the process of breeding for complex quantitative traits. Grain yield and grain quality are the two most essential traits in rice breeding programs. This study aims to develop a marker set useful for GS and effective in the rice germplasm available at the Arkansas Rice Breeding Program. In 2018, a germplasm set composed of 66 Arkansas cultivars that represents the diversity of the Arkansas germplasm were genotyped with the 7K Infinium SNP array. This germplasm set were planted in 2021 in a replicated yield trial where agronomic and grain quality characteristics were analyzed.

An initial subset of 628 single nucleotide polymorphic (SNP) markers has been identified from the 7K array using the *qc.filtering* function from ASRgenomics. Markers were selected based on their minor allele frequency (MAF $\geq$0.4) and call rate (CR >80%). Phenotypic values for plant height, days to heading, and grain yield characteristics were used to determine the genomic estimated breeding values (GEBV). The genomic relationship matrix (K) was calculated from molecular markers with ASRgenomics using the Yang equation due to the high levels of inbreeding. The A matrix was generated by *blending* of the K matrix. The linear mixed models were fit using ASReml-Rv4 and predictive ability was calculated from the correlation between the phenotype trait, and the GEBVs.

Preliminary data on agronomic characteristics showed that the plant height have predicted abilities (PA) of 0.61 and 0.46 in long- and medium-grain class, respectively whereas for days to heading PAs of 0.71 and 0.18 were obtained for long- and medium-grain class, respectively. Yield showed a PA of 0.74 for the long-grain class in contrast to 0.01 for the medium-grain class. Among grain-quality characteristics, phenotypic values for milling yield, seed dimensions, and chalk will also be used to calculate PAs. The prediction accuracy of the final marker set will be tested on rice populations at early generations. Deployment of an effective marker set for GS is expected to reduce the time, hence, accelerating the genetic gain in the Arkansas Breeding Program.

Gene Editing of *UGP3* Confers Herbicide Resistance in Rice

De Leon, T.B., Andaya, C.B., Andaya, V.C., and McKenzie, K.S.

Rice production in California is constrained by several environmental factors. One of which is the presence of high weed pressure that competes with rice for space, light, and soil nutrients causing significant yield loss. To develop herbicide-resistant rice, the California Rice Experiment Station used mutation breeding approach to introduce genetic variants not found in rice germplasm. An oxyfluorfen resistance trait in EMS-treated rice was discovered and was named ROXY®. The herbicide tolerance was genetically controlled by a single recessive gene mapped in chromosome 5 of rice. Fine mapping and DNA sequence analysis indicated a nucleotide deletion in a gene that encodes for a *UDP-Glucose Pyrophosphorylase 3 (UGPase3*). To confirm the herbicide tolerance found in EMS-mutated rice, a *CRISPR-Cas9* gene construct containing multiple guide RNAs was designed and used in rice transformation of Calmochi-203. The gene-edited rice was advanced to T_2 generation and treated with oxyfluorfen. The treated T_2 seedlings of gene-edited Calmochi-203 showed enhanced shoot and root growth under oxyfluorfen treatment consistent with the resistance of ROXY® trait. Gene sequencing of *UGP3* target site confirmed the mutations introduced by CRISPR and recovery of herbicide resistant trait.

QTL Mapping and Genomic Prediction of Disease Reactions of Rice to the Rice Blast Fungus *M. oryzae* Races

Edwards, J.D., Sharma, S., Jia, M.H., and Jia, Y.

Rice blast, which is caused by the fungus *Magnaporthe oryzae*, is one of the most destructive diseases of rice worldwide. Major genes, such as *Pi-ta*, *Pi-kh/m/s*, *Pi-z*, and *Pi-b* have been deployed in U.S. rice varieties for highly effective blast resistance. However, the minor genes and epistatic interactions contributing to broad-spectrum resistance are largely uncharacterized.

The objectives of this study were to validate major quantitative trait loci (QTLs) for blast resistance, discover new minor QTLs, and evaluate QTL interactions across a spectrum of blast races, as well as to assess the accuracy of genomic prediction for blast resistance across fungal races. To accomplish this, we used a mapping population consisting of 272 individuals that were derived from the blast resistant variety 'Katy' and the blast susceptible line 'PI312777.' The parent ‘Katy’ contains blast resistance alleles from the landrace variety ‘Tetep’ at the *Pi-ta* gene complex which includes *R*-genes *Pi-ta*, and *Ptr*, and it contains the blast resistance allele from the tropical *japonica* variety ‘Newbonnet’ at the *Pi-ks* gene. This population was genotyped using the Rice C7AIR Illumina Infinium array and 1,578 SNPs were polymorphic in this population. Pathogenicity assays were performed on this population for 11 *M. oryzae* races: IA-45(75L14), IB-1(YJB1), IB-49(ZN61), IC-17(ZN60), ID-1(ZN42), IE-1(ZN13), IG-1(ZN39), IB-45(YJ45), IB-54(Y54), IH-1(YJH1), and IE-1k(TM2) under greenhouse conditions. QTL and QTL interactions were identified by inclusive composite interval mapping for additive QTLs (ICIM-ADD) and inclusive composite interval mapping of epistatic QTLs (ICIM-EPI).

QTL analysis identified and verified resistance spectra of major genes *Pi-ta*/*Ptr* and *Pi-ks*, and further identified 13 QTLs for 10 of the 11 pathogen races tested, and it detected additive-by-additive epistasis for 32 pairs of QTLs. Genomic prediction results revealed that models trained using only blast races IC17, IG1, IA45, or IB45 have high prediction accuracy when used to predict resistance to other blast races, whereas training with blast races other than these four only provided moderate to low prediction accuracy. A genomic selection rank sum index (GSRI) of genomic estimated breeding values (GEBVs) for overall resistance to 11 pathogen races distinctly separated high and low resistant lines for all races except IE1k. Thus, a GSRI may be a useful breeding tool to select for broad-spectrum blast resistance.

Genomic Dissection of Tropical Japonica x Indica Rice Population for Responses to Variation in Growing Temperatures

Rohila, J.S., Huggins, T.D., McClung, A.M., and Edwards, J.D.

Increasing ambient temperatures during growth and development of rice affect its grain yield and quality. Previous studies identified the rice variety TeQing (TQNG) as heat-stress tolerant and recent experiments have found that tropical *japonica* rice (TRJ) varieties such as Lemont (LMNT) are heat stress susceptible. The objective of this study was to identify thermotolerant quantitative trait loci (QTL) derived from TeQing for use in genetic improvement of the U.S. tropical *japonica* rice varieties. A chromosome segment substitution line (CSSL) mapping population (N=121) derived from LMNT x TQNG was phenotyped for several traits, including percent floret sterility, grain yield and quality, using a replicated study with two planting dates, 30 days apart, over two years. Dense molecular marker data, previously obtained for this population via genotyping-by-sequencing (GBS), was used for QTL mapping. Several QTLs and candidate genes associated with grain yield, quality, and overall thermotolerance mechanisms were identified. Specifically, eight genetic loci on four different chromosomes and nine potential candidate genes were found to be strongly associated with superior performance under heat stress. Identified QTLs are novel targets for fine mapping, candidate gene verification, and marker-assisted breeding in future studies to incorporate heat stress tolerance in U.S. rice varieties.

Marker Identification for Panicle Traits in Rice through GWAS

Talukder, S.K., Uppalanchi, P., Chepuri, R., Harper, C.L., Samonte, S.O.P.B., Sanchez, D., Mondal, S., and Singh, G.

Grain yield of rice is associated with various panicle attributes, i.e., panicle length (PL) and primary (PB) and secondary (SB) branching. The ongoing study aims to capture the variability of PL, PB, and SB and identify genomic regions associated with these traits. A diverse germplasm panel consisting of 220 rice lines or varieties was grown in the field following Augmented Block Design in 2022 at Texas A&M AgriLife Research center at Beaumont, Texas. Data was collected on PL, PB and SB traits. The population was genotyped following genotype by sequencing (GBS) approach from Texas A&M AgriLife Genomics and Bioinformatics Service (TxGen) at College Station. Polymorphic markers were identified using the reference genome of *Oryza sativa* ssp. *japonica* cultivar Nipponbare. The phenotypic data were normally distributed and showed significant variability among the lines. PL data ranged between 10.9 to 34.8 cm with an average of 20.4 cm. The number of PB and SB ranged between 4 to 15.3 and 0 to 11.66 with averages of 9.8 and 3.2, respectively. GWAS (Genome Wide Association Studies) analysis detected few significant ($P < 2.8 \times 10^{-6}$) marker trait association. The experiment will be repeated in 2023, and final marker trait association will be reported with additional information in 2023.

CRISPR-Based Genome Editing for Breeding Applications in Rice

Thomson, M.J., Morales, K.Y., Trisnaputri, A., Tsakirpaloglou, N., Biswas, S., and Septiningsih, E.M.

Genome editing using CRISPR/Cas9 has the potential to accelerate a wide range of plant breeding applications. We are exploring strategies to optimize and deploy genome editing to rapidly validate genes underlying important QTLs and modify critical traits for rice improvement. The rice community is well positioned to take advantage of the power of CRISPR/Cas9 gene editing, as the wealth of cloned genes, diverse genetic donors, and sequence data present numerous opportunities for testing and modification of candidate genes for rice improvement. Texas A&M AgriLife Research has supported the development of the Crop Genome Editing Lab on the College Station campus to support research activities for CRISPR-based genome editing in crop plants. Recent efforts have focused on using multiplexed editing to simultaneously modify multiple gene targets for trait improvement. *Agrobacterium*-mediated transformation of the southern U.S. rice variety Presidio is being used to deliver CRISPR/Cas9 and a tRNA-gRNA expression cassette for multiplexed editing. Two ongoing projects are applying this technology: first, to further understand interactions between genes controlling flowering time in rice, and secondly, to increase the levels of resistant starch in rice grains, as described below.

Flowering time is a key trait to ensure proper heading date in rice, especially when making use of exotic germplasm that is not adapted to local conditions. Many genes affecting flowering time in rice have been previously characterized, largely using single gene mutations, but the interactions between genes are not well understood. Moreover, many published studies focused on *temperate japonica* backgrounds, which may have different genetic effects from the *tropical japonica* germplasm more commonly used in the southern United States. Our team performed a genome wide association study (GWAS) for heading date across a diverse germplasm panel and identified significant associations in a region on chromosome 6 containing the known flowering time genes Hd3a and RFT1. We designed guide RNAs to knock out Hd3a and RFT1, both in combination and individually, to better understand their role in modifying flowering time in the Presidio genetic background. Notably, plants having a double mutant knockout of both genes did not flower even 300 days after planting. At the same time, a second multiplex CRISPR construct targeting six additional flowering time genes, namely Hd1, Ghd7, Hd6, OsCOL10, DTH8, and Ehd1, was transformed into Presidio to develop gene edited progeny with different combinations of flowering time gene knockouts. Multiple mutations were observed and subsequent generations are being analyzed to better understand the roles of these genes in affecting heading date in the Presidio background.

Resistant starch is not easily digestible and cereals with high resistant starch levels may be beneficial for human health. A second project employed multiplex editing of four starch branching enzyme (SBE) genes to increase levels of resistant starch in rice grains and better understand the relationship between high amylose and resistant starch content. Knockout mutations were identified across all four SBE targets in different combinations, leading to a 15% increase in resistant starch in several edited lines. Ongoing efforts are working towards fixing the mutations as homozygous alleles with different combinations of knockout SBE genes in each line to better understand the relationship of these genes in contributing to higher amylose and resistant starch levels. Future work will also evaluate the effects of higher resistant starch on other grain quality characteristics.

Insights from the Phenotypic and Genotypic Characterization of Accessions Belonging to the *Oryza rufipogon* Species Complex (*ORSC*)

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Crop wild relatives are a valuable reservoir of variation for crop improvement, but they are poorly represented in genebanks, their natural habitats are threatened, and most are poorly characterized. This study focuses on the *Oryza rufipogon* Species Complex (*ORSC*), wild progenitor of Asian rice (*Oryza sativa* L.). The *ORSC* includes perennial, annual and intermediate forms which were historically designated as *O. rufipogon*, *O. nivara*, and *O. sativa* f. *spontanea* (or *Oryza* spp., an annual form of mixed *O. rufipogon*/*O. nivara* and *O. sativa* ancestry), respectively, based on morphological, geographical, and/or ecological habitats. The objectives of this study were to 1) understand the relationship between *ORSC* genotypic subpopulations and phenotypic groups, 2) review *ORSC* accessions that have been targeted for rice improvement in Arkansas, USA, and 3) clarify the relationship between the genotypic subpopulations identified by two different collections of *ORSC* accessions.

To probe the relationship between genotypic subpopulations and phenotypic groups, a collection of 240 diverse *ORSC* accessions previously evaluated using genotyping-by-sequencing (113,739 SNPs) was phenotyped for 44 traits associated with plant, panicle, and seed morphology in the screenhouse at the International Rice Research Institute (IRRI) in the Philippines. These included highly heritable traits similar to those reported by genebanks. Over 100 of these *ORSC* accessions were also phenotyped in the greenhouse for 18 traits in Stuttgart, Arkansas, and 16 traits in Ithaca, New York, USA.

A Bayesian Gaussian mixture model was implemented to infer accession groups from a subset of these phenotypic data and three phenotype-based group assignments (P1, P2/P3, P4) were ascertained. Concurrence between the genotypic subpopulations and phenotypic groups was used to identify a suite of phenotypic traits that could reliably differentiate the *ORSC* genetic subpopulations. The traits provide insight into plant morphology, life history (perenniality versus annuality) and mating habit (self- versus cross-pollinated) and were largely consistent with genebank species designations. The phenotypic group identified as "P1" contained accessions that were predominantly classified as *O. rufipogon,* perennial and largely out-crossing. A second group (P4) contained predominantly *O. nivara* accessions that were characterized as annual and largely inbreeding. The third group (P2/P3) included 20% of the collection and 51.2% of the accessions classified as "*Oryza* spp.". This third group was characterized by levels of *O. sativa* admixture comprising more than 50% of the genome.

Nine *ORSC* accessions from this collection were used to develop mapping populations in Arkansas, USA. Three accessions were selected as donors to develop six interspecific libraries of chromosome segment substitution lines (CSSLs) that are currently being distributed through the Genetic Stocks-*Oryza* Collection for breeding and basic genetics studies. The three wild donors included an *O. rufipogon* from Indonesia categorized as P1, an *O. nivara* from Laos classified as P4, and an *O. rufipogon* from China belonging to P1. These wild donors were crossed into two elite varieties, Cybonnet, a U.S. *tropical japonica* and IR64, an *indica* developed at IRRI. In addition, advanced backcross (ABC) populations were developed using five different wild *ORSC* donors and used to identify major QTL for sheath blight and blast resistance, as well as seedling vigor. All five of these *ORSC* donors phenotypically belonged to P4. Finally, *ORSC* accession, IRGC105491, a highly admixed accession belonging to P2/P3 was used to develop five ABC populations using diverse, elite *O. sativa* recurrent parents adapted for cultivation in different geographies and ecosystems. In the USA, introgressions in the *tropical japonica* variety, 'Jefferson,' resulted in the commercial release of 'Scarlett,' the first U.S. red-pericarp variety; along with two germplasms, 'yld2_A' and 'yld6_A,' each having more than a 26% yield increase compared to Jefferson which was attributed to the wild introgressions.

Lastly, the population structure of this collection of *ORSC* accessions was compared to a previously analyzed collection of 435 *ORSC* accessions from China using a set of 55,213 SNPs that were shared between the two datasets. This comparison revealed shared genotypic groups that were represented in different proportions in these two different studies and confirmed the confounding effect of admixture with *O. sativa* when exploring the genetic structure and phenotypic variation of the *Oryza rufipogon* Species Complex.

Genotyping Accessions in the National Small Grains Rice Collection to Enable Curation and Identification of Accessions with Traits Useful for U.S. Rice Breeders

Huggins, T.D., Edwards, J.D., McClung, A.M., and Jia, M.H.

Germplasm collections house and safeguard the genetic diversity of the world's food crops and related wild species. Plant breeders can use this valuable genetic diversity to improve agricultural productivity, disease resistance, and nutritional quality. However, the majority of germplasm collections only possess phenotypic characterization data. The addition of genetic marker data to the germplasm collection can add greater value for use in breeding programs. The National Small Grains Collection (NSGC) contains about 19,000 rice accessions, of which about 3,450 have been genotyped with 11 fingerprint markers (FPM), 14 trait specific markers (TSM), and one subspecies marker. The genetic markers identify the presence of alleles affecting traits such as plant height, apparent amylose content, starch pasting properties, gelatinization temperature, blast resistance, bran color, aroma, and pubescence, as well as classify accessions by species (e.g., *O. sativa* or *O. glaberrima*), and sub-species within *O. sativa* as *indica* or *japonica*.

The genotyping of 3,450 accessions revealed that most have one or more blast resistance alleles, a small number have the semi-dwarf allele, and almost all are pubescent. About 41% of the accessions were identified as high amylose types, while 19 % were intermediate and 23% were low amylose types. Most of the accessions possess the allele for intermediate gel temperature and a moderate number possess the allele for low gel temperature. The number of high gel temperature accessions are very low. This is because accessions with high gel temperature occurs when accessions with the intermediate gel temperature allele also have low amylose. The addition of genotypic data to the GRIN-Global database will benefit U.S. rice breeders by providing them with genetic information, allowing them to select accessions with novel and useful alleles that are not available within their breeding lines. Accessions classified as *O. glaberrima* in the NSGC world rice collection was previously based on their documented country of origin. This best guess approach resulted in misclassification of *O. sativa* as *O. glaberrima* and vice versa. This was also the case for accessions classified as subspecies *indica* or *japonica*. The development of the species and subspecies markers will eliminate this best guess approach and correctly classify each accession. This will allow breeders to have the relevant information needed to broaden their genetic base when selecting parents. The combination of the new genetic data, along with the phenotypic and origin data will allow breeders to more wisely select germplasm that is likely to have a direct impact and will better fit into their breeding objectives.

Development and Exploration of a Global Tropical Japonica Diversity Panel

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Most of the rice grown in the USA is derived from the tropical japonica (TRJ) genepool but traces to very few progenitor parental lines. As a means to broaden the gene pool for U.S. breeders, a diversity panel of over 500 TRJ accessions from 60 countries was established to identify traits and marker linked alleles that may enhance rice breeding efforts. The panel was assembled using TRJ accessions sourced from other diversity panels such as RDP1, the USDA Core, and the Brazil Core as well as key U.S. parental cultivars and 10 known check varieties of *Indica*, Temperate *japonica*, and *Aus* origin. In 2020 and 2021, the TRJ Core was grown at Stuttgart, AR, in a flooded field trial with two replications for extensive phenotyping. Heading, height, panicle length, seed per panicle, seed weight per panicle, panicle primary and secondary branching, flag leaf length, width and pubescence, chlorophyl content (SPAD), awns, plant type, and hull color were among the traits measured. Initial findings from the 2021 study revealed that the TRJ Core contains accessions which exceed the best of the check varieties for panicle length, primary and secondary panicle branching, seed per panicle, chlorophyll content, and flag leaf size. Interestingly, secondary branching on the panicle was more strongly correlated than primary branching with seed number and seed weight per panicle. Traits that were measured over multiple time points, initial and final heading, and collar height over an 11-week period, were strongly correlated indicating that accession growth rates were consistent throughout the season. In addition, chlorophyll readings were negatively associated with plant height throughout the growth cycle. Flag leaf measurements were not correlated with any trait. Protocols are being developed for assessing several biotic and abiotic stress traits over the next few years. These protocols will be used to evaluate a TRJ micro-core which contains approximately 25% of the TRJ Core accessions. Currently, the TRJ micro-core has been evaluated for drought stress, submergence tolerance, and anaerobic germination.

To conduct a genome-wide association study (GWAS) for a wide variety of agronomic, quality, and plant stress-related traits, tissue from each of the TRJ accessions is being genotyped by means of skim sequencing with a target read depth of approximately 1x. To increase marker density, SNP data obtained from skim sequencing will be imputed using data from the 3,000 Rice Genomes (3KRG). The imputed SNPs will be used in GWAS to identify chromosomal regions associated with these traits. The SNP data will also be used in genomic prediction (GP) to train a GP model on TRJ micro-core phenotypes, which will then be applied across the whole TRJ Core to find accessions that have desirable predicted trait attributes and trait combinations. On the basis of the results of GWAS and GP, superior germplasm will be identified for use in complementary crossing to develop improved breeding lines for U.S. programs. Initial findings from all completed studies will be presented.

Discovery of Genes that Regulate the Concentrations of Anthocyanin and Proanthocyanidin Antioxidants in Purple and Red Rice Varieties

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Anthocyanins and proanthocyanidins are the antioxidant pigmented flavonoids that give blueberries, cranberries, and red wine their color and health-beneficial attributes. Rice grains with purple colored bran also contain anthocyanins, and red-bran rice contains proanthocyanidins. Previous work determined that the genes *Pb* and *Rc* are transcription factors that turn on and off the biosynthesis of anthocyanins (purple) and proanthocyanidins (red), respectively, and molecular gene tags for *Pb* and *Rc* were developed. The focus of this study was to determine how the concentrations of these two pigmented flavonoids are regulated in rice grains after activation by *Pb* and *Rc*. We mapped quantitative trait loci (QTLs) affecting the variable grain concentrations of anthocyanin and proanthocyanidin in F_5 and F_6 recombinant inbred lines (RILs) derived from crossing white pericarp 'IR36ae' with '242,' which produces both anthocyanins and proanthocyanidins in its pericarp. QTLs for total anthocyanin concentration (TAC) were mapped using two years of grains from 60 RILs molecularly determined to be fixed *PbPbrcrc* or *PbPbRcRc*, while proanthocyanidin content (PA) QTLs were mapped using 75 RILs that were *PbPbRcRc* or *pbpbRcRc*. The RILs were genotyped for approximately 1,400 SNPs using the IRRI 1K-Rice Custom Amplicon (1k-RiCA) V4 Panel and the LSU500 Panel.

Both TAC and PA independently mapped to a 1.5 Mb QTL region on chromosome 3 between RM3400 (at 15.8 Mb) and RM15123 (17.3 Mb), named *qPR3*. Across two years, *qPR3* explained 36.3% of variance in TAC and 35.8% in PA variance not attributable to *Pb* or *Rc*. The *qPR3* region encompasses *Kala3*, (LOC_Os03g29614) a MYB transcription factor previously known to regulate purple grain characteristics, and now found associated with both TAC and PA. QTL analysis of TAC data also indicated a QTL with lesser effect on chromosome 7 that encompassed the *anthocyanidins 3-O-glucosyltransferase* (AGT) (LOC_Os07g32620) gene. Analysis of PA identified a 2nd QTL between 18.0 and 18.5 Mb on chromosome 5, *qPR5*. No specific candidate gene was identified for *qPR5* because none of the genes in this region had an annotated gene function predicted to impact concentrations of pigmented flavonoids.

Because anthocyanins and proanthocyanidins share a large portion of their biosynthetic pathways, we included in our study investigation of the impact of *Rc*, which activates synthesis of proanthocyanidins, on TAC, and conversely studied the impact of *Pb*, which activates synthesis of anthocyanins, on PA. To study the effect of *Rc* on TAC, we derived four sets of *PbPbRcRc* vs *PbPbrcrc* NILs by self-pollinating RILs found to be *PbPbRcrc* in the F_3 to F_5 generation. The *RcRc* progeny NILs were found to have 2.1 - 4.5x more TAC over their *rcrc* counterparts. Similarly, study of seven sets of *PbPbRcRc* vs. *pbpbRcRc* NIL sets showed that *PbPb* NILs had 1.3 to 2.0x more PA than their *pbpb* counterparts. These data revealed a mutual enhancement, not a trade-off between these compounds that share precursors. This suggests that *Pb* and *Rc* upregulate genes in the shared pathway as they activate TAC and PA synthesis, respectively.

In summary, we identified three antioxidant-enhancing QTLs (*qPR3, qPR5, qPR7*) and provide genetic markers with which to incorporate these regions into nutritionally enhanced rice varieties. Our findings also indicate that combining the *Pb* and *Rc* genes will increase concentrations of health-beneficial antioxidants beyond the combined additive effects of the individual genes due to mutual enhancement of both pigmented antioxidant compounds.

Genetic Improvement of Hybrid Rice for Seed Germinability using Balanced Haplotypes for Linked Genes Controlling Embryo Dormancy

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Hybrid varieties have a higher yield potential but cost more for the commercial seeds than inbred ones. There is a large room for genetic improvement of hybrid rice for seed germinability to lower the cost. Lack of seed dormancy causes on-plant germination in humid environments, resulting in inadequate germination (<80% or 70%) of hybrid seeds. A hybrid seed is developed on the male sterility (MS) plant and has a set of the nuclear genome from the fertility restoration (RF) line in the embryonic cells. In addition, application of gibberellic acid (GA) to promote the panicle emergence from the leaf sheath of MS plants could also stimulate the on-plant germination. Thus, the genetic improvement involves introduction of GA-insensitive genes into the MS and RF lines to manipulate the hybrid (F1) seed dormancy at a level, which is not too weak but is also not so much to minimize the transgression segregation for extremely dormant F_2 genotypes, as they could cause feral plants. This research aimed to develop a balancing-selection theory to manipulate the dormancy level using a set of linked genes (*SD12a*, *b* & *c*) isolated from *qSD12*, a multigenic quantitative trait locus associated with embryo dormancy. A wild-type haplotype for dormancy-enhancing alleles (*ABC*) linked at the *SD12a*, *b* and *c* loci in coupling was identified from a line of weedy rice (*Oryza sativa*) while the mutant haplotype (*abc*) prevails in cultivated rice. The unbalanced *ABC* haplotype was dissected into balanced haplotypes, *Abc*, *aBc*, *abC*, and *ABc*, in the genetic background of an *indica*type line. The isolated *A*, *B*, and *C* genes were similar in additive effect, while two or three together displayed cumulative effects on the dormancy duration. Experiments were also started to introduce complementary sets of the balanced haplotypes into the male sterility (MS, e.g., *Abc*, *aBc* & *ABc*) and fertility restoration (RF, e.g., *abC*) lines, respectively, by recurrent backcrossing combined with genomic selection. Following experiments will be conducted to purify new MS and RF lines that contain different haplotypes but differ in the genetic background; evaluate the pure lines and hybrid F_1s for the seed dormancy level, germination responses to the GA application, and combining abilities and heterosis for agronomic traits; and estimate linkage disequilibria between genes on the haplotypes and frequencies of the dormant transgression segregants in the F_2 seed populations. This research will provide a whole set of genetic materials for the linked genes and technical details to improve hybrid varieties for seed germinability as well as inbred varieties for the resistance to preharvest sprouting.

Molecular-Assisted CMS Conversion for Three-Line Hybrid Production

Mosquera, P.A., Li, W., Angira, B., and Famoso, A.N.

Hybrid rice offers the potential for increased yields and stability compared to inbred varieties in several environments. Production of hybrid seed is a major challenge in the development of commercial hybrid products because its directly related to their final cost. For commercial hybrid production, a pollen-sterile female line is required, and its seed producibility (female and hybrid seed) will affect how expensive a hybrid is to produce.

A challenge for U.S. breeding programs is that sources of sterility are often found in exotic and unadapted germplasm. In many cases, this exotic germplasm can bring undesirable grain quality, maturity, and pubescence traits. However, these introduced lines offer beneficial traits related to increased seed producibility, increased hybrid vigor, and in some cases novel disease resistance.

The LSU rice hybrid breeding project has developed and tested multiple Cytoplasmic Male Sterile lines (CMS) over the years. For example, CMS lines developed in the background of the Louisiana varieties CL161 and Cypress. These lines offered smooth leaves, excellent grain quality, and good agronomics. However, they had limitations with seed producibility, which would result in a very high cost of seed and prevent cost-effective hybrid seed production. Another developed CMS line is 08A (derived from an indica line from China), it is one of the most effective lines regarding seed producibility and yield potential. However, 08A has limitations, such as pubescence, medium-grain length, low amylose, and the production of tall hybrids.

To develop new CMS lines that combine the desired characteristics of CL161 and 08A, new CMS lines were developed by crossing CL161 and 08B (maintainer), marker-assisted selection was conducted on eight different loci in 6,000 individual F_2 and F_3 plants in 2018-19. One hundred conventional and 100 Clearfield plants were selected using molecular markers for the following desired traits - glabrous, semi-dwarf, long grain, intermediate amylose, *Pib*, and intermediate gelatinization temperature. Sixty F_5 B-lines were selected after two years of field evaluation to be converted to the CMS cytoplasm. Currently, we have BC_3F_1 A-lines, which are being testcrossed to well known restorer lines. Hybrids from these testcrosses will be evaluated in 2023, the group of A-lines will be narrowed down based on their general combining ability and seed producibility, followed by characterization by crossing to a diverse panel of restorer lines.

UADA Hybrid Rice Breeding Efforts Including Revamping of the Program

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Efforts have been made by the University of Arkansas Division of Agriculture's (UADA) Rice and Research Extension Center's (RREC) hybrid rice breeding program in developing hybrid rice (*Oryza sativa* L.) varieties. The success of the program's efforts would lead to hybrid rice varieties that would compete with current commercial released hybrids and purelines. This would greatly benefit Arkansas and U.S. rice growers while adding competition to the hybrid rice seed market dominantly controlled by a single company.

Methods of developing hybrid rice includes developing parental lines with specific traits: environmentally sensitive male sterile (EGMS) lines, cytoplasmic male sterile (A) lines, maintainer (B) lines, and restorer (R) lines. The parental lines are developed using standard crossing procedures along with additional procedures necessary for the specific parental traits such as environmental treatments of EGMS lines. Parents are then planted as panicle rows to select based on phenotypes, while simultaneously being crossed with other parental lines to produce hybrid test crosses to be evaluated for the next season. Test crosses were also made to evaluate both aspects: the parents' combining ability and the experimental hybrids' phenotypes. Efforts for hybrid variety development with Provisia® and Clearfield® herbicide technologies are also being attempted by incorporating the herbicide traits into the parents. The revamping of the program is to focus on breeding for competitive hybrids through manual testcrossing and conducting a small plot (rows) observation trial (OBT) to streamline the breeding operation; to maximize the efficiency of developing numerous testcrosses; and to leverage the elite breeding lines, winter nursery space, and yield trial capacity of other RREC breeding projects. This shift is in contrast to the previous pre-emptive scaled-up hybrid seed production of unproven experimental hybrids that resolved with little success. Breeding efforts include the introgression of desirable flowering traits into hybrid parental lines and emphasizing on combining ability.

Year 2022 was the first year for the revamp of the program and lead to the program's greatest efforts of developing hybrid rice varieties so far. Successful hybrid seed (F_1) production of 10 (4 CL, 1 PVL, and 5 conventional) hybrid combinations was achieved, which enables us to test these new hybrids in the Advanced Elite Line Yield Trials (AYT) and/or Arkansas Rice Variety Advancement Trials (ARVAT) across the state in 2023. One of the greatest efforts was that UADA-EGMS lines underwent intense purification measures in which lines were grown and selected during 2021 winter nursery at Puerto Rico, then were grown, transplanted, and single plants were harvested at RREC during the 2022 summer. Over 500 testcrosses were made in 2022 resulting in the largest number of hybrids produced in the program's history. Testcrosses that are observed with desirable phenotypes in 2023 will be crossed again for more seed and later tested in yield trials.

Optimizing Multi-Environment Trials in the U.S. Rice Belt via Smart-Climate-Soil Prediction Based-Models

Fritsche-Neto, R., and Famoso, A.

The phenotypic evaluation is one of the most expensive parts of a breeding program. Therefore, identifying the best trade-off between the number and allocations of trials and the broad-sense heritability is one of the main questions to be answered. Thus, we optimized the rice multi-environment trials (MET) via smart-climate prediction based-models using historical weather and yield data, artificial intelligence, and mixed model equations.

For that, we retrieved 10 years of weather data during the rice growing season (temperature at 2 Meters, Precipitation, Wind Speed at 2 Meters, Relative Humidity at 2 Meters, and All Sky Insolation Incident on a Horizontal Surface). Then, we translate this information into rice response considering the cardinals number for temperature (Tbase1 = 12, Tbase2 = 24, Topt1 = 33, Topt2 = 37) and crop stages (emergency, maximum tillering, panicle initiation, pre-flowering, flowering, post-flowering, maturity). Moreover, we enriched the analysis with 13 soil characteristics (six physical and seven chemical). Finally, we use two years of yield data from 25 genotypes across these locations and a recursive feature selection to identify the most important weather and soil covariates. Furthermore, using a k-means clustering approach and mixed model equations, grouped the sites and optimized the MET.

Using a few environmental-derived covariates (sand, clay, temperature range and wind speed between emergence and panicle initiation), we could explain 50% of grain yield variation across sites and 68% of the "real" GxE stratification. Also, it was possible to cluster the locations, reduce the total number of trials and costs, better allocate the resources, and define the optimal MET in advance without significant losses in accuracy.

Improvement and Characterization of Medium-Grain Rice Germplasm for U.S. Breeders and Growers

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Medium-grain rice like Calrose has been demanded by consumers, and most premium medium-grain rice is grown in California, USA. As a part of base broadening effort, we developed a medium-grain rice germplasm Eclipse with effective blast resistance genes that can be grown in the southern USA and California. Eclipse was developed by crossing a premium long-grain blast resistant rice variety Katy with a medium-grain rice variety M-202 with Calrose quality and resistant F_2 progeny was backcrossed into M202 for another five generations. A BC_5 line #13 (renamed #13 as Eclipse recommended by Dr. McClung) was selfed to produce pure seeds for evaluation of agronomic traits using replicated field experiments in Arkansas and in Uniform Regional Rice Nursery for 2 years. Resistance to rice blast was verified by the use of gene specific markers for blast resistance genes *Pi-ta* and *Ptr* and results were verified with 10 differential blast races under greenhouse conditions and natural infections under field conditions in Louisiana and Puerto Rico. Grain quality is highly similar to M-202 as determined by genetic markers for amylose, aroma, and the *Alk* gene. Eclipse is a semidwarf glabrous type of medium-grain rice has a low amylose content can be directly used by rice growers for premium medium-grain rice production and development of new rice varieties.

A Project to Provide Improved Performance of Arkansas Rice Cultivars under High Night Heat

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Arkansas rice breeding efforts have been continuous for approximately 100 years. Intermittently ever so often, years occur with low yields and milling quality. Often, these are years with higher temperatures particularly higher night temperatures. In the past 30 years, the interval between emergence and heading has been reduced while yields have simultaneously been increased. As the heading dates have gotten earlier, the heading dates of most Arkansas cultivars have moved from Mid-August to Mid-July. The consistently hottest period of the year is around July 10-July 20. Over the 50 years, the day temperatures at Stuttgart have not had an upward trend but night temperatures have increased significantly. Many of the hybrids and cultivars grown in Arkansas are susceptible to reduced yield in response to high night temperatures during the R2-R5 stages of rice development. Many of these same hybrids and cultivars are susceptible to reduced head rice yields and chalk in response to high night temperatures during the R6-R9 stages of rice development. Our work, after preliminary tests and protocol development, had three objectives: (1) Provide parents for the breeding program with resistance to yield and quality reductions from high night temperatures and adaptation to Arkansas conditions and markets; (2) Develop quantitative trait loci (QTL) which are usable by breeders in these efforts to improve high night temperature resistance; and (3) Provide objective tests with quantitative measurements of high night temperature resistance prior to cultivar release.

In our work, we have found Diamond to be very susceptible to reduced yield and quality in response to high night temperatures during the critical stages of development. We have found N22 to be quite resistant to yield and quality reductions in response high night temperatures at critical stages of development. N22 resistance to high night temperatures has been confirmed by research in other locations by other scientists as well. Consequently, we sought to understand high night temperature genetic factors in susceptible (Diamond) and resistant (N22) lines. Crosses were made between N22 and various adapted long-grain Arkansas cultivars and advanced lines. Backcrosses and forward crosses were also made. From these crosses, selections were made for improved plant type and height. A large collection of F_2 crosses (Diamond X N22 and ZHE 733 X N22) made randomly for QTL analysis. Selected lines from the crosses are being advanced in Puerto Rico this winter with promising lines to be tested in Stuttgart field tests in 2023. Promising lines will also be tested in controlled climate conditions for resistance to high night temperature yield and quality reductions.

Random populations of F_4 RILs (Diamond X N22 and ZHE 733 X N22) were tested under high night temperature conditions and submitted to yield and quality phenotyping. The DNA from each of approximately 300 F_4 inbred lines from each cross along with the parents was extracted and submitted to a set of markers for the development of QTLs.

Advanced lines are assessed in control and high night temperature conditions for resistance or susceptibility of yield and quality to high night temperature conditions prior to variety release. We intend to provide our Arkansas breeders with objective information/data for long-grain rice cultivars they release. Initially, we have found considerable variability within the long-grain advanced lines for resistance to yield reductions caused by high night temperatures.

Overall, the high night temperature program has provided information, breeding lines, advanced line testing and preliminary QTLs for resistance to high night temperatures. The program's primary goals are being realized for effective support of the University of Arkansas rice breeding program.

Mapping Night Heat Tolerance QTLs in RIL population of Diamond X N22

De Guzman, C.T., Esguerra, M.Q., Hemphill, C.C., Borjas, A.H., and Counce, P.A.

The Arkansas cultivar 'Diamond' is very susceptible to reduced yield and quality in response to high night temperatures during the critical stages of development. We found N22 to be quite resistant to yield and quality reductions in response to high night temperatures at critical stages of development. The resistance of N22 to high night temperatures has been confirmed by research in other locations by other scientists as well. Consequently, we sought to understand genetic factors in susceptible (Diamond) and resistant (N22) lines by mapping quantitative trait loci (QTL) to discover DNA markers associated with resistance to high night temperature traits.

We generated 700 F_4 recombinant inbred lines (RILs) from the Diamond X N22 population. From this collection, 299 RILs were chosen at random and grown as individual plants in individual pots. These RILs were grown in the greenhouse to growth stage R2 and placed in a growth chamber programmed with graduated changes in conditions with minimum night temperatures of 28°C and maximum day temperatures of 33°C. Lights and temperatures increased and subsequently decreased in gradual progressions diurnally approximating a July day in Arkansas. The night temperatures (28°C) in the diurnal program have been found to induce high night temperature reductions in Diamond yield and quality and slight to no reductions in N22 yield and quality (compared to control night temperatures of 23°C). Leaf samples were collected and genotyped using 1k IRRI RiCa V.4 SNP panel. We found 297 polymorphic single nucleotide polymorphism (SNP) present in the parents Diamond and N22 that are well distributed across the rice genome. At maturity, plants were harvested and data gathered on the main stem including largest and second largest tillers. Data include days to harvest, height, number of panicle branches, and number of filled and unfilled (blank) florets with the percentage-filled grains calculated for each entry.

Preliminary QTL data were generated using JMP Genomics 9. We employed a single marker analysis on the 299 RIL population of Diamond x N22 using 297 polymorphic markers to detect QTLs associated with the traits of interest. Significant QTLs were found for the percentage (%) filled grains in chromosome 12 that explains 12.5% of the variation and minor QTLs (<10%) in chromosome 6 and 3. For other traits of interest, we found major QTLs for height in chromosome 1 that explains 24% of the variation while minor QTLs were found in chromosome 4 and 5. Minor QTLs were also found for the number of tillers in chromosome 12, 3, and 6; days to harvest on chromosome 1, 2, 3, and 5; number of branches in the panicles at chromosome 2 and 6; and stalk diameter in chromosome 2 and 5.

This is the beginning effort on the development of useful QTLs for breeding for improved rice yield and quality performance under high night temperatures. Development and utilization of useful QTLs is a part of the coordinated University of Arkansas rice breeding program to accelerate and improve yield and quality performance of Arkansas varieties.

Fine Mapping of the *CRSP2.1* Narrow Brown Leaf Spot Resistance Locus

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Narrow brown leaf spot (NBLS) is caused by the fungal pathogen *Cercospora janseana*. Symptoms typically appear on the leaf as narrow, red to brown lesions. Symptoms can also form on the sheath or stem and appear as a net blotch pattern. Many popular rice cultivars are susceptible to NBLS and yield losses can be substantial when weather conditions are conducive. Fungicide applications can be used to control this disease, however, pathogen populations have developed resistance to specific chemistries. Host genetic resistance is an efficient strategy to control NBLS. Recently, the *CRSP2.1* resistance locus was mapped to rice chromosome 2, representing the first localized NBLS resistance gene. However, the underlying gene remains unknown, which limits our understanding of how resistance functions in this pathosystem. To overcome this knowledge gap, we took a genetic and genomic approach to fine map the *CRSP2.1* locus and identify strong candidate genes.

Five recombinant inbred lines (RILs) derived from a cross of LaGrue (resistant) x Cypress (susceptible) were identified as heterozygous across the previously mapped *CRSP2.1* region and selfed to generate heterozygous inbred families (HIFs). Approximately 10,000 $F_{2:3}$ HIF individuals were genotyped with eight single nucleotide polymorphism (SNP) markers across the *CRSP2.1* region to identify recombinants. Recombinant individuals were inoculated in the greenhouse with *C. janseana* conidia and rated for disease at 21 days post-inoculation. An F_2 population (n=49) was also evaluated in the greenhouse to determine inheritance. In order to expedite candidate gene identification, an annotated reference genome was generated for the resistant rice cultivar LaGrue using Nanopore sequencing. Additionally, a LaGrue mutant population was generated via fast neutron mutagenesis to identify resistance compromised mutants for gene functional validation. Approximately 4,000 M_2 plants were phenotyped in the greenhouse and putative mutants were targeted for whole-genome sequencing.

Genotyping of nearly 10,000 $F_{2:3}$ HIF individuals identified 26 critical recombinants within the *CRSP2.1* region. Phenotyping of recombinant individuals corresponding to four genotypic classes mapped the *CRSP2.1* gene to a ~240 kb region on rice chromosome 2. Additionally, segregation of resistance in the F_2 population did not deviate from a 3:1 (R:S) ratio, indicating that *CRSP2.1* is a dominant resistance gene. Next, a comparative genomics approach was taken to identify and prioritize candidate genes. Assembly of the long Nanopore reads resulted in a highly contiguous assembly including a contig that spans the entire *CRSP2.1* region. Comparison to the Nipponbare reference genome revealed a reduced gene content in LaGrue and identified three receptor-like kinases as the top candidate genes. Phenotyping of the mutant population has identified 16 putative resistance-compromised mutants which are currently being analyzed. Taken together, fine mapping and comparative genomics have delimited the *CRSP2.1* resistance gene to a small physical interval and identified three strong candidate genes. The identification and validation of the *CRSP2.1* gene will shed light onto host-pathogen interactions within this pathosystem and facilitate the incorporation of NBLS resistance into elite varieties.

Characterizing Variation in Rice Agronomic Performance with Multitemporal UAV Imagery and Manifold Learning

Bellis, E.S., Farag, F., Huggins, T.D., Edwards, J.D., Reba, M.L., Hashem, A.A., and McClung, A.M.

High-throughput field phenotyping via unoccupied aerial vehicles (UAVs) is a promising technology to accelerate plant improvement, but UAV-based phenotyping has not yet been widely deployed in rice breeding programs. Compared to manual trait characterization, UAV-based phenotypes can be captured more rapidly, in larger numbers, at higher resolution, and could replace some subjective measurements. We evaluated the utility of UAVs for accurate rice phenotype characterization across four experiments replicated in two years at the USDA/ARS National Rice Research Center in Stuttgart, AR. Research plots in the four experiments (n = 252) comprised a range of experimental conditions, including four nitrogen rates, two seeding rates, and 21 diverse genotypes. Multispectral images (blue [475 nm], green [560 nm], red [668 nm], red edge [717 nm], near-infrared [840 nm], and thermal [11,000 nm] bands) were collected approximately every 10 days, at 11-12 time points across the growing season. Models based solely on derived image features (p = 50 vegetation indices and image texture features) were strongly predictive of variation in rice phenotypic variation including days to 25%, 50%, and 100% heading (R^2 = 0.92, 0.91, and 0.90, respectively), leaf temperature (R^2 = 0.86), yield (R^2 = 0.84), percent lodging (R^2 = 0.81), and percent stand (R^2 = 0.62), though predictive accuracy was lower for chlorophyll meter readings (R^2 = 0.24). Automated feature selection using the Least Absolute Shrinkage and Selection Operator (LASSO) indicated that best performing models typically used information from multiple image features and at least half of all available time points. However, vegetation index trajectories differed considerably between 2021 and 2022, challenging the transferability of models trained in 2021. To improve transferability across years, we tested an unsupervised machine learning approach based on manifold learning to automatically account for phenological variation in multispectral, multitemporal UAV images. Our results suggest that UAVs capture useful information for rice phenotypic characterization, which can be further leveraged using modern deep learning techniques. Genetic associations with temporal phenotypes from image embeddings represent an additional benefit of using UAV-based approaches to characterize high-dimensional phenotypes in breeding programs.

Grain Quality of Varieties from Countries with which the United States Imports and Exports Rice

Samonte, S.O.P.B., and Sanchez, D.L.

The United States ranks 4th and 3rd in global rice exports and imports, respectively, with estimated values of $1.9 billion and $1.3 billion, respectively, in 2020. However, in the past 10 years, U.S. exports have fluctuated with a decreasing trend while imports have been steadily increasing. This paper presents the 2nd year preliminary results of a study that aims to characterize the grain quality of rice varieties of countries important to U.S. trade. Furthermore, results from this study can be applied to developing selection criteria that U.S. breeders can use in producing cultivars that emulate the grain quality demanded by rice consumers.

Varieties of top countries from which the U.S. imports (Thailand, India, Vietnam, Pakistan, Brazil, China, Italy, and Australia) and exports (Mexico, Haiti, Japan, Venezuela, Honduras, Turkey, Colombia, and Guatemala) rice were obtained from the USDA Germplasm Resources Information Network. The 239 foreign and 24 U.S. varieties were grown in an augmented RCBD design at Texas A&M AgriLife Research Center, Beaumont, Texas, in 2021. Ten of the U.S. varieties served as checks and were replicated. Each rice variety was planted in a plot of 3 rows that were 2.4 m long. Rice samples were harvested from each variety at maturity. Milled rice size dimensions (length, width, and L/W ratio) were evaluated, and chalky grain percentages were estimated using an S21 grain analyzer.

Compared to varieties of the top four countries to which the U.S. exports rice, the U.S. long-grain varieties were not significantly different from those of Mexico, Haiti, Venezuela, and Japan in mean whole milled rice size dimensions (length, width, and L/W ratio). Among medium grains, U.S. varieties were not significantly different from those of Venezuela and Japan but were shorter than those of Mexico and Haiti. Among short-grain rice, there were no significant differences between U.S. and Japanese varieties in grain size dimensions.

Compared to varieties of the top three countries from which the United States imports rice, the U.S. long-grain varieties were not significantly different from those of Thailand and Brazil in mean grain size dimensions (length, width, and L/W ratio) but were wider than those of Brazil. U.S. medium-grain varieties were not significantly different in grain size dimensions compared to India but were wider than the rice of Thailand and shorter than those of Brazil. U.S. short-grain varieties were not significantly different in size dimensions compared to those from Thailand and India.

Each country's mean chalky grain percentage was estimated, and varieties with below-average chalkiness were selected (as representatives of high-quality rice) and evaluated. These selections excluded the waxy and arborio-type rice from the evaluation. The U.S. had a lower mean chalky grain percentage (4.9%) compared to five of the top eight countries it exports rice. Mean chalky grain percentages were 4.0% for varieties of Japan, 5.1% for Mexico, 6.6% for Haiti, and 9.3% for Venezuela. The U.S. had a lower mean chalky grain percentage than all the top eight countries from which it imports rice. Mean chalky grain percentages were 5.7% for varieties of Thailand and Pakistan, 6.7% for Brazil, and 11.0% for India.

This study provides information that improves the opportunity for U.S. rice breeders to develop varieties adapted to our rice-growing environments that meet the grain quality preferred by rice consumers in the U.S. and abroad.

Understanding the Genetic Architecture of Head Rice and Rice Chalky Grain Percentages using Genome-Wide Association Studies

Sanchez, D.L., Samonte, S.O.P.B., and Wilson, L.T.

High head rice and low chalky grain percentages are ideal grain quality traits considered in developing rice cultivars. Phenotypic selection for high grain quality among breeding lines is laborious and time-consuming. Functional DNA markers should be identified to implement effective marker-assisted selection for favorable grain quality traits. The objective of this study was to identify single nucleotide polymorphism (SNP) markers associated with head rice and chalky grain percentages using genome-wide association studies (GWAS).

Diverse U.S. and foreign rice cultivars, landraces, and breeding lines were grown at Texas A&M AgriLife Research Center in Beaumont and evaluated for head rice and chalky grain rice percentages in 2018 and 2019. A total of 217 and 207 rice accessions were analyzed for head rice percentage (HRP) in 2018 and 2019, respectively. Chalky grain percentages (CGP), defined as the percentage of grains that have at least 50% whitish area, were estimated using the S21 grain analyzer for 195 and 199 entries in 2018 and 2019, respectively, after excluding the waxy rice accessions. Phenotypic data were analyzed along with 854,832 SNPs using three GWAS models: mixed linear model (MLM), multi-locus mixed model (MLMM), and fixed and random model circulating probability unification (FarmCPU).

HRP ranged from 30.7% (Khao Phoi) to 68.6% (Taichu Mochi 59) in 2018 and from 5.95% (Chia Nung Yu 242) to 73.42% (RU-1603126) in 2019. CGP ranged from 0.0% (Palmyra) to 46.8% (WIR 3039) in 2018 and from 0.1% (IR 1321-12) to 42.4% (Baber) in 2019. In 2019, one SNP was found significantly associated with HRP in each of chromosomes 6, 8, 9, and 11, and two in chromosome 7, while two marker-trait associations were detected in chromosomes 1 and 2, based on best linear unbiased prediction (BLUP). CGP was significantly associated with five SNPs located in chromosomes 2, 4, 6, and 8 in the 2018 study, and 10 SNPs from chromosomes 1, 2, 3, 4, 7, 8, 11, and 12 in the 2019 study. Eight identified SNPs are within previously-reported quantitative trait loci for head rice and chalky grain percentages. Identification and validation of candidate genes for their roles in determining head rice and chalky grain percentages are necessary to design molecular markers that can be used to effectively develop rice cultivars with desirable grain quality.

Prospects and Challenges in Designing Salt-Tolerant Rice Varieties for Commercialization

Subudhi, P.K., Pruthi, R., Chapagain, S., Coronejo, S., Concepcion, J., and Singh, L.

Rice, a major food staple for more than half of the world's population, is sensitive to salt stress. Since salinity is spreading across fertile farmland in many countries due to climate change, development of salt-tolerant rice varieties is needed to ensure global and local food security. Narrow genetic base of germplasm used in the U.S. rice breeding program is the major hindrance. However, natural genetic variation existing in the world rice germplasm offers unique opportunity for advancing both basic and applied research to design rice varieties with enhanced salt tolerance. We report here the progress at the Louisiana State University Agricultural Center towards this goal.

We have developed several mapping populations using exotic donors and rice varieties of southern rice growing regions of the USA and evaluated for salinity tolerance at both seedling and reproductive stages. Apart from mapping of QTLs for salt tolerance attributes in multiple mapping populations, several QTLs have been validated using introgression lines. Since introgression lines using single donor germplasm did not exhibit high level of salt tolerance, we resorted to pyramiding approach to accumulate superior alleles from multiple donors to high yielding U.S. varieties. One approach used the crossing of salt-tolerant introgression lines developed from individual donor parent whereas the second approach used multi-parental advanced generation backcrossing followed by selfing. While advancing these populations, plants with desirable agronomic traits are selected for multiplication and salinity screening. Although our study showed that salt-tolerant genes/QTLs are unique for seedling and flowering stages, we could identify breeding lines with salt tolerance for both stages. These breeding lines can now be evaluated for agronomic traits including yield in replicated field trials. Our preliminary evaluation indicated that some selected breeding lines showed salt tolerance even better than the donor lines. The advanced breeding lines with enhanced salt tolerance and the genomic resources developed in this project will accelerate development of climate resilient rice varieties and elucidation of the molecular basis of complex salt tolerance mechanisms operating in rice.

Leveraging Rice Mutant Resources for Trait Discovery, Analysis, and Germplasm Enhancement

Tai, T.H.

Classical mutagenesis continues to be employed as a powerful tool for generating novel genetic variation in plants. This induced variation is a key resource for genetics research and the breeding of improved varieties in response to climate-driven challenges. The overall goal of this project is to identify novel mutations and traits to further our understanding of grain quality and productivity in rice and to develop novel genetic resources for breeding new, climate-resilient varieties. This research builds on previous work involving the generation of rice mutant populations and the subsequent identification of novel gene mutations and mutant phenotypes.

There are two specific project goals. The first is to characterize novel traits and mutations affecting rice grain quality, productivity, and climate resiliency. This will be accomplished by focusing on a small number of rice mutants with altered endosperm, cuticular wax, and silicon content traits and determining their impact on grain quality and stress tolerance. The second is to transfer useful rice mutants and populations to the U.S. rice germplasm collections for public distribution to basic researchers and plant breeders, thereby leveraging the genetic variation in these resources to address global food security. Seeds from advanced generation rice mutants and populations derived from three japonica rice varieties will be produced and donated to ARS rice gene banks along with selected phenotypic data to engage the rice community and other potential users.

Completion of the project goals will generate novel genetic resources and associated information for improving rice quality and productivity. Results of this research will contribute to efforts aimed at sustaining and strengthening the U.S. rice industry in a highly competitive, global marketplace.

Rice Breeding Research in Turkey

Unan, R., Yilmaz, S., Enginsu, M., and Azapoglu, O.

Turkey is one of the important rice producer countries of Europe. It produces 1 million tons on an area of 130 thousand ha and also imports 300 thousand tons. Breeding studies, which is one of the arguments used for production increase, started in the 1980s and continues. Breeding studies are carried out by two government research institutes and four private sector research institutions. Released rice variety number was 94 up to now. In this study, it was summarized for which purposes the breeding studies were carried out.

Breeding studies that started with the introduction materials, continued with crossbreeding, and mutation methods. Breeding programs usually focused on yield improvement breeding, herbicide-tolerant rice, and blast resistant. The national yield improvement breeding program is more focused on medium-grain, lodging-resistant, and mid-early maturity time varieties. Varieties have been developed by crossing from the gene pool where the varieties of Italy-origin. The Osmancik-97 variety, which was released in 1997, had a cultivation area of around 80% in the 2000s.

In the 2010s, rice varieties that are tolerant to IMI herbicide became widespread depend on weed problems. In breeding studies, cross breeding was carried out with Italy-origin varieties. Released IMI-tolerant rice variety number was 23 so far. Varieties with IMI tolerance increase the cultivation area up to 30%. In addition to these studies, development of new herbicide-resistant base material studies continued.

Rice blast (*Pyricularia oryzae*) disease has a devastating effect in some years, so a rice blast tolerant cultivar development program has been carried out. In the screening, it was determined that the *Pi40, Pi5, Pi12*, and *Pish* resistance genes provide tolerance to rice blast. In the joint project with IRRI, the *Pi40* gene was transferred to the Osmancik-97 cultivar by cross and backcross method and released on the market. Afterwards, rice varieties were developed which have multi blast-resistant genes.

On the other hand, a program was carried out to develop commercial hybrid rice. Introduction hybrid materials could not adapt to ecology, and seed setting problems were experienced. Thereupon, improvement studies for source material suitable for ecology were carried out. CMS sterile lines originating from the Philippines were used, and some male sterile lines were developed for this ecology with crossing and backcross methods such as Osmancik-97 CMS-A male sterile line.

In addition to these studies, a number of specific breeding programs have carried out such as providing early maturity time, quality improvement, cold tolerance, and salt tolerance, etc.

In summary, the rice breeding program was built up three pillars which national yield improvement breeding, herbicide-tolerant rice, and blast-resistant rice. The herbicide-tolerant rice program was focused on IMI-tolerant rice and rice blast resistance program was intensified on the *Pi40* gene backcross. The program has released 48 varieties since the last 10 years. Program achieved 0.9% annual genetic improvement.

ROXY® Revealed

McKenzie, K.S., De Leon, T.B., Andaya, V.C., and Andaya, C.B.

ROXY® is the name for the heritable non-GM rice trait that provides tolerance to the post patent herbicide oxyfluorfen. It was discovered in the screening of an ethyl methane sulfonate treated M_3 population of the rice cultivar M-206, California’s most widely grown Calrose variety, in July 2014. Greenhouse studies followed shortly, confirming the herbicide tolerance with concurrent crosses made for genetic studies, seed increase of the mutant lines, herbicide tolerance confirmation, and rice weed control performance in field experiments at two locations in 2015.

Breeding and genetic studies revealed and confirmed that this tolerance trait is inherited as a single recessive gene and can be transferred and selected through conventional breeding. The PROTOX gene providing resistance to PPO herbicides is in the short arm of chromosome 1. DNA sequencing of the PPO gene in the ROXY® mutant lines and the M-206 parental line were identical, indicating that a mutation somewhere else in the rice genome resulted in tolerance to oxyfluorfen. The RES Breeding Program proceeded to conduct extensive research to determine the location of the trait and its molecular basis. Fine mapping populations, DNA sequencing, marker development, evaluation of candidate genes, gene editing by CRISPR, and a proposed mechanism of tolerance were employed in this effort. The combined research revealed that the tolerance trait maps to rice chromosome 5 in a gene encoding the *UDP-Glucose Pyrophosphorylase 3 (UGP3*) enzyme which is the first enzyme step in the Sulfolipid Synthesis Pathway. In the original mutant lines, there were three independent mutations found in *UGP-3*. A second type of mutation giving tolerance was mapped to in *UDP-Sulfoquinovose Synthase* (*SQD-1)*, the second enzyme step in the pathway. CRISPR technology was employed editing the *UGP-3* gene in the cultivar Calmochi-203, making it tolerant to oxyfluorfen. This research combined with weed efficacy studies resulted in the granting of U.S. Patent 11,189,771 B2 "Oxyfluorfen Resistant Rice Lines" on November 23, 2021.

The California Cooperative Rice Research Foundation, Inc. has partnered with Albaugh LLC for the commercialization of the ROXY® Rice Production System for rice weed control. Two ROXY®RPS herbicides are being reviewed for registration by EPA and the California Department of Pesticides Regulation with the concurrent release of a California Calrose medium-grain rice cultivar carrying the ROXY® trait. The ROXY® Rice Production System-2023, is being presented in the Weed Control and Growth Regulation Panel session for further information.

Abstracts of Posters on Breeding, Genetics, and Genomics
Panel Chair: Xueyan Sha

Genetic Dissection of Alkalinity Tolerance at the Seedling Stage in Rice

Singh, L., Coronejo, S., Pruthi, R., Chapagain, S., and Subudhi, P.K.

Salinity and alkalinity adversely affect crop production globally. Saline stress occurs due to high concentrations of neutral salts (NaCl and Na_2SO_4), whereas alkaline stress is caused by an excess of carbonated salts (Na_2CO_3, $NaHCO_3$) and high pH ranging from 8.5 to 11.0. The problem of soil alkalization has been increasing due to climate change, improper fertilization, and use of poor-quality irrigation water. Rice is sensitive to alkaline stress. Therefore, plants under alkaline stress not only suffer from osmotic stress and ionic imbalances but also from high pH, which reduces the availability of essential nutrients such as iron and phosphorus and disrupts the cellular metabolism, leading to reduced growth and development in rice plants. We discuss here an approach in which QTL mapping and next generation sequencing (NGS) technology were integrated to identifying the candidate genes responsible for alkalinity tolerance in the QTL regions.

In this study, two recombinant inbred line (RIL) populations developed from the crosses, Cocodrie x N22 and Cocodrie x Dular, were evaluated under alkalinity stress and observations were recorded on eight morphological traits such as alkalinity tolerance score (AKT), chlorophyll content, shoot length, root length, root to shoot ratio, Na^+ concentration, K^+ concentration, and Na^+:K^+ ratio. Genotype-by-sequencing (GBS)-based SNP markers were used to construct a high-resolution genetic map for the identification of QTLs and the allelic variants from the analysis of whole genome sequences of parents helped identify the candidate genes for alkalinity tolerance. The differential expression of some of these candidate genes further supported their involvement in response to alkalinity stress.

Cocodrie was scored as highly tolerant whereas Dular and N22 were susceptible and highly susceptible to alkaline stress, respectively. AKT score was negatively correlated to K^+ concentration and positively correlated to Na^+ concentration. Association of high AKT score with high Na^+ concentration in RILs suggested inefficient exclusion of Na^+ from roots and shoots. In susceptible lines, the expression of K^+ acquisition genes was affected resulting in reduced uptake of K^+. Tolerance to alkaline stress in Cocodrie was most likely due to the low Na^+/K^+ ratio resulting from reduced accumulation of Na^+ ions and higher accumulation of K^+ in roots and shoots. There were 42 and 46 QTLs for alkalinity tolerance responsive traits in Cocodrie/N22 and Cocodrie/Dular populations, respectively. There were seven genomic regions where two or more QTLs for multiple traits colocalized in Cocodrie x N22 population. Seven QTLs were common between both populations. Three and five important QTLs were targeted in Cocodrie x N22 and Cocodrie x Dular population, respectively, and several candidate genes were identified based on high impact variants and differential expression in response to alkalinity stress. Some of these important genes included glucan endo-1,3-beta-glucosidase precursor, F-box domain containing proteins, double-stranded RNA-binding motif-containing protein, aquaporin protein, receptor kinase-like protein, semialdehyde hydrogenase, NAD-binding domain-containing protein genes, NAC protein, WD-40 family protein, MYB transcription factor, *OsWAK28*, protein kinase, and transposon protein. The QTLs and candidate genes originating from the tolerant parent Cocodrie should be targeted for introgression to improve alkalinity tolerance and to elucidate the molecular basis of alkali tolerance in rice.

Pure Line Rice Crossing

Bounds, K., Sha, X., Bulloch, J., Beaty, B., North, D., and Hale, K.

New rice varieties are originated and selected from crosses among pre-breeding germplasms. Since rice is a self-pollinating plant and 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 desired F_1 seeds. For best results, this occurs in a controlled environment; therefore, we use the greenhouse. Parental lines are planted in the field at certain time intervals for synchronized flowering. Female plants are potted and taken to the greenhouse at late boot stage for the emasculation process. During this process, the male parts of the flower, anthers, must be removed or sterilized for a successful cross to take place. A hot water method is used that consists of placing the plant in a tub of water that is at 45ºC for 5 minutes. The plant is then removed from the water and the excess water is shaken off to allow the anthers to emerge from the florets. Once the florets with the anthers are exposed, the anthers and floret are snipped to facilitate the pollination. The florets that didn't open up are snipped off completely to avoid self-pollination. A glycine bag is placed over the female panicle and the plants are placed on a table to await pollination. The panicles of the male parent are picked from the field each morning around 9:15 to 10:30 am and brought into the greenhouse to sit in a semi-controlled temperature and humidity environment to encourage flowering. 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 create 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.

Integration of Breedbase into Rice Breeding for Ease of Management and Analysis of Data

Dartez, V.B., Hernandez, C., and Famoso, A.N.

Cataloguing, retrieval, and analysis of data can be cumbersome and prone to errors when performed by hand or in numerous spreadsheets. By integrating the use of Breedbase (a comprehensive breeding management and analysis software) into our rice breeding program, we have more efficiently created trials, crosses, seed lots, and field books, stored and analyzed phenotypic and genotypic data, linked accessions to their respective metadata, and searched for and downloaded large amounts of data. Breedbase was developed at Cornell University and is the same platform used to develop the rice marker and sequence database "Ricebase." Breedbase is customizable and able to record additional properties/meta data, images, documents, spreadsheets, etc. that may be pertinent to an accession.

It is a web-based, open-source software that users can use to interact with the collected data as well as analytical tools. Breedbase is easily integrated to other breeding and software tools, including PhenoApps (Rife and Poland, 2014), and can be further enhanced through custom Shiny Apps to meet a program's specific needs. To efficiently manage and incorporate molecular markers into the breeding process, Breedbase features a marker database for genome-wide and trait markers. Other major features of Breedbase include cross, accession, and pedigree creation and storage, trial design (both single and multi-location), seed lot maintenance, phenotypic trait organization, genotyping plate management, and location and weather station tracking. Going forward, we intend to implement and/or develop other Breedbase analysis tools, such as GRM spatial adjustments, genomic predictions, and multi-location trial analysis.

By integrating Breedbase into our breeding program, we have saved valuable time in all aspects of our day-to-day tasks and now keep more accurate and extensive records. It has also allowed us to access data from anywhere with internet access and in any time-sensitive situation. This poster highlights some of the features of Breedbase that are most relevant to our applied breeding program.

19Y4000, A Blast-Resistant and Herbicide-Tolerant Conventional Calrose Rice

De Leon, T.B., McKenzie, K.S., Andaya, V.C., Andaya, C.B., Zaunbrecher, G., and Harrell, D.

19Y4000 (*Oryza sativa* L.) is a conventional early-maturing medium-grain cultivar developed by the California Cooperative Rice Research Foundation Inc. and will be officially released in January 2023. 19Y4000 is a blast-resistant semidwarf inbred variety with high tolerance to oxyfluorfen. It contains the *Pi-b* resistance gene and *Rox1.1* allele for oxyfluorfen tolerance. Agronomic characteristics, grain attributes, cooking, and eating qualities of 19Y4000 are similar to M-206 and M-210 which can be traced back to its M-206 parent. Over the four-year statewide performance evaluation, 19Y4000 had an average yield of 9,887 kg/ha (8,821 lb/A), flowered at 88 days, with good seedling vigor, lodging potential, and high cold tolerance like M-206. At 18-20% moisture content during harvest, 19Y4000 had an averaged milling yield of 67% headrice, 72% total. While the original herbicide resistance donor of 19Y4000 was derived through chemical mutation, the 19Y4000 line was developed through pedigree method coupled with marker-assisted selection and therefore a non-GMO rice.

17Y2087, A New Improved Premium Quality Short-Grain Rice

De Leon, T.B., Andaya, V.C., McKenzie, K.S., and Harrell, D.

A rice cultivar with an experimental line ID of 17Y2087 will be proposed for released in January 2023 by the California Cooperative Rice Research Foundation Inc., for premium quality short-grain market. 17Y2087 was developed through pedigree method. It is a semidwarf, early-maturing, non-pubescent, high-yielding rice. From 2018 to 2022 Statewide Yield Trials, 17Y2087 significantly outyielded Calhikari-202 in all test locations by 11%. 17Y2087 had an average yield of 10,143 kg/ha (9,050 lb/A) compared to 9,143 kg/ha (8,158 lb/A) of Calhikari-202. Days to 50% heading is two days later at 89 days, it is cold tolerant, more lodging resistant, and with seedling vigor suitable for organic rice farming. At 18-20% moisture content during harvest, 17Y2087 had milling yield of 66% head rice, 72% total milled rice. Internal and external blind test evaluations of rice marketing companies and some Japanese individuals indicated the grain appearance, cooking, and eating qualities of 17Y2087 as closely similar to Koshihikari and Calhikari-202 parents, thus supporting its market acceptability.

18Y2070, A Promising California Risotto Rice

De Leon, T.B., Andaya, V.C., McKenzie, K.S., and Harrell, D.

An experimental line designated as 18Y2070 was developed to accommodate the niche market for risotto rice cooking. The line is currently in headrow purification and seed increase for possible variety release in January 2024. With pedigree that traced back to Italian rice varieties such as Arborio, Carnaroli, and Faro, the 18Y2070 has the signature bold kernels and white belly typical of risotto rice varieties. Four-year multi-location statewide yield testing indicated the very good yield potential and favorable agronomic characteristics of 18Y2070 over 89Y235, a released germplasm by the station for Arborio type. Overall, 18Y2070 is a semidwarf, glabrous rice, flowers at 89 days, lodging resistant, averaged grain yield of 9,932 kg/ha (8,862 lb/A), and 50% head rice, 66% total milled rice at 21% moisture content. With positive external blind evaluations for grain appearance, cooking and eating characteristics, the 18Y2070 may be released as the first risotto rice variety of California Cooperative Rice Research Foundation Inc.

Phenotypic Characterization of a Suite of Wild Introgression Lines in Elite *Indica* and *Japonica* Rice Backgrounds

Eizenga, G.C., Singh, N., Harrington, S.E., Akther, K.M., and McCouch, S.R.

Wild relatives of crop plants are a critical gene pool that can be used to expand the diversity of modern cultivars for improved yield and stress tolerance. Cultivated rice (*Oryza sativa* L.) has two widely diverged varietal groups, *Japonica* and *Indica* that were domesticated from the *Oryza rufipogon* Species Complex (*ORSC*). The *ORSC* includes accessions classified as *O. rufipogon*, *O. nivara* or *Oryza* spp. (mixed *O. rufipogon*/*O. nivara* and *O. sativa* ancestry). To exploit this gene pool for rice improvement, six libraries of wild introgression lines were developed by crossing three phenotypically and genotypically diverse wild donors originating from China, Laos, and Indonesia to *Japonica* and *Indica* cultivated recurrent parents, Cybonnet, a *tropical japonica* long-grain variety from Arkansas, USA and IR64, an *indica* long-grain variety from the International Rice Research Institute in the Philippines. The libraries provide complete genome coverage of each of the three wild donors in the two recurrent parent backgrounds and were released as chromosome segment substitution lines (CSSLs).

The six CSSL libraries were genotyped with 7,098 SNPs using the Cornell 7K SNP (C7AIR) array. Across the three Cybonnet libraries, the number of polymorphic SNPs ranged from 2,116 to 2,693 SNPs and the number of lines per library was 63 to 77 CSSLs. Across the three IR64 libraries, the number of polymorphic SNPs ranged from 1,596 to 2,962 SNPs with 68 to 81 CSSLs per library. Seed of the six CSSL libraries is currently available from the Genetic Stocks-*Orzya* Collection and the associated genotypic data is available at: http://cssl-identifier.rcac.purdue.edu/.

Greenhouse-grown plants of the CSSLs were characterized for flowering, shattering, bran (pericarp) color and pigmented hull. Recently, greenhouse plants of the three IR64 CSSL libraries were further characterized for plant height, culm color, culm habit, awn presence, seed length, seed width and seed length-to-width ratio, and mature plant architecture was documented with a digital image.

Previous studies identified trait-enhancing QTLs associated with *O. rufipogon* introgressions in the U.S *tropical japonica* variety, Jefferson. One study documented eight Jefferson/*O. rufipogon* introgression lines (ILs) with grain yields 15.5 to 27.7% greater than the Jefferson recurrent parent, despite the poor agronomic traits of the wild donor. A subsequent study supported an additive model of transgressive variation, where the wild donor introgressions contributed to delayed growth rate, flag leaf length and panicle size in the Jefferson genetic background, resulting in increased grain yield.

To determine whether introgressions from different *ORSC* donors in the same chromosomal regions also enhance yield and yield components in the Cybonnet background, plants of the three Cybonnet CSSL libraries were evaluated over two field seasons in Arkansas, USA. Evaluations included five agronomic traits (days to heading, plant height, culm habit, flag leaf length and width), six panicle architecture traits (panicle length, number of primary panicle branches, florets, seeds and unfilled florets per panicle, and percent seed set), four seed traits (seed length, width, length-to-width ratio and 100-seed weight), grain yield per panicle and grain yield per plant. Additionally, culm color was recorded, and mature plant architecture was documented with a digital image.

Preliminary results suggest that wild introgressions in the Cybonnet CSSLs do not enhance grain yield in the same way as in the Jefferson ILs. This may be because different wild *ORSC* donors were used to develop the Jefferson ILs and Cybonnet CSSLs. There also were substantially fewer background introgressions in the Cybonnet CSSLs as compared to the Jefferson ILs, suggesting that multiple, wild introgressions may be necessary to achieve the same level of transgressive yield enhancement. The differences in observed performance among these lines provide opportunities for further genetic dissection to identify the underlying genes involved.

Across all Cybonnet CSSLs, preliminary results identified 20 CSSLs where the seed size was significantly different from Cybonnet. For most of these lines, seed length decreased, width increased, and length-to-width ratio decreased compared to Cybonnet, thus more like the wild parent. The location of wild introgressions in these 20 lines corresponded to the location of three known genes for grain size, *GRAIN WIDTH-2* (*GW2*), *GRAIN SIZE-3* (*GS3*) and *GRAIN LENGTH-7* (*GL7*). It is also possible that the wild introgressions in these lines harbor novel genes regulating grain size in rice.

Exploring the Genetic Variation among *Oryza sativa* Accessions in the AfricaRice Genebank Collection

Eizenga, G.C., Ndjiondjop, M.N., Warburton, M.L., Gouda, A.C., Kpeki, S.B.,
Wambugu, P.W., Gnikoua, K., and Tia, D.D.

Rice (*Oryza sativa* L.) is grown in 40 of the 54 African countries, acting not only as a source of income for more than 35 million farmers, but also as a staple food in West Africa and Madagascar. In Africa, rice is grown in three main environments: upland, rainfed lowland, and irrigated lowland ecologies. About 4% of rice is cultivated in other ecologies, including in mangrove swamps, hydromorphic fringes (the fringes of rainfed lowlands), and as floating rice. The AfricaRice genebank holds 14,480 *O. sativa* accessions, of which 8,994 accessions have been characterized using 24 phenotypic descriptors under field conditions and 27 grain physicochemical characteristics. This information is available in Genesys (https://www.genesys-pgr.org/datasets/v2OkQW9jEGA) along with passport data.

Genotypic characterization of genebank collections can complement phenotypic data and provide an increased understanding of the relationships between accessions and their potential genetic value. This study explores the genetic variation and population structure of 5,738 *O. sativa* accessions that were previously phenotyped, and which represent 39.6% of the *O. sativa* accessions conserved in the AfricaRice genebank. Of these genotyped accessions, 4,242 (73.9%) originated from African countries. The genotyping revealed 25,904 polymorphic DArTseq-based single nucleotide polymorphisms (SNPs), which were used to (i) investigate the genetic variation, relatedness and subpopulation structure of the genotyped accessions and (ii) create an AfricaRice *O. sativa* Core Collection (AROSCC) that captures most of the genetic variation for future basic genetics and breeding studies.

The genotypic data revealed the genetic distances between pairs of accessions, which indicated high variability, with 21.0% of pairs being moderately distant and 78.2% highly distant from each other. Based on neighbor-joining tree, principal component and model-based population structure analyses, the accessions were divided into four genotypic groups representing the two *O. sativa* subspecies, *Japonica* (787 accessions) and *Indica*, which was further divided into “traditional cultivars/landraces” (1,879 accessions) or “advanced breeding lines/improved cultivars” (3,027 accessions), and a fourth small group of admixed accessions. Subclusters identifying specific agro-ecology (upland, lowland, mangrove swamp, hydromorphic or floating), originating country or continent, were noted.

To form the “AfricaRice *O. sativa* Core Collection” (AROSCC), 600 (10.5%) of the genotyped and phenotyped *O. sativa* accessions were selected using the maximum length sub-tree method. This subset captures more than 95% of the SNP polymorphisms in the entire collection. The percentage of accession pairs that were highly distant from each other increased from 78.2 to 92.3% in this core collection, indicating the AROSCC has avoided most of the similar pairs of accessions. The AROSCC includes 400 *Indica* (AROSCC-*indica*) and 200 *Japonica* (AROSCC-*japonica*) accessions, representing 7.96 and 27.97%, respectively, of each genotyped subspecies and 18 *Indica* accessions classified as “Admixed” based on the neighbor-joining tree analysis. The most prevalent germplasm type in both the AROSCC-*indica* and AROSCC-*japonica* accessions were the more variable traditional cultivars and landraces, which included 218 and 134 accessions of the 400 and 200 total accessions, respectively. The African continent was most heavily represented in both AROSCC-*indica* and AROSCC-*japonica* accessions with 306 and 148 African accessions, respectively. The AROSCC is a well characterized and important resource to support pre-breeding and rice improvement programs around the world.

Hybrid Rice Breeding Planting Arrangement and Use of Vegetative Borders for Hybrid Seed Production

Hale, K.F., Sha, X., North, D.G., Beaty, B.A., Bullock, J.M., and Bounds, W.E.

The hybrid rice (Oryza sativa) breeding project at the University of Arkansas System Division of Agriculture Rice Research Center (RREC) has started implementing different techniques in order to further its efforts in hybrid seed production. Firstly, the planting arrangement is set up so that the female parent has ample pollen from the desired male. This is achieved by bordering the selected female plots with desired male plots. This also makes the next process possible which is supplemental pollination. During peak pollination a rope is drug through the male plots toward the female causing the pollen to move in the desired direction thus pollinating the female. Corn is planted on the dividing levees to be used as a border. These borders are used to split these male/female group to reduce the movement of pollen to an undesired target as well as pollen from adjacent fields. These practices have been developed to be able to grow hybrids efficiently on a smaller scale.

Genomic Selection: Improving Rice Breeding Efficiency and Reducing Costs

Maulana, F., De Leon, T.B., Sharma, N.S., Zaunbrecher, G., and Harrell, D.L.

The Rice Experiment Station (RES) breeding program has successfully bred new and improved rice varieties for California growers using pedigree breeding method. The station also employs marker-assisted selection (MAS) for blast resistance, grain quality traits, and herbicide resistance. The whole variety development takes about 10-12 years, from the time the cross is made until variety release. While the pedigree method is proven effective, it is time consuming, labor-intensive, and costly. New breeding tools, such as genomic selection, are emerging and may help speed up the breeding cycle and improve the overall genetic gain of a breeding program. Genomic selection (GS) in principle is another form of MAS. However, instead of using fewer markers for high heritable traits, GS uses all markers spread across the genome to predict the performance of lines with genotypes but no phenotypes. GS can reduce breeding cycle by earlier selection of potential parents for crosses with improved chance of obtaining superior lines, reduce phenotyping costs by predicting the performance of lines before field testing, and increase genetic gain over time. The objective of this project is to integrate GS, as a complementary breeding tool to MAS, into RES rice breeding program to improve overall breeding efficiency. This poster will outline the station’s roadmap to achieve the objective.

New Breeding Data Collection and Management Tools

Mosquera, P.A., Dartez, V.B., and Famoso, A.N.

One common denominator through breeding programs is the need for an efficient data collection process, improvements done in this regard at the LSU breeding program have reduced the cost, and time spent recording and analyzing phenotypic information, as well as improving the breeding lines tracking from the F_1 creation along different stages of progeny development and evaluation. For the introduction of new tools and data collection practices, we focused our efforts on labeling improvement, data collection of crosses in the greenhouse and, trials in the field.

For labeling improvement, we have integrated on our labels QR (Quick Response) codes - frequently used to track information about products in a supply chain. QR codes can be created in Microsoft Word and printed on mailing tags using an office printer or generated by a designing software such as GoLabel and printed directly on greenhouse stakes, envelope labels, and harvesting tags using a low-cost thermal printer. For efficient data collection, we have implemented the use of smartphones and the suite of open-source applications in PhenoApps, providing us with simple and intuitive solutions for 1) planning, tracking, managing crosses, and printing labels for crossing bags with the Intercross App. 2) Taking phenotypic notes replacing paper field books and enabling increased collection speed with the Fieldbook App. 3) Simultaneously collecting sample weight and exporting to database-ready CSV files with the Inventory App. The simplicity of the PhenoApps has allowed us to adopt the technology without a steep learning curve. All apps are installed on phones with internet access, allowing us to upload the information in real-time to the cloud and BreedBase, facilitating the immediate access to breeding data. These new data collection and management tools and practices have proven to be highly scalable, reliable, and easy to use.

Grain Quality of Top, Middle, and Bottom Portions of Rice Panicles

Samonte, S.O.P.B., and Sanchez, D.L.

Grain quality is a significant factor affecting the commercial adoption, production longevity, and marketability of rice cultivars. Variations in grain quality within a panicle may exist due to differences in flowering dates of spikelets and varying carbohydrate stress levels during grain filling. This second-year study evaluated the variation in grain dimensions and percentages of milled and chalky grain in the top, middle, and bottom panicle portions of chalky and low-chalky rice cultivars.

Two low-chalky (Presidio and Kaybonnet) and two chalky (Leah and LaGrue) rice cultivars were evaluated in a randomized complete block-designed field experiment with three replications at the Texas A&M AgriLife Research Center at Beaumont in 2022. Panicles were picked from plots at maturity (40 days after heading). Each panicle was partitioned into top, middle, and bottom portions based on its number of primary rachis (branches). Using an S21 grain analyzer, preliminary estimates of milled rice length and width, vitreousness, and percentages of chalky, total milled, and whole milled rice were obtained.

Mean total milled rice percentages significantly differed among cultivars and panicle portions. These ranged from 60.3 (LaGrue) to 66.7% (Presidio) and from 62.5 (bottom portion) to 65.4% (top portion), respectively. Mean whole milled rice percentages were significantly different among cultivars and panicle portions. These ranged from 34.6 (Leah) to 53.8% (Kaybonnet) and from 42.9 (bottom portion) to 46.1% (middle portion), respectively. When panicle portions were compared within each cultivar, no significant differences in mean whole milled rice percentage were observed for Kaybonnet, Leah, and Presidio. However, the bottom panicle portion of LaGrue had a significantly lower mean whole milled rice percentage.

When averaged across four cultivars, milled rice grains in the top panicle portion were significantly longer (6.32 vs. 6.20 mm) and wider (1.91 vs. 1.87 mm) than those in the bottom panicle portion.

Chalky grain percentages were 2.0 (Kaybonnet), 3.2 (Presidio), 8.6 (LaGrue), and 9.8% (Leah). The top panicle portions of Leah and Presidio and the bottom panicle portions of Kaybonnet and LaGrue exhibited the lowest chalky grain percentages.

Vitreousness was highest in Presidio, followed by Kaybonnet, Leah, then LaGrue. The top panicle portions were significantly more vitreous than the middle and bottom portions. Vitreousness decreased from top to bottom panicle portions in Kaybonnet, LaGrue, and Leah. Only Presidio was able to maintain its high vitreousness across panicle portions.

In summary, rice grains in the top panicle portion were significantly longer and wider than those in the bottom. Kaybonnet and Presidio maintained low chalky grain percentages across panicle portions. In addition, Presidio was able to maintain high vitreousness across panicle portions. Minimizing the size reduction and/or maintaining high vitreousness in rice grains from the top to bottom panicle portions may improve overall grain quality.

Breeding for Specialty Rice: Jasmine, Basmati, and Healthful Rice

Samonte, S.O.P.B., Sanchez, D.L., Talukder, S.K., and Wilson, L.T.

The United States ranks 4th globally in rice imports, valued at $1 billion in 2021. Its rice imports have steadily increased due to the increasing number of Asian-American and non-Asian consumers leaning toward Asian aromatic (jasmine and basmati) rice. The U.S. imported jasmine rice from Thailand, Vietnam, and Cambodia ($338M) in 2021, which is 38% of U.S. rice imports. It imported basmati rice from India ($194M in 2020-2021) and Pakistan ($38M in 2019). Jasmine and basmati rice have distinct flavors, aromas, and textures. The aroma of these varieties is due to their higher 2-acetyl-1-pyrroline (2AP compound) concentration than non-aromatic rice. Furthermore, cooked basmati rice elongates significantly more than any other rice.

Rice, as a major staple food, has great potential to be a healthful food. Unfortunately, unlike basmati rice which has a medium glycemic index (GI), conventional U.S. long-grain and jasmine varieties have high GI. Breeding rice varieties with high amylose and high resistant starch concentrations with lower GI values are healthful for consumption by people who have diabetes, obesity, and colon diseases.

Texas A&M AgriLife Research launched a Specialty Rice Breeding Program in 2022 that will focus on developing jasmine and basmati rice, as well as healthful rice, such as high amylose. This poster will present the status of this breeding program and the selection procedures that will be applied. F_2 populations and F_3 thru F_8 lines with jasmine, basmati, and high amylose genetic background or potential were selected and grown in the breeding nurseries at Beaumont in 2022. Panicle samples harvested from these nurseries will be evaluated for grain quality. F_4 lines, selected for high amylose using marker-assisted selection, are currently being advanced in the 2022-2023 winter nursery. Crossing nurseries are being established in the greenhouse to generate new breeding populations from selected parentals. Marker-assisted selection will be applied to identify rice lines with desired grain quality traits, such as cooked rice elongation for basmati rice using the grain length and elongation ratio (*GRL* and *elr*) genes, aroma using the fragrance and aromatic (*fgr* and *aro*) genes, high amylose (*Waxy-Intron 1* and *Waxy-Exon 6* genes), and low chalkiness (*chalk5* gene). Selection procedures will also be applied to evaluate uncooked and cooked grain quality (grain and panicle evaluation and taste tests). The development and release of jasmine, basmati, and high-amylose rice cultivars by the Specialty Rice Breeding Program will provide competition against U.S. rice imports.

Identifying Genomic Regions Associated with Panicle Length and Weight in Rice using Association Mapping

Sanchez, D.L., Samonte, S.O.P.B., and Wilson, L.T.

Panicle length and panicle weight are traits that positively affect rice grain yield. Both are quantitative traits and can be affected by genotype, environment, and the interaction of these factors. This study aims to map the genomic regions associated with panicle length and weight using genome-wide association studies (GWAS).

More than 200 diverse rice accessions were grown at the Texas A&M AgriLife Research Center in Beaumont. A minimum of 10 panicles for each accession were collected in 2018, 2021, and 2022. The average panicle length and weight were calculated for each accession. Phenotypic data were analyzed along with 854,832 single nucleotide polymorphism (SNP) markers using mixed linear model (MLM), multi-locus mixed model (MLMM), and fixed and random model circulating probability unification (FarmCPU) approaches.

This study describes the phenotypic variation in panicle length and weight among rice accessions. It identifies SNPs and candidate genes significantly associated with rice panicle length and weight. Panicle lengths ranged from 15.4 (Katy) to 34.5 cm (Karang Serang) in 2018 and 13.3 (Sung Liao 2) to 34.4 cm (Bhim Dhan) in 2021. In 2022, panicle length ranged between 15.5 (Csornuj) to 36.4 cm (WW8/2290), based on preliminary results from 151 accessions. Significant marker-trait associations were not detected in the 2018 dataset, while six SNPs in chromosome 5 were significantly associated with panicle length in the 2021 dataset. GWAS for panicle length in 2022 is ongoing. Phenotypic and association analyses of panicle weight will also be presented. Mapping the genomic regions associated with panicle length and weight is an essential step towards marker-assisted selection to breed for rice cultivars with increased yield potential.

USDA-ARS *Aus* Rice Panel: An Untapped Resource to Enrich Natural Genetic Variation for Abiotic Stress Tolerance in U.S. Rice Breeding Programs

Rohila, J.S., Sookaserm, T.B., Mitchell, J.R., Jackson, A.K., Edwards, J.D.,
McClung, A.M., Huggins, T.D., and Ponniah, S.K.

Aus is a subpopulation of rice that is historically cultivated in rainfed areas in north-east India and Bangladesh. The USDA-ARS Aus Rice Panel (hereafter called UARP) is a diverse global collection of approximately 100 purified, *Aus* accessions with seeds lacking pigmented pericarp. It was established as a genetic resource to discover genes and allelic variations that can be used to improve U.S. rice varieties (primarily *Japonica*) for agronomic traits such as abiotic stress tolerance, climate resiliency, and sustainability. Single-nucleotide polymorphism (SNP) data for the UARP was obtained from the publicly available 3,000 Rice Genomes (3KRG) imputed resequencing data. Approximately two million SNPs were found to be variable in the UARP with a minor allele frequency greater than three percent. The dense genotype data is suitable for genome-wide association studies (GWAS) using phenotypes measured on the UARP.

UARP phenotypes for major morphological, developmental, physiological, and agronomic traits under severe drought conditions (-80 to -100 kPa) were determined over multiple years in a replicated field study conducted in Stuttgart, Arkansas. The UARP was found to have a wide range in traits under drought conditions, such as aboveground biomass, thousand kernel weight, grain length, grain width, and total yield. GWAS revealed significant associations with known genes for seed length at *GS3* and *qLGY3*/*GW3p6*/*OsLG3b*, for seed width at *GW5,* and for yield at *GS2*/*GL2* and *GWi7.1*/ *GWi7.2*. Additional significant associations with other chromosomal regions were found across 22 traits, many of which have no previously reported candidate genes or trait associations. Among the genetic loci uncovered by GWAS, several have large estimated additive effects and explain a substantial percent of the phenotypic variation observed in the field. Identified loci are good potential targets for fine mapping and candidate gene verification in future studies and may be used for marker-assisted breeding aimed at improving water use efficiency and related stress tolerance traits in U.S. rice production.

Identification and Characterization of Rice Endosperm Mutants

Tai, T.H., Kim, 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 in the form of whole milled kernels. As such, rice starch provides the bulk of the daily calorie intake for billions of people worldwide. Major differences in local, regional, or social-cultural preferences require the development of a wide array of grain quality characteristics to meet the needs of diverse consumers.

Reverse and forward genetic approaches were applied to identify mutants of interest from populations derived from chemical mutagenesis of the japonica varieties Nipponbare and Kitaake. Targeting of Induced Local Lesions in Genomes (TILLING) by sequencing and targeted sequencing by exon capture have been employed to identify mutations in starch synthesis-related genes and corresponding rice lines harboring those mutations are being characterized for changes in physico-chemical grain traits and other properties.

Forward screens based on visual evaluation of grains and physico-chemical assays (e.g., iodine staining, alkali digestion) have resulted in the identification of additional rice mutants with altered endosperms. These mutants are currently being used for genetic studies to identify the underlying mutations and developed as genetic resources for grain quality studies and non-table rice uses.

Identification and Characterization of Metalloid Uptake Mutants in Rice

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

Rice is a hyperaccumulator of the metalloid element silicon. The uptake and accumulation of silicon and other metalloids, including arsenic and germanium, is facilitated by various transporters. Using both reverse and forward genetic approaches, novel mutations in these transport genes and mutants with altered uptake of these metalloids have been identified.

The effect of these mutations on uptake and accumulation of metalloids in the rice mutants harboring them is currently being investigated. Rice mutants identified by forward genetic screening with germanium, which is phytoxic to rice in micromolar concentrations, are being genetically analyzed to identify the mutations responsible for them. Mutants identified using both approaches are also being developed as genetic resources to facilitate research on understanding the interaction of metalloids and plants in the environment.

ROXY® Purity Certification Assay Development

Zaunbrecher, G.M., Yeltatzie, G.B., McKenzie, K.S., Shelton, C.W., and Harrell, D.L.

ROXY® is the name for the heritable non-GM rice trait that provides tolerance to the post patent herbicide oxyfluorfen. Foundation, Registered, and Certified seed with the ROXY® trait must be certified tolerant to the registered Albaugh rice herbicide to ensure its performance in producers' fields. Non-biased results from an independent laboratory will be obtained using the assay protocol developed at the Rice Experiment Station. The protocol establishes optimized conditions for the growth of tolerant seeds while allowing the non-trait seeds to germinate thus allowing the researcher to distinguish between normal, abnormal, and non-viable seeds according to the requirements of the Association of Official Seed Analysts agencies. Varieties M-206 and M-210 were used as non-trait seeds and the soon to be released variety, 19Y4000, was used at the trait bearing seed. M-206 and M-210 were selected as controls because the pedigree of 19Y4000 can be traced back to both varieties.

The establishment of multiple parameters were required for an effective assay. These include: seed pre-treatment, herbicide concentration, exposure length to herbicide, growth conditions and procedures, and assay result evaluation. Experiments were performed comparing germination in rolled vs flat germination paper, the most effective exposure to oxyfluorfen (i.e., pre-germination soak (24 hr vs 48 hrs) only or substrate imbibition), as well as the use of a programable growth chamber vs a climate-controlled room. Research is ongoing to determine the optimal concentration of oxyfluorfen to differentiate trait and non-trait seeds.

Epicuticular Wax-Deficient Mutant of Rice

Tai, T.H., Butterfield, T.S., and Shim, K.C.

Epicuticular waxes are the outermost protective barrier of land plants, working together with other parts of the plant cuticle to prevent unregulated water loss and provide protection against external environmental stresses. A hallmark of wax-deficient rice mutants is the adhesion of water on their leaf surfaces. Using this simple screen, over a dozen mutants were identified from a population derived from chemical seed mutagenesis of the southern long grain Sabine. Almost all the mutants detected exhibited a "wet leaf" or glossy appearance; however, one mutant SAB-1558 presented a distinct phenotype consisting of the adherence of small, discrete water droplets. Scanning electron microscopy confirmed that the mutant exhibited more and larger epicuticular wax crystals than the others.

The wax content and composition of this mutant is being characterized and the effect of this novel phenotype on physiological functions is being undertaken. Progress towards genetic mapping and identification of the underlying mutation using next-generation sequencing-based approaches will also be described. Understanding the function of epicuticular waxes in rice may lead to discoveries impacting resiliency against climate-driven changes to rice production areas.

Genetic Analysis of Two Starch Synthase Genes, Starch Branching Enzyme 3 and Granule-Bound Starch Synthase 1, in Regulating Amylose Content and Starch Physicochemical Characteristics in Rice

Shim, K.C., Tai, T.H., and Ahn, S.N.

Genetic variation in starch synthase genes has been reported as a key factor in determining rice quality and starch characteristics. Sequence variations in *starch branching enzyme 3* (*SBE3*) and *granule-bound starch synthase 1* (*GBSS1*) were identified between the high-amylose variety 'Dodamssal' and the Korea elite variety 'Hwayeong.' To understand the effect of the variations, near-isogenic lines (NILs) with four different allelic combinations of *SBE3* and *GBSS1* were developed using Hwayeong as a recurrent parent. Four NILs showed significantly different seed translucency, starch structure, crystallinity, amylopectin length, starch digestibility, apparent amylose content (AAC), and resistant starch content (RS). In addition, significant genetic interaction was identified between *SBE3* and *GBSS1* in controlling AAC and RS. To understand the different starch characteristics of the four NILs, transcription levels of starch-related genes were examined using panicle samples 15-day after heading. Four NILs showed significantly different gene expression in starch branching enzymes, starch debranching enzymes, ADP-glucose pyrophosphorylase, soluble starch synthase, and starch phosphorylase. Our study suggests that *GBSS1* and *SBE3* variation led to changes in expression of starch-related genes which resulted in differences in AAC, RS, and physico-chemical properties of the rice starch in the NILs.

CRISPR/Cas9 Mediated Multiplex Genome Editing to Develop High Lysine in the U.S. Rice Cultivar Presidio

Rastogi, K., Ibarra, O., Mankar, S., Molina-Risco, M., Faion-Molina, M., Thomson, M., and Septiningsih, E.M.

Rice, being one of the largest grown staple sources of energy, feeds nearly half of the world's population. Although rice grain provides nearly 90% of the total calories to the developing world, its nutritional value is reduced by its low lysine content. Of the total 20 essential amino acids, lysine is one of the most limiting factors as low levels of lysine can lead to malnutrition in developing countries. Our aim for this study is to knockout genes in the lysine catabolic pathway using the endogenous tRNA-processing CRISPR-Cas9 system for increasing lysine levels in the rice grain. A vector construct containing sgRNAs for the target genes was transformed into the U.S. elite rice variety Presidio using *Agrobacterium*-mediated transformation. We have successfully transformed 20 rice plants and 19 of them were confirmed through amplicon sequencing to be CRISPR edited plants. Based on the agronomic traits and single event occurrence of T-DNA we selected 4 events to advance into further generation. PCR screening confirmed transgene free lines in the T_1 plants. Currently the T_2 plants from homozygous or biallelic mutants are being grown for further phenotyping, including lysine content measurement. We believe that this approach will help lay a foundation in addressing the nutritional value of rice by improving the lysine content in the popular varieties.

Positive Effects of Breeding on U.S. Rice Yields under Future Climates

Wang, D., Jamshidi, S., Han, R., Edwards, J., McClung, A., and McCouch, S.

In this study, we model and predict rice yields by integrating molecular marker variation, varietal productivity, and weather variation at the landscape level. Rice production in the United States occurs primarily in two regions: California (where *temperate japonica* varieties are grown) and Southern U.S. (where *tropical japonica* varieties are grown). We focus our study on the Southern U.S. states as production spans a larger area, mainly in Arkansas, Louisiana, Texas, and Mississippi. By digitizing and combining four decades of county-level variety acreage information with genotyping-by-sequencing data, we estimate historical county-level allele frequencies. This frequency information is used in conjunction with county-level yield data from NASS to develop ensemble machine learning models for yield prediction with weather variables. Models are evaluated against observations from the Uniform Rice Regional Nursery trials and used with forecasted weather data from the Coupled Model Intercomparison Project (CMIP) in the rice-growing counties to predict production in the coming decades.

Exploring Utility of Trial Data from the LSU Rice Breeding Program to Inform Crop Growth Models

Jamshidi, S., Murgia, T., Morales Ona, A., Cerioli, T., Famoso, A., Cammarano, D., and Wang, D.

There has been much interest in the crop modeling community to expand the utility of process-based models to wider germplasm panels (for example, breeding lines or diversity panels). The performance of new genetics combinations under (untested) environmental scenarios and various management practices can be virtually examined using crop models. In this study, we used data collected from long-term trials from of the Southern U.S. rice breeding program to parameterize and calibrate the DSSAT CSM-CERES-Rice model. We run three sets of simulations to address the following questions: (1) Which combinations of planting date and existing genetic variation for phenology optimize yield? (2) How does expanding planting date beyond the current range affect interactions with phenology to influence yield? (3) How do novel combinations of genetic variation for phenology interact with current planting dates to affect yield? We ask these questions under current and two forecasted environmental scenarios (mid-century and end-of-century) to demonstrate how data collected from breeding programs could be leveraged to inform process-based models of crop growth and performance that can address questions that are otherwise challenging to answer without the use of simulations.

Abstracts of Papers on Plant Protection
Panel Chair: Nick Bateman

Effect of Tadpole Shrimp Size and Seedling Stage on Rice Stand Establishment

Espino, L., Clark, T., Giron, M., and Baez, C.

The tadpole shrimp, *Triops longicaudatus*, a freshwater crustacean, is a pest of water-seeded rice during the period of seedling development and establishment. Field experiments were conducted in 2021 and 2022 to improve the monitoring and management of this pest. Treated and untreated leveed plots were seeded at five dates after plots were flooded. Tadpole shrimp density and growth, rice seedling development, tadpole shrimp injury to rice, and dislodged rice seedlings were monitored for 30 days after seeding. Additionally, stand establishment was assessed 3 or 4 weeks after seeding and grain yield obtained at the end of the season.

Tadpole shrimp growth and density was similar both years, with shrimp becoming noticeable with the naked eye when their carapace reached 3-4 mm. Initial tadpole shrimp growth was fast and reached a maximum carapace size of 7 mm by 10 days after field flooding. Tadpole shrimp densities were highest early, averaging over 100 individuals per m^2 two weeks after flood and declining to zero by 40 days after flood.

Tadpole shrimp injured seedlings did not exceed 10% in plots seeded 2 or 3 days after flood. In plots seeded 5 or 8 days after flood, 80 to 100% of the seedlings were injured. Injury in plots seeded 4 days after flood ranged from 40 to 80%. In 2021, stand was significantly reduced in plots seeded 4 days or later, with higher reductions in later plantings. Yields were only significantly reduced in plots seeded 5 or 8 days after flood. In 2022, stand was significantly reduced for all seeding dates; however, the highest reductions occurred in plots seeded 4 days after flood or later. Yields were only reduced in plots seeded 8 days after plot flooding.

Comparison of seedling stage and tadpole shrimp injury showed that small shrimp (3-4 mm carapace) produced less than 40% injured seedlings when only the coleoptile and radicle were present. Large shrimp (6-7 mm carapace) injured more than 80% of these seedlings but did not injure seedlings when the prophyll or first true leave was present. In 2021, the number of dislodged seedlings was similar between treated and untreated plots. In 2022, untreated plots had significantly more dislodged seedlings than treated plots; most of these were found 18 days after flood, when shrimp had reached a carapace size of 8-9 mm. An interaction between herbicide injury and tadpole shrimp may have caused significant differences in the number of dislodged seedlings between treated and untreated plots in 2022.

Changes in Insect Management Strategies in Arkansas Rice

Bateman, N.R., Thrash, B.C., Floyd, C.A., Newkirk, T.B., Felts, S.G., Plummer, A., Mann, M., Ibbotson, T., Murray, Z., Whitfield, A., Harris, T., and Maris, G.

While the major insect pest complex in rice has not changed in recent years in Arkansas, some of the management strategies have. Rice water weevil is the most important insect pest of rice in Arkansas and the mid-South. In recent years, foliar applications for rice water weevil have not provided sufficient control. Insecticide seed treatments are still providing adequate control. Multiple studies were conducted to determine the economic benefit of combining seed treatment classes. Better control, higher yields, and higher net returns were observed when combinations of a diamide and neonicotinoid seed treatment were used compared to either class alone. New defoliation thresholds have also been developed in Arkansas. Experiments evaluating multiple defoliation levels over multiple planting dates and growth stages were conducted. Defoliation had less impact on April planted rice as compared to May and June plantings. For all plantings, yield loss was worse when large amounts of defoliation occurred at the ‘green ring’ growth stage. Less yield loss was observed during the seedling and early tiller growth stages. The most concerning issue currently in the mid-South is the lack of control observed with lambda-cyhalothrin for rice stink bug control. This has caused some adjustments in how we approach rice stink bug control. Multiple products were evaluated at different spray timings to determine the most cost-effective approach to rice stink bug management. In most cases, spraying either Tenchu or Endigo ZCX at the late milk early soft dough stage provided season long control of rice stink bug, as well as reducing 'pecky' rice compared to multiple applications of lambda-cyhalothrin.

Update of the Rice Delphacid (Hemiptera: Delphacidae) in Texas Rice

Bernaola, L., Sarkar, N., and Pearson, B.

The rice delphacid, *Tagosodes orizicolus* (Muir), is an invasive pest of rice that was detected in the U.S., specifically found in Texas in 2015. Historical records show this pest had previously invaded the U.S. in the mid-1960s, likely moving with strong weather patterns from Central or South America, the native origins of this pest. *T. orizicolus* is the most destructive pest of rice in Latin America. This insect pest causes two types of damage. Direct damage happens from ovipositing and feeding on rice leaves where the rice delphacid sucks up plant juices destroying plant tissue and producing hopperburn, which usually results in significant yield loss. In South America, indirect damage happens when the rice delphacid transmits the *rice hoja blanca virus* (RHBV), which causes a devastating plant disease called "hoja blanca." This insect transmitting the virus can cause up to 100% yield loss in susceptible rice cultivars. The rice delphacid was relatively widespread on ratoon rice in Texas in 2015 and 2018 and was found from 2019-2021 at very low levels. Texas rice farmers and crop consultants are aware of this pest since its appearance in 2015. In response to this threat, the United States Environmental Protection Agency granted a Quarantine Section 18 Emergency Exemption for Endigo ZC (active ingredients lambda-cyhalothrin + thiamethoxam) which can be used through the 2025 field seasons in Texas.

In 2022, to monitor the spread of the rice delphacid populations and test for the presence of the virus, we collected samples from 16 infested rice fields in Texas, ranging from fields that were flowering to harvested fields of ratoon crop rice. After recording numbers of those sampled areas, insects will be sent to College Station to test for the presence of RHBV. Our results showed that rice delphacid was found in several counties this year. Most infested fields were estimated to have medium level infestations. Rice delphacid was found in very low numbers (less than 1 adult per 100 sweeps) in a rice field at the Beaumont Center, which may indicate this pest is spreading to nearby areas of Texas with potential to spread to neighboring states. Continued monitoring is necessary to screen populations for the RHBV and track the spread of the rice delphacid range.

Management of Insect Pests in Stored Rice in Mississippi

Cook, D., Threet, M., Gore, J., and Crow, W.

Numerous insects can infest stored rice, *Oryza sativa* L., in Mississippi. Many of these are beetle and weevil species, but several caterpillars can also infest stored grain. The risk of insect infestations when storing grain on-farm can vary depending on the level of site and grain bin sanitation, the length of grain storage, and the use of preventative treatments including insecticide application to the empty grain bin and/or insecticide grain protectants (applied directly to the grain). Typically, the risk of infestation/damage is relatively low with short-term grain storage (till late winter/early spring). However, if winter conditions are mild insects that infest stored grain could remain active. Also, some producers are holding grain for longer periods of time for marketing purposes. The longer grain is stored, the greater the risk of insect infestations. Currently, little research is being conducted on stored grain insect pests in Mississippi or the Mid-South. The label for Storicide II, which has been considered a premier stored grain treatment for rice, has recently been revoked. This leaves producers with very limited options for insect management in stored rice.

These trials were conducted using 113.6 L (30 gal) plastic drums as a means of storing grain. A total of 68 kg (150 lbs) of rough rice was placed in each drum. Plots (drums) were arranged in a randomized complete block design with four replications. Treatments included Storicide II (deltamethrin plus chlorpyrifos-methyl, 275 ml/20,412 kg), Sensat (spinosad, 289.8 ml/20,412 kg), Suspend (deltamethrin, 202.9 ml/20,412 kg), Suspend plus PBO (deltamethrin 202.9 ml + piperonyl butoxide 399 ml/20,412 kg), fumigation with aluminum phosphide (monthly May through Oct), and an untreated control. Storicide II is no longer labeled but was a standard for many years. Sensat is currently not labeled for use in rice. These were applied using a seed treater large enough to treat the entire sample. The tops of drums were covered with hardware cloth to prevent intrusion and disturbance by birds and rodents. However, the mesh size was large enough for insects to access the grain. Drums of grain for the experiment were stored under an open air equipment shed for rain protection and to allow natural infestations of insect pests. Samples from each container were collected ca. monthly and grain temperature, moisture content, and the density of insect pests were determined. Grain temperature was determined using a 30.5 cm (12 in) digital thermometer. The thermometer was inserted ca. 28 cm (11 in) into the grain mass. Grain samples were collected using a standard 101.6 cm (40 in) slotted grain probe. The probe was inserted into each plot (drum) at random locations to yield a sample volume of 473 cm^3 (1 pint) of grain. Insects were separated from grain using a 0.212 cm (0.0833 in) mesh size sieve. Grain moisture was determined using a Dickey-John 500XT grain analysis computer. After grain moisture and insect densities were determined, the grain samples were stored in a freezer for ca. two weeks. Approximately 236 cm^3 (8 oz) of grain from each plot was placed in plastic containers, sieved to remove any existing insects, and infested with 10 maize weevils from our laboratory colony. This weevil colony was obtained from the University of Georgia in 2019 and has not been exposed to insecticides for at least four years. Weevil mortality was determined after seven days of exposure. Data for each sample date were subjected to analysis of variance and means separated according to Fisher's Protected LSD.

No differences in grain temperature or grain moisture were observed among treatments during March through November 2022. No differences in maize/rice weevil, *Sitophilus zeamais* Motschulsky, *Sitophilus oryzea* (L.), densities were observed during March or April. All of the insecticides, except Storicide II, reduced weevil densities compared to the untreated control in the May sample. Weevil densities were <1 per sample and no aluminum phosphide treatments had been initiated at this point. For the June sample, all of the insecticides, except Suspend, reduced weevil densities compared to the untreated control. For the July sample, the Sensat-treated bins had more weevils than the untreated bins. In August, all of the insecticide treatments, except Sensat and Suspend, reduced weevil densities compared to the untreated control. For the September, sample only aluminum phosphide reduced weevil densities compared to the untreated control. For the October and November samples, weevil densities in the untreated bins were low, and weevil densities in the Sensat plots (October) and Storicide II, Sensat, and Suspend bins (November) were higher than those in the untreated bins. Data for total insect pests followed similar trends as that for weevils.

For the laboratory bioassays with maize weevil, Storicide II, Sensat, and Suspend plus PBO resulted in >50% mortality during March, May, June, July (except Sensat), August, and September (only Sensat). Suspend resulted >50% mortality only during March.

Water Management to Control Rice Water Weevil (*Lissorhoptrus oryzophilus)* Larvae

Landry, K.J., Wilson, B.E. and Musgrove, T.R.

When a permanent flood is established in rice fields, adult weevils lay eggs on rice leaf tissue. After eclosion, larva will translocate below the water line to feed on the roots. Yield loss can reach more than 50% without effective management. Historically in Louisiana, the practice of draining and drying of fields to control rice water weevil larvae is used when insecticides are not available. Rice fields are routinely scouted for symptomatic abnormalities. When rice water weevil larval infestations are present, the field is drained to create unfavorable conditions for the larvae, which are aquatic. The field is maintained without a flood until the soil cracks due to the lack of moisture. A flood is then reestablished to continue traditional rice management practices. This practice may have the potential to reduce larval infestation to acceptable levels while protecting yield. To test this, a field trial was conducted to evaluate rice water weevil management through flood removal as compared to continuous flood at the LSU AgCenter Rice Research Station in Crowley, Louisiana, in 2022. Seeds were drill-planted in small plots (1.4 m X 4.9 m with 7 rows at 18 cm spacing), and insecticide seed treatment and untreated check were assigned to plots following a randomized complete block design with four blocks and three treatments per block. Levees were constructed to separate continuous flood plots from drained plots. Seed was treated with Dermacor (chlorantraniliprole) at a rate of 0.109 liters/ha (1.5 fluid oz/A). The field was flushed with water 12 days post emergence. A permanent flood was established 34 days post emergence. Weevil larvae populations were quantified by collecting root/soil core samples twice per plot and counting the number of larvae. Water was removed from plots that were assigned drainage, core samples were collected from both flooded and drained at plots every 4 days for 20 days. Samples were collected again 30 days after reestablishment of flood on all plots. Rainfall amounted to 4.62 cm (1.82 inches) during the soil moisture drying period which increase the days required for soil drying. Data was analyzed using generalized linear mixed model (SAS, PROC GLMMIX) with insecticide treatment and water management included as fixed effect and block as a random effect. Means were separated using Tukey's HSD (a=0.05). Results demonstrate that water management can be used to reduce larval infestations. The drain fielded exhibited a 29% reduced weevil larvae population. Further research is needed in soil moisture levels as relates to timing of flood reestablishment as well as water-seeded rice into a flooded field.

Evaluating Control Options for Rice Billbug (*Sphenophorus pertinax*)

Floyd, C.A., Bateman, N.R., Thrash, B.C., Felts, S.G., Plummer, W.A., Ibbotson, T., Newkirk, T.B., Whitfield, A., Murray, Z., and Maris, G.

Arkansas rice producers have increased furrow-irrigated rice (FIR) production hectares to reduce labor and tillage. The elimination of a flood across the field has made rice more susceptible to rice billbug (*Sphenophorus pertinax*). Rice billbug feeds on the roots and tillers of rice plants, causing tiller death and aborted heads, resulting in indirect yield loss. As FIR hectares continue to increase in Arkansas, a cost-effective management strategy for rice billbug is needed. Multiple experiments were conducted during the 2020-2022 growing seasons to evaluate application methods, timing, and efficacy of selected insecticides for control of rice billbug. Insecticide seed treatments, foliar insecticide applications, and insecticide-coated urea fertilizer were all evaluated to determine the best application method to manage rice billbug. Multiple insecticides were evaluated for control of rice billbug. Additionally, two sampling methods were tested in an attempted to correlate rice billbug injury to grain yield. Injured tillers prior to green ring and blank heads were both sampled for a total of 1.524 meters (5 row feet) for each plot. A relationship was observed with all tested variables and grain yield. Confirming both tiller injury as well as blank heads need to be addressed when assessing billbug injury. Results from the studies show that insecticide seed treatments containing both a neonicotinoid and a diamide seed treatment provides greater control of rice billbug, compared to any other product of application method. These data also suggest that no labeled foliar applications of insecticide should currently be recommended rice billbug suppression.

Using Pheromone Traps for True Armyworm in Rice: Influence of Trap Location through Time and Space

Grettenberger, I.G., Espino, L.A., Goding, K., and Koning, M.

Armyworms, specifically true armyworm, are sporadic pests in rice that can show up quickly and rapidly defoliate rice. The unpredictability of outbreaks and difficulty scouting for larvae can complicate management. Pheromone traps are now used in a monitoring network with several traps deployed in a small area at many sites across the rice-growing region. High trap captures and the timing of the moth peak have been used to predict the possibility of infestation. If traps are to be used more widely as a monitoring tool, we need to better understand how trap captures vary spatially and temporally. With the objective of better utilizing traps, we deployed a high number of traps in a given area and asked the following questions: 1) Are the two peaks correlated for a given trap?; 2) Do certain traps always catch the most moths (based on ranking)?; and 3) Are trap captures aggregated spatially? Across two years, we deployed a grid of pheromone traps for true armyworm, each separated by 0.5 mi. We checked traps weekly during the growing season. We determined the maximum moths caught for each trap during the first and second peaks. Results from this study indicate that pheromone traps are a useful but perhaps imprecise tool. This is also supported by other work demonstrating that high trap captures do not necessarily lead to high larvae numbers. Because of the variability associated with trap captures, multiple traps are likely needed for monitoring and interpretation of absolute trap captures should be interpreted carefully.

Pest Status of Florida's Rice Stink Bug Complex

VanWeelden, M.T., Beuzelin, J.M., and Camarozano, C.T.

Florida's rice stink bug complex is composed of three species; the native rice stink bug, *Oebalus pugnax*, and two invasive species, *O. insularis and O. ypsilongriseus*. In 2017 and 2018, industry-wide surveys revealed *O. insularis* as the most abundant stink bug species in Florida rice, prompting additional studies to examine its feeding behavior, as well as potential management strategies. In 2019 and 2020, field assays were conducted in rice to determine differences in feeding injury among *Oebalus* spp. Mesh cages were tied around rice panicles at three stages of development and exposed to *Oebalus* spp. at varying densities of adults. Results from this study were inconclusive, as major differences in feeding injury were not detected among each species. Additional field and laboratory evaluations were conducted in 2021 and 2022 to evaluate the efficacy of biological insecticides of botanical (azadirachtin, pyrethrins) and microbial (*Beauveria bassiana, Isaria fumosorosea*, *Chromobacterium subtsugae*, *Burkholderia rinojensis*) origin. A pyrethroid (lambda-cyhalothrin) was used as a standard. Whereas the pyrethroid controlled *O. insularis* and *O. pugnax* under field conditions and caused high mortality in under laboratory conditions, the biological insecticides had little to no adverse effects on the stink bugs. Future studies will continue to examine the feeding behavior of *O. insularis* and *O. ypsilongriseus*, as well as additional tactics for managing these pests in rice.

Genetic Characterization of the Quantitative Disease Resistance to Bacterial Panicle Blight

Ontoy, J.C., Bruno, J., Shrestha, B., Barphagha, I., and Ham, J.H.

Bacterial panicle blight (BPB) is a chronic rice disease in the southern United States, and the bacterial pathogen *Burkholderia glumae* is the major causal agent for this disease. Most rice cultivars grown for U.S. rice production are susceptible to this disease, and only a few have a moderate level of quantitative resistance. The medium-grain cultivar, Jupiter, is one of the U.S. varieties showing significant levels of quantitative resistance to BPB. We have studied the genetic feature of Jupiter related to its disease resistance to BPB using two recombinant inbred line (RIL) populations derived from two difference parent combinations, i.e., Trenasse (long-grain susceptible cultivar)/Jupiter (T/J) and Bengal (medium-grain susceptible cultivar)/Jupiter (B/J).

Our quantitative trait locus (QTL) mapping for BPB resistance with the T/J RIL population was conducted based on the Kompetitive Allele Specific PCR (KASP) data of 286 RILs and the whole genome sequence (WGS) data of 15 selected RILs composed eight resistant and seven susceptible lines. From these two separate lines of genotype data, we detected a major QTL on the upper arm of chromosome 3. This major locus for BPB resistance overlapped with the quantitative resistance to SB and the days-to-heading, suggesting a strong influence of the timing for heading on the broad-spectrum quantitative disease resistance to BPB and SB. Additional QTLs were also detected on chromosomes 1, 2, 4, 5, 9 and 11. Genes involved in jasmonic acid synthesis and salicylic acid signaling were identified within these QTLs as candidate genes contributing to the quantitative disease resistance to BPB.

The other mapping study with the B/J RIL population was based on the genotype data obtained from a genotype-by-sequencing (GBS) approach for 186 RILs. Because Bengal and Jupiter are closely related medium-grain cultivars having similar days-to-heading traits, we could minimize the influence of the differential heading timing on BPB in genetic mapping of QTLs for BPB resistance by using this RIL population. From this QTL mapping, we detected nine QTLs having a percentage variance explained (PVE) range between 0.6 – 27.9%, however, only one QTL on chromosome 3 was consistently detected with three years of field data on BPB. Furthermore, we performed an RNA-sequencing analysis to characterize the genes differentially expressed upon BPB infection depending on the disease resistance trait of Jupiter, which provides clues to understand the mechanism of rice disease resistance to BPB. From this study, we found that rice disease resistance to BPB was associated with higher expression of genes involved in defense-signaling, cell wall formation, and biosynthesis of secondary metabolites. Conclusively, the information obtained from this study will be a valuable resource to understand the genetic background of rice for BPB resistance, to breed more disease-resistant cultivars, and to develop innovative disease management strategies.

Rice Quarantine Activities within USDA-APHIS Plant Germplasm Quarantine Program

Adhikari, B.N., Turner, R.S., Harvey-White, A., and Foster, J.A.

The Plant Germplasm Quarantine Program (PGQP) of the U.S. Department of Agriculture-Animal and Plant Health Inspection Service (USDA-APHIS) is the largest federal plant quarantine center in the United States. PGQP serves as the portal for the legal and safe introduction of prohibited plants and plant materials imported into the country. The PGQP manages the importation of more than 25 economically important plant genera, establishes them in our facility, inspects growing plants regularly, and tests them for the presence of regulated bacteria, viruses, viroids, and phytoplasmas through four major quarantine programs. Diagnosis of regulated pathogens involves a wide range of tests including biological indexing, serological and molecular tests, and Hight-Throughput Sequencing (HTS).

The Poaceae quarantine program manages the importation and processing of rice germplasm. Quarantine regulations are designed to prevent the importation of several exotic seed-borne bacterial, fungal, and viral rice pathogens and control the introduction of certain rice species (*Oryza longistaminata, O. punctata,* and *O. rufipogon*), which are on the Federal Noxious Weed list. Following a request by an importer, the PGQP manager sends a request letter, mailing label, and the proper permits directly to the exporter to arrange for the importation. Rice germplasm is exchanged as seeds, and occasionally as bare-rooted seedlings. Upon entry in spring, the rice seeds are inspected and treated with hot water (56°C, 15 min) by an APHIS-PPQ inspector at the Beltsville Plant Inspection Station. Dried and repackaged seed, which serves as the parental seed, is released to the crop manager. For each accession, at least 25 healthy seeds are dehulled and surface sterilized in a 1.575% sodium hypochlorite solution for 2 hours. After rinsing in sterile deionized water, seeds are grown in a tissue culture medium containing Potato Dextrose Agar (PDA) plus 0.5x Murashige and Skoog (MS) for 2-3 weeks. Seeds contaminated with bacterial and fungal growth are discarded. Plants from microbe-free cultures are transplanted into pots in the greenhouse. Rice seeds are mostly planted in the early spring, but photo-insensitive varieties are also grown during the summer and fall. Rice plants are inspected visually during growth for fungal or bacterial pathogens. The growing plants are tested for the presence of endornaviruses, which are regulated viruses in rice seeds, using virus-specific Polymerase Chain Reaction (PCR) tests. Comprehensive pathogen testing is also done using HTS which can detect both known and novel pathogens including viruses. The quarantine period for imported rice is usually about 12 months. After the quarantine period, seeds free of pests are released in the fall or early winter and shipped to the importer.

Since its inception, the Poaceae Quarantine Program at PGQP has processed and released several thousand rice accessions, including the cultivated and wild varieties, to the rice research programs of universities and USDA ARS, rice industries, and private citizens. We continue to support the germplasm exchange and rice breeding programs in the country for this economically important crop while preventing the entry and establishment of pathogens that could be harmful to the rice industry.

Characterization of the Major Sheath Blight Resistant QTL *qShB9-2* on Rice Chromosome 9

Jia, Y., and Wang, G.L.

Sheath blight disease caused by the soil borne necrotrophic pathogen *Rhizoctonia solani* is a major threat to rice production in the USA. The disease is managed by the use of fungicide. Because major resistance (*R*) genes to *R. solani* are lacking, minor *R* genes or QTLs have been identified and used in rice breeding programs. Among the over dozens of QTLs, *qShB9-2* located on chromosome 9 contributes to 25% phenotypic variation. The role of *qShB9-2* in resisting sheath blight disease was verified by repeated phenotyping of 77 recombinant inbred lines with and without *qShB9-2* under greenhouse and field conditions. Within the *qShB9-2* region*,* we found one ATP-binding cassette (ABC) transporter gene family encoding pleiotropic drug resistance-like ABC transporters. The gene specific high-resolution melting (HRM) DNA marker derived from *OsABC9* was developed and the existence of an HRM marker for the resistant allele correlated well with the resistant phenotype, suggesting that *OsABC9* is a promising candidate for sheath blight resistance. To validate the functional role of *OsABC9,* we analyzed DNA sequences of *OsABC9* in both susceptible variety Nipponbare and resistant variety Jasmine 85. Two polymorphic nucleotides that altere amino acids in Jasmine 85 were identified and were used to for designing guide RNAs for single-base editing using CRISPR-Cas9. At the same time, two overexpression contructs of *OsABC9* were generated for transformation in Nipponbare. Transgenic lines containing these constructs will be developed and evaluated for resistant function of the ABC transporter in response to *R. solani*.

New Rice Diseases Found in the United States

Zhou, X.G., Gaire, S.P., Imran, M., Khanal, S., Zhou, Y., Shi, J., Antony-Babu, S., Jo, Y.-K., and Atiq, M.

Diseases are among the most important factors limiting the profitability of rice production. There are numerous diseases, especially fungal ones, present in the United States, particularly in the Texas Rice Belt with its long, warm, and humid cropping seasons. Such environments are particularly favorable for the development of various pathogens. Correct and timely identification of the causal agents of existing and new diseases is critical to developing effective management strategies to minimize losses. This presentation summarizes the recent discovery of five new fungal pathogens – *Curvularia hawaiiensis*, *Epicoccum sorghinum*, the *Fusarium incarnatum-equiseti* species complex, *Marasminus graminum,* and *Rhizoctonia solani* AG-4 – that cause seedling and foliar diseases in U.S. rice. These pathogens were identified based on their morphological characters and molecular diagnosis followed by pathogenicity tests with Koch's postulates.

Curvularia hawaiiensis, causing brown leaf spot, was identified in Beaumont, Texas, in 2021, though it was first reported in Malaysia in 2015 and Pakistan in 2019. Lesions start as small pinhead-size blackish spots on the leaf tips or from the edges of leaf blades. After approximately 2 weeks, the spots enlarge to become irregular or oval brown with a slight chlorotic halo. *Curvularia* species are frequently found on rice grains and cause blackish discoloration symptoms on grain kernels.

Eagle Lake, Texas, had a confirmed case of leaf spot, caused by *Epicoccum sorghinum* in 2021, just one year since the disease was first reported on rice in China. Lesions start as small dark brown spots on the lower leaves and sheaths, enlarging to become round or oval (1.5 to 5.0 mm in diameter) spots with round ends, gray centers, dark-brown borders or rings, and slight gold halos. The spots on the sheaths are similar to those found on the leaf blades, with lesion size ranging from 2 to 5 mm. Typical symptoms can occur after 5 days of infection.

Also at Eagle Lake, Texas, in 2021, the *Fusarium incarnatum-equiseti* species complex was identified and confirmed to be causing Fusarium sheath rot. Symptoms begin with initial oblong or irregular oval lesions with gray to light brown centers and a dark reddish-brown diffuse margin occurring on the upper flag leaf sheaths. The lesions enlarge, coalesce, and cover a large area of the sheath, in turn leading to panicle rot with kernels turning dark brown. Unlike the sheath rot caused by *Sarocladium oryzae*, sheath infection by *F. incaarnatium-equiseti* species complex leads to inside culm infection with irregular dark brown lesions. The *F. incarnatum-equiseti* species complex was reported to be associated with panicle infection in wild rice in Brazil in 2021. *F. incarnatum* has been reported to cause panicle rot in China in 2021, and *F. proliferatum* was reported to cause Fusarium sheath rot in India in 2021 and in the United States in 1995.

Marasmius graminum, a sterile white basidiomycetes fungus, is a new pathogen causing seedling blight of rice, which has been reported only in the United States, originally Louisiana and Texas in 2018. Infection causes severe damping-off of seedlings, showing dark-brown necrotic lesions on the mesocotyls and/or roots where white superficial mycelium is usually present.

Another new pathogen reported in 2018 in Arkansas, Missouri, and Texas as causing seedling blight of rice is *Rhizoctonia solani* AG-4. Infection causes seed rot and damping-off of seedlings; those infected have dark brown necrotic lesions on the radicles, coleoptiles or mesocotyls. *R. solani* AG-4 is more aggressive in virulence than *R. solani* AG-11, the most common fungus that causes seedling blight of rice.

22 Years of Fungicide Studies on the Control of Sheath Blight Control in Louisiana: A Meta-Analysis

Dalla Lana, F., and de Nux, C.

Sheath blight, caused by the fungus *Rhizoctonia solani* AG1-1A, is the most important rice disease in Louisiana and one of the most important in the USA and worldwide. With no major resistant gene and limited quantitative resistance, cultural and chemical control are the most effective strategies to mitigate the disease's impact. Fungicides from the group of quinone outside inhibitors (QoIs) and succinate dehydrogenase inhibitors (SDHIs) are the most used to control sheath blight, with fungicides from the demethylation inhibitors (DMIs) group also eventually used. These fungicides are constant test under experimental field conditions, which are used to develop application guidelines. However, these studies frequently have conflicting results, statistically low power, and are susceptible to specific environmental variations, such as unusual weather. A way to increase the statistical power and consolidate these results is through a meta-analysis, which summarizes multiple independent studies in a single analysis. In addition, an expansion of the meta-analytic model using moderator variables can account for covariates that influenced the results, such as variety resistance or management. This study will use meta-analytic procedures to summarize fungicide efficacy and yield return of 175 studies over two decades (1998-2020). Moderator variables will be used, such as year, growth stage application, and resistance class. A simulation of the profitability of these fungicides, considering variations in application cost and crop price, will also be performed. The results of this analysis will consolidate two decades of chemical control studies on sheath blight in Louisiana and help identify gaps in the knowledge. Future studies will include additional years, locations, and states.

Abstracts of Posters on Plant Protection
Panel Chair: Nick Bateman

Value of Diamide Seed Treatments in Upper Midsouth Rice

Lytle, M.J., Gore, J., Crow, W.D., Cook, D.R., Catchot, A.L., and Bond, J.A.

Rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) is the most injurious insect pest of rice (*Oryza sativa* L.) in Mississippi and across the midsouth. This insect has the potential to injure rice as an adult by feeding on foliage, causing linear scars that run parallel to the leaf veins. Damage leading to yield loss from the rice water weevil is caused by the larval stage. Larvae feed on rice roots, resulting in reduced nutrient uptake, delayed maturity, stunted growth, and ultimately, a reduction in yield. Historically, neonicotinoid seed treatments (CruiserMaxx®; NipsIt INSIDE®) have been used for control of rice water weevil in rice. Previous work has shown that neonicotinoid seed treatments may not provide adequate control of rice water weevil due to short residual activity and foliar applications may become necessary in some situations. The other currently labeled control option for rice water weevil, diamide seed treatments (Fortenza; Dermacor X-100), has considerably longer residual activity but comes at a substantially higher cost than neonicotinoids. Mississippi State University has conducted field experiments to evaluate the value of diamide seed treatments in upper midsouth rice production. Field experiments were performed at three locations across the Mississippi Delta (Washington County, Coahoma Country, and Tunica County). Treatments included thiamethoxam (Cruiser 5 FS), chlorantraniliprole (Dermacor X-100), clothianidin (NipsIt INSIDE), cyantraniliprole (Fortenza), a grower standard fungicide seed treatment, all at currently labeled rates as well as a nontreated control. Reduced rates of cyantraniliprole were evaluated as well. To determine rice water weevil impact, soil cores were collected, including the root mass and lower portion of the plant. Plant biomass and soil were then washed and rice water weevil larvae separated and counted. Yield data were collected at harvest. The study was designed as a randomized complete block, with four replications at each location. Evaluating reduced rates of cyantraniliprole, thiamethoxam + cyantraniliprole at all rates resulted in greater yield than all other treatments except cyantraniliprole alone. When comparing thiamethoxam, clothianidin, and chlorantraniliprole, when averaged across all locations, the chlorantraniliprole-treated rice resulted in higher grain yield than all other treatments. There are clear yield protecting benefits when utilizing these insecticide seed treatments alone or in combination. In situations where weather and soil conditions will impact seed emergence and early vegetative growth, there may be a benefit to using a diamide seed treatment in order to prolong control. Current input prices surrounding rice production will certainly impact insect pest management decisions. There may be hesitation to choose a more costly control option, such as a diamide seed treatment, but the possibility of a necessary foliar application may remain.

Use of Mutant Rice Lines to Elucidate the Role of Silicon in Rice Resistance to Insects

Sharma, J., Tai, T., and Stout, M.J.

High levels of silicon (Si) in rice plant tissues have been hypothesized to enhance rice resistance against various insect pests. However, the mechanism by which Si enhances rice resistance against insects has not been fully elucidated. The goal of this study was to evaluate the influence of Si uptake on the resistance of rice to *Spodoptera frugiperda* Smith, the fall armyworm (FAW), and to investigate morphological and biochemical correlates of resistance. To examine this, three silicon transporter mutants (one >95% deficient in the uptake of Si, a second ~55% deficient in uptake of Si, and a third with uptake similar to WT) were utilized for FAW feeding assays along with the corresponding wild-type rice (WT). An *in situ*, long-term feeding assay was carried out in which FAW neonates (<6 h old) were reared to pupation on mutant and WT plants in pots. Higher levels of Si in tissues were associated with reduced larval and pupal weights. Larval and pupal durations as well as time to emerge were also prolonged in plants with higher Si contents. Induced resistance, however, was not compromised by low Si content. Phenolic contents and activities of oxidative enzymes were assayed in mutant and WT plants to determine whether deficiency in Si affects these biochemical traits. The results of initial experiments show that Si negatively affects the growth of FAW and deficiency in silicon transporter *OsLsi1* compromises rice constitutive resistance to FAW.

Blast Panel Investigation of Disease Resistance of High Yielding Breeding Lines

Box, H., Jia, Y., Wang, X., Wamishe, Y., and Jia, M.H.

Rice blast disease caused by the fungus *Magnaporthe oryzae (syn. M. grisea)* is one of the most lethal diseases for sustainable rice production worldwide. Major blast resistance (*R*) genes have been used singularly, once at a time or in combination that provides overlapped resistance to a wide range of blast races.

In the USA, major blast *R* gene *Pi-ta, Ptr* (previously named as *Pi-ta2*), *Pi-b, Pi-z, Pi-k* have been effectively deployed over decades using classical plant breeding added with closely linked genetic markers or markers derived from portions of cloned genes. The efficacy of major *R* genes is determined by the corresponding avirulence genes (*AVR*) in *M. oryzae*. *AVR* genes in *M. oryzae* are highly mutable under changing climate and deployed *R* genes. Therefore, continued characterization and evaluation of *AVR* genes in *M. oryzae* can guide *R* gene deployment.

Thus far, a panel of blast races consisting of 12 isolates were identified from diseased samples since 2015 based on *AVR* gene composition and pathogenicity assays using IRRI monogenic lines carrying 23 major blast *R* genes. This blast panel has been used to verify function of deployed *R* genes in advanced breeding lines developed by ARS, university and industry scientists including 50 lines from the Uniform Regional Rice Nursery (URRN) under greenhouse conditions, and results will be presented.

Response of California Rice Varieties to Stem Rot and Aggregate Sheath Spot

Espino, L., Brim-DeForest, W., Clark, T., Giron, M., and Baez, C.

Stem rot (*Sclerotium oryzae*) and aggregate sheath spot (*Rhizoctonia oryzae-sativae*) are common diseases of rice in California. Before the 2000s, burning crop residue after harvest was the main management method for both diseases. Since the phase out of straw burning in 2000, the two diseases have become more important and, in some cases, cause yield reductions. Field experiments comparing the response of eight common California rice varieties to each disease was conducted in 2021 and 2022. For stem rot, results showed that varieties with longer development time to maturity had lower incidence and severity. Treatment with the fungicide azoxystrobin reduced disease severity by 20-30% and resulted in a 4% yield increase in all varieties in 2021 and a 4% increase in head rice yield in 2022. For aggregate sheath spot, disease incidence and severity for short- and medium-grain varieties was similar and tended to be lower for long-grain varieties. Treatment with the fungicide azoxystrobin reduced disease severity by 60% both years and resulted in a grain and milling yield increase of 4 and 5%, respectively, in 2022.

Insecticides for Armyworm Control

Espino, L., Clark, T., Giron, M., and Baez, C.

Insecticides are an important tool for managing armyworms, *Mythimna unipuncta*, an emerging pest of rice in the Sacramento valley of California. To evaluate the efficacy of insecticides, a field trial was established in a commercial rice field in Butte County. Insecticides tested were Dimilin (diflubenzuron) at 293 or 586 ml/ha, Leprotec (*Bacillus thuringiensis*) at 1.1 lt/ha in combination with SpearLep (GS-omega/kappa-Hxtx-Hv1a) at 1.1 or 2.2 lt/ha, Intrepid (methoxyfenozide) at 207 or 296 ml/ha, Xentari (*Bacillus thuringiensis*) at 1.1 or 2.2 kg/ha, and Sevin (carbaryl) at 3.5 lt/ha. Larval population in the field was high, averaging 78 true armyworm larvae/m^2. Larval populations were evaluated 0, 3, 5, 7, and 11 days after treatments were applied. Methoxyfenozide and diflubenzuron provided the best control. Methoxyfenozide reached 90% control 5 days after the application while diflubenzron reached 84% 7 days after application. Both products reached more than 90% control 11 days after treatment.

Results from six trials conducted between 2016 and 2021 were summarized. Insecticides considered were pyrethroids, diflubenzuron, methoxyfenozide, chlorantraniliprole, and *Bacillus thuringienses*. Median control with pyrethroids and *Bacillus thuringiensis* ranged from 20 to 40%. Diflubenzuron, methoxyfenozide, and chlorantraniliprole provided more than 90% control, with methoxyfenozide and chlorantraniliprole achieving higher control quicker than diflubenzuron.

Defoliation Threshold Recommendation in Arkansas Rice

Felts, S.G., Bateman, N.R., Thrash, B.C., Floyd, C.A., Newkirk, T.B., Plummer, A., Mann, M., Ibbotson, T., Murray, Z., Whitfield, A., Harris, T., and Maris, G.

Armyworms are commonly found in rice fields in the mid-southern United States and have the potential to cause severe defoliation to the rice crop. The two main armyworm species observed in rice in this region are true armyworms and fall armyworm. It is common to see infestations occur at all growth stages of rice. The current threshold for armyworms in rice is based on the number of larvae per square foot. A defoliation-based threshold would provide growers and consultants with a simple way to make economically sound decisions for controlling armyworms in rice. Studies were conducted from 2019 through 2021 where rice was mechanically defoliated at 0, 33, 66, and 100% with a weed eater at 2-3 leaf, early tiller, late tiller, and green ring growth stages across three planting dates. No yield loss was observed at the 2-3 leaf or either tillar stage. However, large amounts of yield loss were observed when plants were defoliated either 66 or 100% at the green ring growth stage. A delay in heading was also observed when plants were defoliated at 66 or 100% during any growth stage in 2019. Maturity delays were also observed in 2020 and 2021 but was not as severe as what was observed in 2019. Yield loss and delays in heading were greater for the May planting date compared to the April or June planting date. This data has helped to develop a defoliation-based threshold in rice to keep rice growers profitable.

Mosquitofish as a Potential Biological Control Strategy for Tadpole Shrimp (*Triops longicaudatus*)

Grettenberger, I.M., Hendrick, M.L., Goding, K., and Espino, L.A.

Tadpole shrimp (*Triops longicaudatus*; TPS) are the key, early season pest of rice in California. TPS have desiccation-resistant eggs that begin hatching within 24-48 hours after flooding under the right conditions. Because California rice is planted after the fields are flooded, their biology gives them a unique advantage. By the time rice begins sprouting, many TPS are already large enough to begin damaging the plants. They feed on the weak roots of young rice seedlings, killing them or causing them to float to the surface, creating stand loss. TPS are a severe pest with few control options, and growers are typically limited to chemicals such as pyrethroids to treat. Because there are so few management options, alternative control methods could be vital to managing insecticide resistance. We conducted field trials testing different densities of mosquitofish (*Gambusia affinis*) as a control agent. 9.29 meter^2 (100 ft^2) rings were built in fields and flooded before fish were added. Trials were conducted in two different fields with known differing TPS densities. The results of these trials demonstrate the potential of mosquitofish as a control agent. Since mosquitofish can be acquired from vector control agencies, they could serve as an accessible means of alternative pest control. Rice as a crop is incredibly valuable to California's economy, and severe infestations of TPS can threaten this crop before it is even planted, thus highlighting the need for additional management tactics.

Mapping Blast Resistance Genes in Rice Varieties 'Pecos' and 'M205'

Jia, M.H., Lin, M., McClung, A.M., and Jia, Y.

Rice blast caused by the fungal pathogen *Magnaporthe oryzae* is one of the most devastating diseases of rice worldwide. Disease resistance is most durable when varieties possess both non-race specific, quantitative resistance, and race specific resistance due to the presence of major (*Pi*) genes. More research has been conducted on identifying *Pi* genes that convey resistance to a number of blast races commonly found in the United States and deploying these in new varieties. Much less is understood about the contribution and inheritance of field (dilatory) blast resistance. However, a few U.S. and global varieties that lack any known *Pi* gene have been identified as having relatively slow development of blast disease symptoms. Pecos is medium-grain variety released in 1983 that possesses no *Pi* genes but demonstrates dilatory resistance to common races of blast found in the United States. As a means to evaluate the inheritance of this resistance, a cross was made between Pecos and M205 by Carl Johnson at the California Rice Research Foundation, Biggs, CA, in 1998. M205 is a variety that possesses only the *Pi-ks* gene which confers resistance to just the IB54 pathotype, and it is highly susceptible to all other races of blast common to the United States. The F_2 seed of the cross was provided to USDA-ARS for genotypic and phenotypic analysis. The F_3 generation (n=315) was evaluated for resistance (1=resistant, 9=very susceptible) after inoculation with a mixture of blast races in a nursery setting at Beaumont, TX. Pecos (22 replications) was rated as 4 whereas M205 (16 replications) was rated as 9, indicating a clear difference in resistance, and although the *Pi-ks* gene was present in M205, it was not affecting resistance to the races present in this setting. A continuous distribution of reactions was observed among the progeny with ratings of <3, 4, 5, 6, 7, 8, and 9 representing 0.5, 17, 21, 37, 18, 5, and 1.5% of the population, respectively. The population was subsequently advanced to the F_6 generation and 211 progeny were evaluated against six blast isolates: IB54 (3 replications), IE1, IE1K, IA1, IA45, and IB1 (1 replication each) under greenhouse conditions at Stuttgart, AR. The population was genotyped with 122 SSR and indel markers. Utilizing ICIM QTL mapping software, a map was developed that spanned 1420.28 cM. Subsequently, QTL analysis was performed using ICIM mappers ICIM-Add portion of the BIP function. We identified a major QTL on chromosome 11 that colocalizes with the *Pi-ks* locus ranging from a LOD score of 8.5-16.2 in response to the blast isolate IB54. No QTL were identified with the other blast isolates. More markers will be developed to fill in chromosomal gaps and additional replications of phenotyping will be performed using the five pathotypes that have only one replication completed so far. In addition, subsequent studies will be conducted to determine disease progress curves during the four weeks following seedling inoculation with scoring performed visually and using digital imaging. These results will be used to identify QTL associated with dilatory resistance due to quantitative inheritance as well as due to the presence of the *Pi-ks* gene in response to isolates other than IB54.

Management of Rice Water Weevils in Arkansas Rice

Plummer, A., Ibbotson, T., Bateman, N.R., Thrash, B.C., Floyd, C.A., Newkirk, T.B., Felts, S.G., Mann, M., Murray, Z., Whitfield, A., Harris, T., and Maris, G.

Rice water weevil is the number one insect pest of rice in Arkansas. While the adult will feed on the foliage of rice, the yield limiting stage of this pest is the immature stage. The larval stage of rice water weevils feed on the roots of rice and can cause major yield losses. Multiple control strategies were evaluated to determine the most efficient and cost-effective control method for rice water weevil management. Urea treated with multiple insecticide classes were compared to insecticide seed treatments. While control was achieved when a diamide or a neonicotinoid was coated on urea, it was less consistent than a diamide seed treatment. Costs were similar between methods, but due to inconsistency with the coated urea treatments, yields and net returns were better with seed treatments.

Evaluation of FullPage® Rice Cropping System for Weed Control and Yield Improvement in Texas

Zhou, X.G., and Samford, J.

Control of weeds, especially troublesome weeds, is a challenge to rice production. Herbicides have been commonly used for the control of numerous weeds, including grasses, broadleaves, and sedges. However, herbicides are not always effective. The recent development of FullPage® Rice Cropping Solution can be a new tool in farmer’s toolbox to combat weed issues. FullPage® Rice Production System consists of imidazolinone (IMI)-tolerant rice and use of IMI herbicides to improve weed control and provide herbicide application, timing, and flooding flexibility. RT7321 FP, RT7421 FP, and RT7521 FP are the three newly released FullPage® hybrid varieties. FullPage® rice is paired with Preface (imazethapyr) and Postscript (imazamox) herbicides. Preface has post-emergence and residual activities and can control troublesome weeds such as red rice, weedy rice, and barnyardgrass. Postscript can be applied post-emergence or post-flood for any escapes. The objective of this study was to evaluate the performance of FullPage® Rice Production System on crop injury, weed control, and yield improvement in main and ratoon crops under Texas environments.

A field trial was conducted in a randomized complete block design with four replications at Eagle Lake, Texas, in 2020, 2021, and 2022. The trial evaluated three FullPage® rice varieties, RT7321 FP, RT7421 FP, and RT7521 FP. Preface, Postscript, and other herbicides were applied as recommended. Plots consisted of seven 4.87-meter (16-ft) rows, spaced 19.05 cm (7.5 in.) between rows. Rice was drill seeded, and fertilizer, disease, insect, and water management followed local production recommendations. Weed seeds of broadleaf signalgrass, hemp sesbania, barnyardgrass, jointvech, yellow nutsedge, morningglory, and palmer amaranth were planted into plots at planting. Main crop was harvested on August 12, 11, and 17 for 2020, 2021, and 2022, respectively. After the main crop harvest, ratoon crop was followed based on location recommendations. There was no ratoon crop for 2022 due to historical drought weather conditions. Percent plant injury caused by herbicides and overall weed control were visually rated multiple times in a cropping season as compared to the untreated control plot in the same replicated block. Rice was harvested using a plot combine at maturity of each variety. Grain yield and moisture were determined, and rice yields were adjusted to 12% moisture content. Milling quality (% whole rice and % total milled rice) was also determined.

The FullPage® herbicides Preface and Postscript did not cause injury to both main and ratoon crops each year. The FullPage® herbicide program treatments provided excellent (100%) control of weeds, including Northern jointvetch, hemp sesbania, morningglory, and barnyardgrass. In the main crop, RT7321 FP had the highest yield ranging from 11,823 to 12,420 kg/ha (10,549 to 11,081 lb/A), with an average of 12,190 kg/ha (10,876 lb/A) over 3 years, followed by RT7521 FP having the yield ranging from 10,690 to 12,272 kg/ha (9,538 to 10,949 lb/A), with an average of 11,448 kg/ha (10,214 lb/A). The yield of RT7421 FP was 12,017 kg/ha (10,722 lb/A) in 2022. In the ratoon crop, the yield of RT7321 FP was also significantly higher ($P \leq 0.05$) than RT7521 FP, with the average yield of 5,447 and 3,901 kg/ha (4,860 and 3,481 lb/A) over 2 years evaluated, respectively. The main crop whole rice and total rice of RT7321 FP were significantly higher than those of RT7521 FP in 2020 and 2021. However, RT7421 FP had the highest level of main crop total rice and whole rice among the three varieties evaluated in 2022. The ratoon crop total rice and whole rice of RT7321FP were similar to or better than RT7521FP.

In conclusion, FullPage® herbicides are safe to the FullPage® rice and are effective for control of weeds. All three FullPage® rice varieties performed well under Texas environments, with high yields and good milling quality. RT7321 FP outperformed RT7421 FP and RT7521 FP on yield.

Disease Loss Estimates from the Rice Producing States in the United States: 2020 and 2021

Allen, T.W., Dalla Lana, F., Wamishe, Y.A., Espino, L., Chlapecka, J., and Zhou, X.G.

Disease loss estimates are an important aspect when considering the yield losses that occur as a result of important plant diseases. Even though the number of rice hectares grown in the United States are rather limited, the losses associated with major plant diseases remain a significant concern and continue to significantly reduce rice production on an annual basis. In 2020 and 2021, plant pathologists with rice Extension and research responsibilities continued to add to their effort to compile loss estimates for their respective states. Prior to 2018, rice was one of the only major row crops that was not compiling estimates of loss from occurring from plant diseases. Loss estimates are helpful in relating the effectiveness of research programs, aid in determining where future research needs may be necessary, and aid in tracking the importance of major plant diseases should large reductions or increases occur over time. Following the 2018 season, a spreadsheet was circulated amongst the authors with a list of 15 of the most important rice diseases (autumn decline, bacterial panicle blight, bakanae, blast (leaf and neck), brown spot, crown sheath rot, false smut, kernel smut, narrow brown leaf spot, seedling diseases, sheath blight, stem rot, straighthead, and a category marked as "other" to include diseases of importance that may have occurred within a specific state that were not included in the list). Estimates were made by rice pathologists or the state specialist with rice responsibilities in the absence of a pathology contact. Multiple techniques were employed to arrive at estimates but were based on field-level experience with each of the diseases that were based on observation of cultivar trials, fungicide efficacy trials, or answering rice farmer troubleshooting calls in commercial rice fields related to each of the diseases.

In 2020, rice diseases accounted for an estimated total of 6.1% rice production losses. The greatest losses were observed as a result of sheath blight, caused by *Rhizoctonia solani*. Four diseases were listed as having the lowest impact on rice production and included Autumn decline, bacterial panicle blight, bakanae, crown sheath rot, and straighthead. All four diseases accounted for no production losses observed across the rice producing states. The top four yield-reducing diseases based on percent yield suppression across the entire rice producing area during the 2020 season were: sheath blight, neck blast, stem rot, and narrow brown leaf spot. Considering total disease losses by state, sheath blight was the most important disease with estimated losses of between 1.5 and 4% from Texas and Mississippi, respectively. The greatest total estimated losses were observed to occur in Louisiana (10%), followed by Texas (9.9%), and Arkansas (6.6%), with the lowest estimates of loss in Mississippi (1.8%).

In 2021, rice diseases accounted for an estimated total of 5.7% loss of the total U.S. rice production. Similar to 2020, the greatest losses were observed as a result of sheath blight, and the disease with the least impact on the rice production area included eight diseases with no losses observed. The top four yield-reducing diseases based on percent yield suppression across the entire rice producing area during the 2021 season were: sheath blight, neck blast, seedling diseases which are caused by multiple organisms, and narrow brown leaf spot. On a state basis, sheath blight was the most important disease with estimated losses of between 2 and 5% from Missouri and Arkansas, respectively. The greatest estimated losses were observed to occur in Arkansas (6.2%), followed by Louisiana (6.1%) and California (5.5%), with the lowest estimates of loss in Mississippi (3.2%).

In 2020, the total number of hectares devoted to rice accounted for 1.21 million hectares versus only 984,600 hectares in 2021. Between the two years, a reduction of 22.8% in the total number of hectares occurred with a reduction between 2020 and 2021. Total rice production, averaged across the six rice producing states, accounted for 6,818 kg/ha in 2020 as compared to 6,838 kg/ha in 2021. Between 2020 and 2021, a 0.3% reduction in average rice production across the entire rice producing area was observed.

Management of Tadpole Shrimp with Insecticides

Grettenberger, I.M., Espino, L.A., Goding, K., and Hendrick, M.L.

Tadpole shrimp are the key invertebrate pest in rice early in the season. Management relies heavily on insecticides. Currently, pyrethroids are the most-used mode of action, but additional materials have been employed in some cases. Because tadpole shrimp can be difficult to detect when they are small and because they can grow very quickly, the timing of applications can vary widely. This likely will affect efficacy for some materials. We evaluated a number of different insecticides for managing tadpole shrimp. We tested insecticides from multiple modes of action due to the threat of resistance to pyrethroids. In addition, we tested multiple rates and application timings to address the economics of management and different scouting situations. We used two methods. In the first, we used one-meter diameter metal rings and natural infestations of tadpole shrimp. We evaluated management success by performing visual counts of tadpole shrimp in the rings at multiple time points, as well as a final destructive assessment by netting and counting the shrimp. We also are evaluating stand establishment and yield. We also used an “inner ring” method. Here, we placed a metal trash can within the larger ring and then added 10 shrimp to each ring before making the insecticide application. We then counted the shrimp to evaluate mortality at multiple time points. Through this work, we are identifying alternatives to pyrethroids and establishing best practices for their application that can factor in both economics and efficacy. Managing shrimp with multiple modes of action will be critical for preventing insecticide resistance from spreading more broadly.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Tom Barber

Determining Anaerobic Germination Capacity in California Weedy "Red" Rice (*Oryza sativa spontanea*) Accessions

Galvin, L.B., and Al-Khatib, K.

Weedy "red" rice continues to be a problematic species of interest for California rice producers. There are currently no chemical control options for this pest available in California, so cultural and mechanical methods targeting early-season phenological stages are being developed. One option for suppressing weedy rice seed germination and emergence is creating anaerobic soil conditions. However, some California weedy rice accessions have close phylogenetic ties to California cultivars which have some ability to germinate under anaerobic conditions. The objective of this study was to determine whether California weedy rice accessions 1, 2, 3, and 5 demonstrate anaerobic germinability compared with M206, a medium-grain, medium-maturity cultivar developed in California. A single seed was planted under 1.3 cm of soil within a single cell of a 2.5 by 2.5 by 5 cm plug tray. Each plug tray contained 10 seeds of each accession as well as M206. Plug trays were nested within clear plastic tubs to maintain a flood for the duration of the experiment. Anaerobic replicates were flooded to the soil surface 24-hours in advance of planting, while aerobic replicates did not receive moisture before planting. Once all seeds were planted, anaerobic replicates were flooded to 12 cm above the soil surface. Aerobic replicates remained flooded to half the depth of the soil surface (1.3 cm) to ensure adequate soil moisture and oxygen for germination. Tubs were uncovered and placed into a dark growth chamber at 30°C for 14 days. Plants were removed by hand from the soil at termination; length of cotyledons, radicles, and number of emerged seeds was recorded. Accessions 3 and 5 exhibited anaerobic germinability while accessions 1 and 2 as well as M206 were never able to successfully germinate anaerobically. Germination of accessions 3 and 5 was less than 30% when anaerobic conditions were present and over 90% under aerobic conditions. This information can be used to implement strategic flooding practices to suppress germination of California weedy rice accessions 1 and 2.

Barnyardgrass in Rice - What are Our Current Knowledge Gaps?

Godar, A.S., and Norsworthy, J.K.

Barnyardgrass (*Echinochloa* spp.) has been the focal point of weed management interventions ever since the beginning of commercial rice culture in the United States. Introduced from multiple sources and events, several economically relevant species of *Echinochloa* exist in U.S. rice; often collectively called 'barnyardgrass' in the Mid-South and 'watergrass' in California. The abundance of *Echinochloa* species is distinctly associated with the method of rice culture practiced in the region, with *E. crus-galli* being predominant in drill-seeded rice in the Mid-South and *E. oryzicola* in water-seeded California rice. *E. crus-galli* has a distinctively wider geographic distribution compared to other barnyardgrass species and has received a proportionate amount of attention. The basic biology of barnyardgrass as a rice weed has been extensively studied, and a recent analysis at the genomic level has provided a deeper insight into the evolution of barnyardgrass species.

Despite the availability of more than a half dozen different modes of action to target barnyardgrass, many U.S. rice growers face a challenge as populations of barnyardgrass have expanded their resistance profile. Crop mimicry, allelopathy, aggressive competition, and tolerance to abiotic stress have historically been the adaptive tools of barnyardgrass to persist in rice ecosystems globally. The persistence and abundance of barnyardgrass in the more sophisticated U.S. rice culture indeed lie in its ability to evolve resistance to herbicides. It is not that its significance as a threat to U.S. rice had not received considerable academic attention; only in the past two decades has the widespread recognition of herbicide resistance as an inevitable consequence emerged. Peremptorily, attention is being drawn to non-chemical methods of its control as a fundamental element of an IPM strategy. Use of harvest weed seed control (HWSC) methods and cover crops in the Mid-South and stale-drill seeding in California are being evaluated as potential IPM components for its sustainable management. These practices have the potential to modulate weed

seed recruitment, and/or weed emergence. In recent years, furrow-irrigated rice has rapidly supplanted a significant acreage of conventional rice in the Mid-South. On the cusp of this shift, the question at the forefront is how this will affect barnyardgrass interference in rice and how this change will dictate its management efforts.

Successful interference of barnyardgrass species in rice is a result of complex interactions of its seedbank dynamics (as affected by control efforts), water management, degree of disturbance, and plant cover. A clear understanding of the impact of the changing agroecosystems on barnyardgrass as well as its response to the prospective integrated control interventions is lacking.

Is Gene Amplification and Expression Involved in Cyhalofop-Resistant Barnyardgrass Accessions?

González-Torralva, F., and Norsworthy, J.K.

Rice, *Oryza sativa* L., is one of the most relevant cereal crops in the world. In the United States, Arkansas is the largest rice-producing state. One of the main challenges in rice production is the presence of weeds, especially those resistant to herbicides. Among those, barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] is the most common and troublesome weed of the crop. Barnyardgrass has evolved resistance to different site of action herbicides applied to rice, including those that inhibit acetyl CoA carboxylase (ACCase). In this research, the contribution of gene amplification and expression of *ACCase* genes in a cyhalofop-resistant barnyardgrass accession was investigated. For that purpose, gene-specific ACCase primers were designed to quantify the *ACCase* gene copy number and gene transcripts in a cyhalofop-resistant and -susceptible barnyardgrass accessions. Results suggest that *ACCase1* and *ACCase3* are contributing to ACCase resistance. Those genes were approximately two- and three-fold overexpressed in the resistant accession for *ACCase1* and *ACCase3*, respectively. Additionally, outcomes have indicated that increase in gene copy number of *ACCase* genes are not contributing to ACCase resistance in this cyhalofop-resistant barnyardgrass accession.

Responses of Barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] to Cyhalofop-butyl following Pretreatment of Malathion or NBD-Cl

Hwang, J.I., Norsworthy, J.K., Barber, L.T., and Butts, T.R.

Postemergence management of barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] resistant to herbicides may be a challenging task. In a previous study, we confirmed barnyardgrass biotypes that have evolved resistance to multiple herbicides such as acetyl-CoA carboxylase inhibitor cyhalofop-butyl (CyB) and synthetic auxin herbicide florpyrauxifen-benzyl. The present study as a follow-up investigated responses of the multiple-resistant barnyardgrass biotypes to CyB following pretreatment with malathion and/or 4-chloro-7-nitrobenzofurazan (NBD-Cl), well-known as broad inhibitors of cytochrome P450s and glutathione *S*-transferases, respectively. As the result, pretreatment of metabolic inhibitors was not effective in reversing the CyB resistance in the tested barnyardgrass biotypes, which means no relevance of the cytochrome P450s and glutathione *S*-transferases inhibited by the compounds in resistance evolution. Rather, treatment with malathion followed by (fb) CyB resulted in antagonism to debase the herbicide activity and led to more active growth of some resistant biotypes. Alterations in absorption, translocation, and metabolism of CyB following pretreatment of malathion were examined in both susceptible and resistant barnyardgrass biotypes, but the cause of CyB antagonism by malathion in the resistant biotypes could not be addressed based on the results obtained in this study. Some interesting results were found in metabolism analysis. Residual amounts of the applied form CyB in all the tested biotypes were 1.5- to 10.5-fold greater when treated with malathion fb CyB than when treated with CyB alone. In contrast, production of cyhalofop-acid, an active form metabolite, was maintained similar in both treatments with (1.0 to 19.3%) and without malathion (1.8 to 17.3%). Taken together, cytochrome P450 enzymes can be involved in metabolism of CyB but not in its conversion to cyhalofop-acid which may be closely related with the herbicide's activity and further lead to the herbicide resistance evolution due to reduction in its production.

Will Use of Quizalofop for Weedy Rice and Barnyardgrass be Short-Lived?

Norsworthy, J.K., Gonzalez-Torralva, F., Barber, L.T., Butts, T.R., Sha, X., Hardke, J., and Famoso, A.

Barnyardgrass and weedy rice are among the most troublesome weeds of rice in the mid-southern United States. Commercialization of the Clearfield technology by BASF enabled in-crop use of imazethapyr and imazamox beginning in 2002 in U.S. rice. Even though resistance to acetolactate synthase inhibitors has historically been quick to evolve, the technology proved to be effective for control of both weeds in most fields for more than 10 years. However, today in Arkansas more than 20 years after introduction of the technology, approximately 50% of the barnyardgrass accessions submitted for screening test positive for resistance to imazethapyr whereas the frequency of resistance in weedy rice samples is >90%. In 2018, BASF commercially launched the Provisia technology, enabling over-the-top use of quizalofop in rice. Subsequently in 2022, RiceTec commercialized the Max-Ace Rice Cropping Solution, that was somewhat similar to Provisia in that it allowed for quizalofop use in rice. Today, the Provisia and Max-Ace technologies have been used on limited acres in Arkansas, mainly restricted to continuous rice fields with dense infestations of barnyardgrass and/or weedy rice having resistance to multiple herbicides. Of the barnyardgrass samples from fall of 2021 screened for resistance, 22% of these tested positive for resistance to both cyhalofop and fenoxaprop. Samples from 2021 were screened for resistance to quizalofop along with samples from the 2022 growing season. Recent research has shown that cyhalofop resistance is partly a result of enhanced metabolism and it is unknown whether quizalofop metabolism would likewise be enhanced in these resistant accessions. In regard to weedy rice, 21 accessions were collected in 2022 by Arkansas growers, county Extension agents, and consultants for screening. Eight accessions have been evaluated thus far, with all being resistant to imazethapyr and quizalofop failing to control two of eight accessions. The two weedy rice accessions, both with a red pericarp, were collected from a field in Jefferson County, AR, where Provisia rice had been grown for at least three consecutive years. One weedy rice accession was awned and the other awnless. This finding represents the first confirmation of weedy rice with resistance to quizalofop in Arkansas. Research to identify the resistance mechanism is on-going. Based on these findings, field failure of weed control programs that rely almost solely on quizalofop and where rice is not routinely rotated with soybean or other crops will likely result in the Provisia and Max-Ace technologies being short-lived as effective options in Arkansas.

Feasibility of Redekop™ Harvest Weed Seed Control in Furrow-Irrigated Rice

Piveta, L.B., Norsworthy, J.K., Smith, D., Woolard, M.C., Arnold, C.T., Barber, L.T., and Butts, T.R.

Barnyardgrass and Palmer amaranth are difficult-to-control weeds in furrow-irrigated rice (FIR), especially as herbicide resistance continues to grow throughout the Midsouth. The lack of a flood on FIR considerably changes weed management for rice; most growers that use only chemical weed management programs are looking for alternative methods to limit soil weed seedbank replenishment from escaped weeds. The objective of this experiment was to evaluate the large-scale use of a Redekop™ seed destructor as a non-chemical management strategy for harvest weed seed control (HWSC) of barnyardgrass and Palmer amaranth in FIR. The experiment was designed as a strip-plot (168 by 7.6 m) with eight replications, in Keiser, Arkansas, in 2022. Half of the total number of plots were harvested conventionally, and the other half using the Redekop seed destructor. In plots where the Redekop seed destructor was used, seedbank replenishment was reduced by 72 and 75 percentage points for barnyardgrass and Palmer amaranth, respectively, based on initial exhaustive germination conducted in the greenhouse; however, final exhaustive germination assessments are still ongoing. Based on initial evaluations, the Redekop seed destructor could be an asset for rice producers. As HWSC methods become available for commercialization, additional parameters need to be further evaluated, specifically shattering of weed seed before crop harvest and the height distribution of seed on targeted weed species. Incorporation of HWSC may allow producers searching for a systems approach to better manage difficult-to-control weeds by diminishing the number of viable seeds placed back into the soil-seedbank over time.

Benzobicyclon Field Trial Results from the Mid-South of the U.S.A.

Sandoski, C.A. and Schmidt, L.A.

Benzobicyclon is a novel herbicide that received federal registration for use on rice in 2022 as Rogue™ SC. The molecule is characterized by excellent safety to both *japonica* and *indica* rice varieties, has a favorable toxicological and eco-toxicological profile and offers broad spectrum control of grasses, sedges and broadleaves at rates of 250 – 370 g ai/ha. Benzobicyclon is a slow releaser of the active triketone metabolite that functions as an inhibitor of *p*-hydroxyphenylpyruvate dioxygenase (HPPD).

University field trials have demonstrated that Rogue SC Herbicide provided excellent control of ducksalad, sprangletop, annual sedges (to include ALS herbicide-resistant species such as rice flatsedge and smallflower umbrella sedge), arrowhead, gooseweed, and weedy rice. These trials have also demonstrated that Rogue SC Herbicide can be applied as a liquid spray, on coated fertilizer, as a drip application or injected into side-inlet irrigation.

Recent results from recent Mid-South university trials with benzobicyclon will be reported. Results will be presented from trials evaluating weed control, application methodologies, and rice cultivar tolerance.

Benzobicyclon (Rogue® SC): A New Post-Flood Herbicide Option for Southern Rice Production

Schmidt, L.A. and Sandoski, C.A.

Benzobicyclon (Rogue® SC) was first sold commercially in the southern USA rice producing areas in 2022. It is a novel herbicidal chemistry (HPPD) for rice and is well suited for controlling susceptible grasses, broadleaves, sedges, and aquatic weeds in a permanently flooded water-seeded or dry-seeded rice culture. Benzobicyclon is a pro-herbicide that will react with water and convert to its herbicide active form when applied to post-flood rice.

Commercial fields and research trials treated with benzobicyclon in 2022 provided key learnings to best manage further use by producers of southern rice. In past years, benzobicyclon had very limited availability to producers under an experimental use permit (EUP) for use in a water-seeded rice production system only, but in 2022, the expanded label for benzobicyclon allowed for post-flood applications in dry-seeded, delayed flood rice production systems. Applications of benzobicyclon to maintain optimum weed efficacy were applied to largely submerged weeds as well as prior to the rice canopy becoming too dense or past the two-tiller rice stage. Applying earlier reduced obstruction of herbicide delivery into static, deep-flooded fields. In a delayed flood rice system, benzobicyclon was shown to be an excellent post-flood component of a multi-spectrum weed control program when tank-mixed or applied sequentially with halosulfuron-methyl containing products (Permit Plus®, Gambit®). These programs required a foundation preemergence herbicide such as clomazone for early grass weed control. Tank-mix partners that performed well on escaped grasses when mixed with benzobicyclon include fenoxaprop-p-ethyl (Ricestar® HT) and bispyribac-sodium. Benzobicyclon also provided a good residual post-flood herbicide when used in imadazolinone and quizalofop herbicide tolerant rice programs. Herbicide application techniques such as aerial direct stream, fertilizer coating, drip, and chemigation through multiple inlet appear to provide improved delivery efficiency of benzobicyclon into the established flood.

Comparison of Max-Ace™ versus Provisia™ Programs

Smith, D.A., Norsworthy, J.K., Piveta, L.B., Avent, T.H., Barber, L.T., and Butts, T.R.

Provisia™ and Max-Ace™ rice, *Oryza sativa* L., are two options available to producers that enable the use of quizalofop for barnyardgrass and weedy rice control among other grass weeds. The Highcard™ formulation of quizalofop is labeled for use on Max-Ace™ rice while the Provisia™ formulated product is labeled for use on Provisia™ rice. Provisia™ and Highcard™ formulations differ in that the later also contains isoxadifen to help safen the herbicide in Max-Ace rice. Weed control and crop tolerance were evaluated at the Rice Research and Extension Center near Stuttgart, Arkansas, to compare Highcard™-based herbicide programs in Max-Ace™ rice to a standard Provisia™ program in Provisia™ rice. For both technologies, long-grain, inbred cultivars were drill-seeded at recommended densities. Both rice technologies included sequential applications of Provisia™ or Highcard™ with

Zurax™ in the first postemergence application and Vopak™ in the second application (preflood). Two additional programs in Max-Ace™ rice included the addition of Zurax™ and Permit Plus™ or Vopak™ and Stam™ at early postemergence and preflood applications, respectively. Provisia™ rice was injured 17% by Provisia™ herbicide at 3 weeks after final treatment (WAFT), whereas rice injury in the Highcard programs ranged from 1 to 6% at the same evaluation. Weedy rice, *Oryza sativa* L., control was greater than 95% in all treatments at 4 WAFT. Barnyardgrass, *Echinochloa crus-galli* (P.) Beauv., control exceeded 99% at 4 WAFT for all herbicide treatments. Rough rice yields were similar among all herbicide treated plots, regardless of rice technology. These findings show that timely applications of Highcard™ in Max-Ace™ rice result in end-of-season weedy rice and barnyardgrass control levels comparable to those in a Provisia™ rice system.

Control of Weedy Rice with Spot Treatment of Clethodim and Glufosinate

Unan, R., Galvin, B., Alvarez, A., and Al-Khatib, K.

Spot-spraying is an herbicide application method which conducting directed sprays using a precise handheld or backpack sprayer with an adjustable nozzle. Spot spraying is especially useful for control to herbicide-resistant weeds, and it greatly reduces the use of chemicals. On the other hand, chemical control of weedy rice (*Oryza sativa* f. *spontanea* Roshev.) is difficult due to the same species of cultivated rice. Spot spraying can be a logical approach for the weedy rice challenge. In preliminary studies in greenhouse, the doses of clethodim and glufosinate, which controlled weedy rice by 90%, were determined as 80 g ai ha^{-1} and 420 g ai ha^{-1}, respectively. In this study, spot spray experiment was carried out at different herbicides doses and at different application times in field conditions. The aim of this study is to evaluate the efficacy of clethodim and glufosinate spot spraying applications in the rice field.

The experiment was conducted on randomized block design with five replications at the Rice Experiment Station, Biggs, CA, in 2022. M209 rice variety was cultivated in the field, the trial was carried out in two locations (North and South Fields). Clethodim and glufosinate were used to control weedy rice in field. Clethodim rate was 0.08% v/v (1×=150 g ai ha^{-1}) and 0.16% v/v (2×=300 g ai ha^{-1}). Glufosinate rate was 0.26% v/v (1×=492 g ai ha^{-1}) and 0.52% (2×=984 g ai ha^{-1}). Clethodim was applied at rice 3-4 leaf seedling stage (BBCH13) and tillering stage (BBCH23), however, glufosinate was applied only at the panicle emergence stage (BBCH52). Backpack sprayer application pressure was set to 75 PSI and application area was 100×50 cm. Herbicide spray volume was 187 L ha^{-1} of water. Observations were taken at application point (100×50 cm application area), first dispersion area (beyond to application point at 0-25 cm), and second dispersion area (beyond the application point 25-50 cm) to determine how far clethodim and glufosinate would spread, and to determine rice injury within those distances.

In the north field, 1× clethodim had 97% and 73 efficacies when applied at the 3-4 leaf stage and tillering stage, respectively. No injury was detected both in first and second dispersion area for 1× application. The 2× application rate of clethodim gave 83% rice injury in the treated area. In terms of dispersion, injury was 7% in first dispersion area, but no injuries were seen second dispersion area in 2× clethodim. Glufosinate gave 100% rice control at panicle emergence stage. Plant injury was 5 and 10% in the first dispersion area, however, no injuries were observed in second dispersion area for 1× and 2× glufosinate rate, respectively.

In the south field, 1× clethodim rate provided 93% and 89% rice injury when applied at the 3-4 leaf stage and tillering stage, respectively. No injury was detected both in first and second dispersion area. The 2× application rate of clethodim gave 93% rice injury. In terms of dispersion, injury was 8% in first dispersion area, but no injuries were seen second dispersion area. All of rates of glufosinate gave 100% rice injury when applied at panicle emergence stage. Plant injury was 5 and 10% in the first dispersion area, but no injuries were reported in second dispersion area for 1× and 2× glufosinate rate, respectively.

In summary, clethodim and glufosinate were successful to control weedy when applied as spot treatment. The efficacy of herbicides was between 73 to 100%, depending on the application time and application dose. Glufosinate was more effective than clethodim. The efficacy of clethodim was decreased when application time was delayed. One of the most important result that both herbicides had little adverse dispersion effects. Even at high spray doses, the dispersion extended up to 15 cm beyond application point and the plant injury was observed up to 10% in first dispersion area. This result indicated that clethodim and glufosinate has a great potential as a spot spray treatment for the management of weedy rice.

Fimbristylis littoralis, an Increasing Issue in South Louisiana Rice Production

Webster, L.C., Williams, J.A., and Arcement, M.P.

Over the past few growing seasons, the amount of inquiries concerning the control of *Fimbristylis littoralis* has grown exponentially. *Fimbristylis* is oftentimes misidentified as rice flatsedge (*Cyperus iria* L.), which leaves many growers in a dilemma later in the growing season. Both *Fimbristylis* and rice flatsedge belong to the cyperaceae (sedge) family; however, chemical control of these two weeds differs greatly.

An on-farm study was conducted in 2022 in Abbeville, Louisiana, to determine the most effective control measures for *Fimbristylis*. The study was a randomized complete block design containing a nontreated check and 15 herbicide treatments replicated four times. Plot size was 1.5 by 5.1 m with water-seeded Provisia 'PVL03' rice at 67 kg ha^{-1}. A natural stand of *Fimbristylis* was present across the entire research area. Herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Each herbicide was applied with the recommended adjuvant at the recommended rate. Visual evaluations for crop injury and *Fimbristylis* control were recorded at 7, 14, 21, and 28 d after treatment (DAT), where 0 = no control and 100 = plant death.

Two herbicides that are commonly used for postemergence control of rice flatsedge in rice production, halosulfuron and florpyrauxifen, provided 0 and 1% control, respectively, of *Fimbristylis* 14 DAT. Of the 15 herbicide treatments evaluated, 2,4-D and triclopyr provided the highest levels of control of *Fimbristylis*. At 14 DAT, 2,4-D applied at 795 and 1,064 g ai ha^{-1} controlled *Fimbristylis* 90 and 99%, respectively, and triclopyr applied at 314 g ai ha^{-1} controlled *Fimbristylis* 98%. A reduction in control compared with 2,4-D and triclopyr was observed for bispyribac applied at 34 g ai ha^{-1}, with 79% control. All other herbicide treatments provided 18 to 54% control of *Fimbristylis* 14 DAT.

Rice Response to Simulated Drift Rates of Reviton

Butts, T.R., Collie, L.M., Barber, L.T., Norsworthy, J.K., Bond, J.A.,
Mangialardi, A., Webster, L.C., Reed, N.H., and Davis, B.M.

Growers in the Mid-South are in constant need of new and improved methods to control early season herbicide-resistant weeds. Reviton (tifenacil) is a new PPO-inhibiting herbicide labeled for burndown applications to assist in creating a weed-free cropping system. However, as burndown applications can be stretched out across a wide range of dates in the Mid-South, there can be a high potential for off-target movement to occur onto emerged crops. As a result, research was needed to determine the effects of simulated drift rates of Reviton to rice (*Oryza sativa*).

In 2022, an experiment was established in Lonoke, Arkansas, and Stoneville, Mississippi, to assess the tolerance of rice to simulated drift rates of Reviton herbicide at two exposure timings. Treatments were arranged in a randomized complete block design with four replications. Simulated drift rates of Reviton were applied at 3.1, 1.55, 0.77, 0.387, 0.194, and 0.096 g ai ha^{-1}. These applications were applied to one leaf rice (EPOST) and three leaf rice (MPOST) with a spray volume of 94 L ha^{-1}. Visual estimations of crop injury were recorded at both locations using a scale of 0 to 100% where: 0% is no visual injury and 100% is complete plant death. Rice was harvested using a plot combine, and rough rice yield was adjusted to 13% moisture and recorded. Data were subjected to analysis of variance and means were separated using Tukey's HSD test at a 5% level of significance.

In Arkansas, rice exposed to the highest rate of Reviton (3.1 g ai ha^{-1}) EPOST resulted in the most visual injury (56%) 7 days after application (DAA) but was reduced to only 13% injury by 30 DAA. Less than 7% injury was observed 21 DAA when rice was exposed to Reviton EPOST at rates less than 1.55 g ai ha^{-1}. No visual injury was observed 50 DAA for all rates at the EPOST timing. Rice exposed to all rates at the MPOST timing exhibited less than 4% injury 7 DAA and there was no visual injury by 21 DAA. In Mississippi, rice exhibited 38% injury 7 DAA when exposed to 3.1 g ai ha^{-1} of Reviton EPOST, while no injury was observed for the rates of 0.194 and 0.096 g ai ha^{-1}. Less than 20% visual injury 7 DAA was observed for all rates of Reviton at the MPOST timing and simulated drift rates less than 1.55 g ai ha^{-1} resulted in less than 5% injury. Rice exposed to all rates of Reviton at MPOST resulted in no crop response 21 DAA. Both locations showed no differences in yield resulting from exposure to simulated drift rates of Reviton herbicide.

At the rates in which rice was exposed in these studies, Reviton appears to cause greater visual injury at higher simulated drift rates when occurring at an early growth stage but rice recovers without yield reduction. Though these experiments suggest that a drift rate of Reviton will not cause lasting damage to rice, appropriate measures should always be taken to reduce off-target herbicide applications.

The ROXY® Rice Production System-2023

Shelton, C.W., Harrell, D.L., and McKenzie, K.S.

Albaugh LLC has partnered with the California Cooperative Rice Research Foundation, Inc. to introduce a new non-GMO herbicide-tolerant rice production system for rice weed control, the ROXY® Rice Production System, (ROXY®RPS). The system will include a patented herbicide tolerance trait, branded herbicides, adapted germplasm, and a production system stewardship program. The ROXY® Trait was recovered by Rice Experiment Station in a quest to bring a herbicide-tolerant rice technology to California rice growers. It is the first grower owned rice trait and will bring performance and value to U.S. rice growers and targeted rice growing markets around the world.

The ROXY trait provides tolerance to the herbicide oxyfluorfen. Albaugh will register and launch two branded herbicides to help manage weeds and weed resistance in rice production. ALB2023 is a 4 lb./gallon AI Flowable formulation that is applied pre-flood and pre-plant in water-seeded rice or applied post plant and pre-flood in drill-seeded rice. ALB2024 is a 2 lb./gallon AI EC formulation that will be applied early post emerge targeting weedy rice infestations and other seedling grasses. These two Albaugh ROXY®RPS Branded herbicides (yet to be named) will be the only EPA registered formulations of oxyfluorfen that can be applied in the ROXY®RPS. The ROXY® herbicide-tolerance trait will be introgressed into regionally adapted varieties/germplasm through conventional breeding methods by licensing agreements. ROXY®RPS grower agreements will include a stewardship program focused on prolonging the use and utility of the production system through use of certified seed and implementing best management practices to help manage and slow the development of resistant weed biotypes.

Eight years of field testing in California including replicated small plot and large-scale field testing in growers' fields have demonstrated the performance of the system as a foundation weed management tool for both water-seeded and drilled rice. ROXY®RPS will provide a Group 14 mode of action for weed resistance management against Group 2 (ALS) & Group 1 (ACCase) resistance. As a pre-plant herbicide, it provides early season control of yield robbing grass and broadleaves weeds and has potential value for weedy rice management. It will serve as a new tool to broaden the Best Management Weed Control Systems in rice production.

The two ROXY®RPS herbicides are being reviewed for registration by EPA and the California Department of Pesticides Regulation with the concurrent release of a California Calrose medium-grain rice cultivar carrying the ROXY® trait.

Abstracts of Posters on Weed Control and Growth Regulation
Panel Chair: Tom Barber

Weedy Rice Size Strongly Impacts Control with Oxyfluorfen

Arnold, C.H., Norsworthy, J.K., Woolard, M.C., and Butts, T.R.

Oxyfluorfen herbicide (ALB2024) is a WSSA group 14 protoporphyrinogen oxidase inhibitor that acts as a contact herbicide when applied postemergence. Oxyfluorfen may offer a control option for weedy rice in the ROXY Rice Production System, but the influence of weed size on effectiveness of the herbicide is not known. In 2021 and 2022, field trials were conducted at the Rice Research and Extension Center in Stuttgart, AR, to determine the effect of weedy rice growth stage on effectiveness of oxyfluorfen over a range of rates. The trial was conducted as a randomized complete block design, with herbicide rate and application timing as factors. The oxyfluorfen (ALB2024) rates tested were 0.56, 1.12, and 1.68 kg/ha (0.5, 1.0, and 1.5 lb ai/acre), applied at the 1-leaf, 2-leaf, 3-leaf, and tillering rice growth stages. Weedy rice control was visibly rated at 14, 21, and 28 days after treatment (DAT). The year by timing interaction and main effect of oxyfluorfen rate were significant for all evaluations. At 14 DAT, the 1-leaf application resulted in the greatest weedy rice control at 85% in 2021 and 84% in 2022, when averaged over rates. As weedy rice size increased, control generally decreased both years, with the lowest control being 58 and 30% in 2021 and 2022, respectively, following the tillering application. Averaged over years and application timings, oxyfluorfen at 0.56, 1.12, and 1.68 kg/ha (0.5, 1.0, and 1.5 lb ai/acre) controlled weedy rice 58, 66, and 72%. These findings clearly show that an early application of oxyfluorfen (AB2024) is critical for suppressing weedy rice and that improvement in control is likely as the herbicide rate increases.

Hybrid Rice Response to Acetochlor with Various Rates of a Fenclorim Seed Treatment

Avent, T.H., Norsworthy, J.K., Piveta, L.B., Arnold, C.H., and Carvalho-Moore, P.

Rice (*Oryza sativa* L.) producers in the United States need effective herbicides to control problematic weeds. Previous research has demonstrated that acetochlor can provide in-season weed control in rice; however, undesirable injury is common. Thus, trials were initiated on a silt loam soil at the Rice Research and Extension Center near Stuttgart, AR, in 2020 and 2021 to evaluate a dose-response of a fenclorim seed treatment ranging from 0 to 5 g ai kg^{-1} of seed with and without a microencapsulated acetochlor formulation. For both years, acetochlor was applied delayed-preemergence at 1,260 g ai ha^{-1} (4 to 7 days after planting). The two hybrid rice cultivars RT 7231 FP and RT 7521 FP did not differ in response to either the seed treatment or acetochlor. In the absence of acetochlor, the fenclorim seed treatment caused less than 10 and 5% injury in 2020 and 2021, respectively. In the presence of acetochlor, the fenclorim seed treatment rate of 2.5 g ai kg^{-1} reduced rice injury and increased rice plant heights and shoot numbers relative to acetochlor without fenclorim. Additionally, the same fenclorim rate with acetochlor provided comparable heights and shoots to the nontreated control in all evaluations. Acetochlor or fenclorim did not influence rough rice yield for both cultivars. Based on the results of these studies, the fenclorim seed treatment rate at 2.5 g ai kg^{-1} of seed provided the most consistent safening response for hybrid rice tolerance to the microencapsulated formulation of acetochlor.

Rice Herbicides Coated on Urea: Is It an Effective and Safe Option?

Carvalho-Moore, P., Norsworthy, J.K., Avent, T.H., Arnold, C.H., Pritchett, S., and Piveta, L.B.

The herbicide Loyant (florpyrauxifen-benzyl) was launched in 2018 as a new option to control barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] in rice fields. Off-target movement from aerial applications of this herbicide was observed in adjacent fields and became a serious concern to row crop growers across Arkansas. Strategies to minimize this movement are highly sought, and the objective of this study was to evaluate rice tolerance and weed control efficacy when Loyant or Novixid, a mixture of florpyrauxifen-benzyl with penoxsulam, were coated on urea in comparison to foliar applications. The experiment was conducted in tubs filled with silt loam soil in 2022 in Fayetteville, Arkansas. These tubs were organized as a two-factor factorial in a completely randomized design with three replications. Factor A was the two different herbicides (florpyrauxifen-benzyl or florpyrauxifen-benzyl + penoxsulam). Factor B was the application method: coated on urea or foliar. A nontreated control was included for comparison. Percentage control of yellow nutsedge (*Cyperus esculentus* L.), barnyardgrass, and hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], as well as rice (*Oryza sativa* L.) injury, were rated at three weeks after treatment. Rice had 8% injury when coated on urea, which was lower than foliar applications (53%), averaged over herbicides. Hemp sesbania control did not differ among treatments. Barnyardgrass control was significantly reduced when the herbicides were coated on urea. Florpyrauxifen-benzyl alone coated on urea resulted in lower yellow nutsedge control (33%) compared to the other treatments tested (80 to 96%). Coating florpyrauxifen-benzyl or its combination with penoxsulam on urea is a safer option for aerial applications in rice fields near row crop fields. However, the control of some weeds, such as barnyardgrass, might be compromised, and additional herbicides will likely be needed throughout the season.

Efficacy of Florpyrauxifen-Benzyl-Coated Urea on Key Rice Weeds

Castner, M.C., Norsworthy, J.K., Cotter, B.L., and Butts, T.R.

Following the commercial launch of Loyant® (florpyrauxifen-benzyl) in 2018, instances of off-target movement of the herbicide were prevalent from aerial applications made to rice (*Oryza sativa* L.) onto adjacent soybean [*Glycine max* (L.) Merr.]. Aerial applicators can save on application costs and limit herbicide drift by coating herbicides onto urea prills. A field experiment was conducted at the Arkansas Rice Research and Extension Center near Stuttgart, AR, in 2020, and at the Pine Tree Research Station, in 2021, to determine if coating florpyrauxifen-benzyl (30 g ae ha^{-1}) and a florpyrauxifen-benzyl plus penoxsulam mixture (24 g ae ha^{-1} and 41 g ai ha^{-1}, respectively) on urea compromised weed control on aquatic and sedge weed species as opposed to a foliar spray of the two respective herbicides. All applications were made at the preflood timing and flooded 24 hours after treatment. Visible control of California arrowhead (*Sagittaria montevidensis* Cham. & Schltdl.), ducksalad [*Heteranthera limosa* (Sw.) Willd.], rice flatsedge (*Cyperus iria* L.), and yellow nutsedge (*Cyperus esculentas* L.) was evaluated at 28 and 35 days after treatment (DAT). Both herbicides provided comparable levels of control on all evaluated weeds; however, application method impacted efficacy on all species. Excluding ducksalad, for all weed species and both rating dates, a foliar spray outperformed herbicide-coated urea. However, effective control (>95%) of ducksalad and rice flatsedge were obtained with the florpyrauxifen-benzyl-coated urea. Depending on the weed species present, coating could be an economical and effective option for producers managing ducksalad or herbicide-resistant rice flatsedge populations.

Effect of Cover Crops on Palmer Amaranth Emergence in a Furrow-Irrigated System

King, T.A., Norsworthy, J.K., Souza, M.C., Carvalho-Moore, P.,
Zaccaro-Gruener, M.L., Barber, L.T., and Butts, T.R.

With an increased adoption of the furrow-irrigated rice system in Arkansas, additional herbicide applications may be needed to combat Palmer amaranth due to the extended germination period provided in the absence of a sustained flood. In crops such as soybean and cotton, cover crops have been proven effective in reducing Palmer amaranth emergence, lessening the selection for herbicide resistance. In 2022, a field trial was conducted at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR, to determine the effect of cover crops on total Palmer amaranth emergence and rough rice yield. The cover crops in the study included none, cereal rye, wheat, Austrian winter pea, and hairy vetch, all seeded at recommended rates. Cover crops were terminated on April 22, 2022, and rice was planted on May 13, 2022. Biomass, including weeds in plots, present at rice planting totaled 248, 512, 620, 408, and 824 g/m^2 for none, hairy vetch, Austrian winterpea, wheat, and cereal rye, respectively. Wheat and cereal rye failed to reduce the total seasonal Palmer amaranth emergence relative to the no cover crop treatment. Palmer amaranth emergence in both legume cover crops, hairy vetch and Austrian winterpea, was statistically greater than for both cereal cover crops. Rough rice yields were similar among treatments, ranging from 6,660 to 8,680 kg/ha. Findings from this research fail to show a weed control benefit for the evaluated cover crops in rice. Research should be conducted across additional site years to provide greater confidence in the results observed here.

Nozzle Selection and Row Width Impact on Spray Coverage and Weed Control in Flooded Rice

Reed, N.H., Butts, T.R., Norsworthy, J.K., Hardke, J.T., Barber, L.T., Bond, J.A., Bowman, H.D., Davis, B.M., Dillon, T.W., Arnold C.H., and Kouame, K.B.J.

Weeds in Mid-south rice production are more problematic every year. Integrated weed management strategies including cultural methods must be incorporated to better control these pests. Some strategies that are often overlooked are manipulation of drill row width spacing and optimization of herbicide applications, specifically through nozzle type selection. As a result, the objective of this experiment was to evaluate the impact of drill row width spacing and nozzle selection on spray coverage and weed control in flooded rice. A field experiment was conducted in 2021 and 2022 at Lonoke, Pine Tree, and Rohwer, AR, as a randomized complete block split-plot design. The rice was drill-seeded in four row widths (13-cm, 19-cm, 25-cm, and 38-cm) as the whole plot factor. Two herbicide applications (PRE and preflood) were made using common commercially available rice herbicides with five nozzle types [XR, AIXR, and TTI, (single-fan nozzles); TTI60 and AITTJ60 (dual-fan nozzles)] as the subplot factor. BYG density was assessed at the 5- to 6-leaf rice stage (preflood) and preharvest. Water sensitive cards were sprayed preflood and collected to assess spray coverage of each nozzle type using DepositScan from the USDA-ARS. All data were analyzed using JMP Pro 16.1 and subjected to ANOVA using Tukey's HSD (P=0.05). Regardless of response variable or location, no interaction was observed between drill width spacing and nozzle type. Across locations and years at the 5- to 6-leaf rice stage and preharvest stage, there was a 66% decrease in barnyardgrass (BYG) density from the 13-cm spacing compared to the 38-cm spacing. The XR and AIXR nozzles had a 25% greater spray coverage than the TTI, TTI60, and AITTJ60. No increase in coverage was observed from dual-fan nozzles compared to single-fan counterparts. Narrower drill row width of 13-cm produced greater weed control than the widest 38-cm spacing, and the smaller droplet-size producing nozzles provided better spray coverage than the larger droplet-size producing nozzles. Mid-south rice producers could enhance their weed management efforts through the reduction of drill row width spacing to 13-cm and selection of an appropriate nozzle type such as the AIXR when making ground-applied herbicide applications.

A Fenclorim Seed Treatment Does Not Adequately Safen Rice to Foliar-Applied Metolachlor

Noe, S.C., Norsworthy, J.K., Avent, T.H., Souza, M.C., Barber, L.T., and Butts, T.R.

Overlapping residual herbicides in rice production systems is an important aspect of season-long weed control. At a time when herbicide-resistance in problematic weeds such as barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and Palmer amaranth [*Amaranthus palmeri* (S.) Wats.] continue to contribute to yield losses in rice, the need for additional herbicides is paramount. Metolachlor is a WSSA Group 15 herbicide that provides residual control for both grasses and small-seeded broadleaves. An experiment was conducted in the Spring of 2022 at the Pine Tree Research Station to evaluate the tolerance of fenclorim-treated rice to foliar applications of metolachlor. Applications of clomazone and pendimethalin were made in each treatment as a baseline residual program, followed by various rates of metolachlor (560 or 1,121 g ai ha^{-1}) and propanil at an early-post application timing. Injury to rice was evaluated throughout the season after the early-post application was made. Yield was evaluated compared to the average of the nontreated plots to determine a relative percentage. In terms of injury to rice, the standard treatment of clomazone and pendimethalin showed less than 5% injury at any given time, while the highest rate of metolachlor resulted in up to 48% injury. When propanil was combined with a high rate of metolachlor, injury to rice was not significantly different when compared to metolachlor alone. However, with a low rate of metolachlor in combination with propanil, injury to rice was below 15% and did not statistically separate from the standard program. Relative yield showed a similar trend to injury with the highest rate of metolachlor yielding only 80% compared to the standard program which was greater than 100%. The implications of these findings show that fenclorim-treated rice is not tolerant to foliar applications of metolachlor.

Evaluation of Benzobicyclon Tank-Mixes for Post-Flood Control of Annual Grasses in Drill-Seeded Rice

Pritchett, S.L., Norsworthy, J.K., Carvalho-Moore, P., Arnold, C.T., Arnold, C.H., Barber, L.T., and Butts, T.R.

Benzobicyclon is a 4-hydroxyphenylpyruvate dioxygenase inhibitor that controls both broadleaf and grass weeds. Benzobicyclon is currently labeled for use in dry-seeded and water-seeded rice and can be mixed with other herbicides to broaden spectrum of control. This experiment aimed to evaluate the level of control from benzobicyclon when paired with certain tank-mix partners for control of annual grasses in drill-seeded rice.

The experiment was initiated on April 30, 2022, at Rice Research and Extension Center near Stuttgart, Arkansas. The design was a two-factor randomized complete block with four replications. Benzobicyclon was applied at 0, 247, and 371 g/ha alone or with penoxsulam at 35 g/ha, cyhalofop at 280 g/ha, imazamox at 44 g/ha, fenoxaprop at 87 g/ha, quinclorac at 289 g/ha, and florpyrauxifen-benzyl at 29 g/ha. Each benzobicyclon rate with each herbicide was compared to the efficacy of each herbicide alone to determine whether benzobicyclon improved control. The control of three grasses, barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster], and large crabgrass [*Digitaria Sanguinalis* (L.) Scop] was evaluated at 2, 3, and 4 weeks after treatment (WAT). Visible control estimates of each weed species were rated (0-100%). Rough rice yield was harvested at crop maturity.

Overall, weed control in the trial was low because complete herbicide programs were not utilized, weeds were large at application, and the grass spectrum evaluated was not highly sensitive to benzobicyclon. For each evaluation and weed species, the addition of benzobicyclon at 247 or 371 g/ha did not improve control over the corresponding herbicide alone. Surprisingly, rough rice yields in benzobicyclon-treated plots in combination with imazamox or florpyrauxifen-benzyl were greater than with the later herbicides alone. On no occasion did the addition of benzobicyclon to other herbicides reduce rough rice yields. The lack of improved control with addition of benzobicyclon to the evaluated herbicides is not surprising because benzobicyclon alone provided no control and is not highly active on the grass weed species evaluated. Future research should examine combinations with benzobicyclon targeting sprangletop species due to the high level of control of this weed with the herbicide alone.

Weed Control in Roxy Rice Using Oxyfluorfen Alone and with Clomazone or Quinclorac

Smith, T., Norsworthy, J.K., Arnold, C.H., Arnold, C.T., and Butts, T.R.

Barnyardgrass is the most problematic weed in Arkansas rice production systems. Barnyardgrass control has become difficult for rice producers due to the evolution of resistance to multiple herbicide modes of action. Oxyfluorfen is a WSSA group 14 herbicide which is currently not labeled in rice. Oxyfluorfen could provide rice producers another option for barnyardgrass control in a Roxy Rice Production System. In 2021 and 2022, field trials were conducted at the Rice Research and Extension Center near Stuttgart, AR, to evaluate postemergence barnyardgrass control with oxyfluorfen (ALB2024) when following applications of clomazone, oxyfluorfen (ALB2023), and quinclorac. Quinclorac, clomazone, and oxyfluorfen alone were applied preemergence at 0.356, 0.3, and 1 lb ai/A, respectfully. Additional preemergence treatments included clomazone and quinclorac mixed with oxyfluorfen. All preemergence treatments were followed by a postemergence application of oxyfluorfen (0.5 lb ai/A; not to exceed 1.5 lb ai/A) and methylated seed oil at the 2-leaf growth stage of rice. At 2 weeks after the preemergence applications in 2021, clomazone and quinclorac alone provided 93% control of barnyardgrass, which was comparable to the 96% control provided by oxyfluorfen. Quinclorac + oxyfluorfen and clomazone + oxyfluorfen provided 99 and 97% control, respectively. At 2 weeks after the postemergence application in 2021, all treatments provided greater than 96% barnyardgrass control and greater than 99% control in 2022. By 10 weeks after the postemergence application, clomazone + oxyfluorfen and quinclorac + oxyfluorfen provided comparable barnyardgrass at 93% both year years. When clomazone and quinclorac were applied alone, barnyardgrass control at 10 weeks after treatment was 88% with both herbicides in 2021 compared to 82% control with oxyfluorfen alone in 2021. The combination of quinclorac + oxyfluorfen and clomazone + oxyfluorfen resulted in 93% barnyardgrass control 10 weeks after application in 2022. This research shows that oxyfluorfen would be an effective option for barnyardgrass in the Roxy Rice Production System, but mixing it with clomazone or quinclorac would be preferred over applications of oxyfluorfen alone.

Do Rice Cultivars Differ in Tolerance to Preemergence-Applied Fluridone?

Souza, M.C., Norsworthy, J.K., Piveta, L.B., Arnold, C.H., Woolard, M.C., Barber, L.T., and Butts, T.R.

Alternative modes of action are needed to control problematic weeds in rice due to the development of resistance to herbicides. Fluridone has been used in cotton production systems, providing good weed control when applied preemergence. Preliminary research showed that fluridone might be a valuable addition to weed control programs in rice. This study aimed to assess the tolerance of 12 rice cultivars to fluridone applied preemergence. The experiment was conducted at the Pine Tree Research Station in 2022, and it was organized as a two-factor factorial with four replications. Factor A was cultivars, and the following cultivars were tested: CLL15, CLL16 (Clearfield®), RT7321 FP, RT7521 FP (FullPage®), PVL03 (Provisia®), RTV7231 MA (Max-Ace®), DG263L, Diamond, Titan, Jupiter, Lynx, and XP753 (conventional). Factor B was the fluridone rate. The herbicide was applied preemergence at 0, 168, and 336 g ai/ha. Visible injury was rated, and yield was collected at harvest (kg/ha). At the highest fluridone rate, the cultivar Lynx demonstrated the highest injury levels while the cultivar RTv7321MA showed the lowest level. The cultivars XP753 at the fluridone rates of 0 and 168 g ai/ha and the cultivar RT7321 FP in the absence of fluridone obtained the highest yield. Except for the cultivar PVL03, the highest fluridone rate of 336 g ai/ha led to lower yields in comparison to corresponding checks. There were significant differences among fluridone rates, with the higher rate negatively impacting grain yield. No yield penalty was observed among the cultivars when fluridone was applied at 168 g ai/ha. These findings show that there may be potential for fluridone use preemergence in rice at 168 g ai/ha, but higher rates are unlikely due to the increased risk for injury.

Efficacy of Salvage Treatments Following Simulated Failed Herbicide Applications for Barnyardgrass (*Echinochloa crus-galli*) Control in Rice

Whitt, D.R., Bowman, H.D., Bond, J.A., Burrell II, T.D., Eubank, T.W., and Mangialardi, G.A.

Due to herbicide resistance, barnyardgrass has become increasingly difficult to control in rice (*Oryza sativa*). Residual herbicides such as clomazone may be utilized preemergence (PRE) for barnyardgrass control; however, with multiple-resistant populations, postemergence (POST) herbicide options have become limited. Florpyrauxifen-benzyl was commercialized in 2018 to target barnyardgrass and aquatic or broadleaf weeds. A field study was conducted from 2019 to 2021 in Stoneville, MS, to evaluate barnyardgrass control with florpyrauxifen-benzyl treatment following simulated failure treatments of POST rice herbicides. The study was designed as a randomized complete block with a two-factor factorial treatment structure and four replications.

Factor A consisted of initial herbicide treatments included no herbicide and half rates of imazethapyr, quinclorac, bispyribac-Na, and propanil to simulate failed herbicide applications. Factor B was sequential applications at 0, 7, or 14 d after the initial herbicide treatments, which included florpyrauxifen-benzyl at 0 and 30 g ai ha^{-1}. Data were subjected to ANOVA using the PROC GLIMIX procedure in SAS v. 9.3 with site year and replication (nested within site year) as random effects. Estimates of the Least Square Means at 5% significance level were used for mean separation. An interaction of initial herbicide treatment and sequential florpyrauxifen-benzyl timing was detected for barnyardgrass control 21 d after final treatment (DAFT). While no differences in barnyardgrass control 21 DAFT were detected whether florpyrauxifen-benzyl was applied 7 or 14 d after initial (DA-I) application of any herbicide utilized, ≥80% control was only achieved when florpyrauxifen-benzyl application was delayed 14 DA-I application. These data suggested that florpyrauxifen-benzyl application should be delayed 14 d after a herbicide failure.

Rice Response to Low Concentrations of Diflufenican

Woolard, M.C., Norsworthy, J.K., Piveta, L.B., Souza, M.C., Barber, L.T., and Butts, T.R.

Diflufenican (DFF) is a group 12 herbicide that can help control herbicide-resistant Palmer amaranth in soybean. In the United States, there are no group 12 herbicides labeled for use in soybean production, which would make DFF unique. Although DFF is targeted for use in soybean, additional research was needed to evaluate the sensitivity of rice, a crop commonly grown in rotation with soybean in Arkansas. Therefore, an experiment was conducted in 2022 at the Rice Research and Extension near Stuttgart, AR, to determine rice sensitivity to soil-applied DFF. Applications of DFF were applied preemergence at 0.0065, 0.0125, 0.25, 0.50, and 1.0 times the anticipated labeled rate of 120 g ai/ha for a silt loam soil. At the highest rate of DFF, rice injury was 20% at 7 days after emergence (DAE) and lessened as the herbicide rate declined. Rice stand counts taken 7 DAE did not differ among DFF rates, and all emerged rice plants had recovered to <5% injury by 28 DAE. Rough rice grain yield was collected at maturity, and no statistical differences occurred among treatments. Future research should determine whether low concentrations of DFF could potentially injure other commonly grown rotational crops. If DFF is labeled for use in U.S. soybean production, there does not appear to be a high risk for carryover into rice sufficient to cause substantial injury and negatively affect the crop based on this single site year of data.

Viability and Dormancy of Weedy Rice over the Winter: Impacts of Soil Moisture and Burial Depth

Brim-DeForest, W.B., Guan, T., Clark, T., and Espino, L.

Non-chemical controls are the main tools we have to control weedy rice (*Oryza sativa* spp.) in California. Cultural controls, including winter flooding and zero fall tillage, have been proposed as management techniques but have not previously been tested. This experiment compared winter flooding versus ambient conditions and seeds that remain at the soil surface (simulating zero fall tillage) versus seeds buried at about 6 cm of depth (simulating fall tillage). It took place outdoors over the winter (October through March) at a fenced site on Colusa County property, in Colusa, CA.

It began in the fall of 2019 and the first year finished in the spring of 2020. It was repeated in the winter of 2020 through the spring of 2021, as well as 2021-2022. Homogenized rice-field soil was placed about 6 inches deep into the tubs. One hundred seeds each of weedy rice biotypes 1, 2, 3, and 5 were placed in mesh bags. M-206, a widely grown California medium-grain variety, was utilized as a control. Bags were removed at 1-month intervals, and removed seeds were placed in an incubator at 30ºC as soon as they were removed from the soil. Germination counts were taken at 7 days and 14 days after placement in the incubator. At 14 days, any seeds that had not germinated were assessed for viability and dormancy. The remaining seeds were gently pressed, and if seed contents evacuated from the seed coat, seeds were rated as "dead.' Seeds that did not evacuate from the seed coat were cut in half (lengthwise) and placed in a solution of 1% Tetrazolium. Approximately 24 hours after placement in the solution, seeds were evaluated for staining of the embryo. If the embryo was stained red, seeds were assumed to be viable. Seeds that were still viable after 14 days of incubation, and had not germinated, were assumed to be "dormant."

Over the 3 months, there was an increase in death (mortality) as well as an increase in seed dormancy and a decrease in germination. Some of the seeds (Type 5 and M-206) pre-emerged before removal from the soil in the control treatments. For mortality at the end of the 3 months, shallowly buried seeds (seeds near the soil surface), had greater mortality than seeds that were buried, across both treatments as well as across both biotypes. Type 3 had the lowest mortality rate, which means that most of the seed was either viable or dormant. This correlates well with what we have seen of Type 3's persistence in the field (some fields have been infested for 10 or more years). For Type 1 and Type 5, non-flooded (ambient) conditions proved to be most effective at causing mortality, whereas, for the other types (Type 2 and 3), there were no large differences between the flooded and control treatments. Evidence from the southern United States found that weedy rice seeds under flooded winter conditions showed greater mortality than those under ambient conditions. The difference between the two locations could be due to winter rains which are typical in California, so even fields that are not purposefully flooded are often waterlogged.

Survey of Weedy Rice Infestation and Severity in California Rice Fields

Clark, T., Baez, C., Brim-DeForest, W., and Espino, L.

After several decades without reports of weedy rice, a weedy rice biotype was found infesting rice fields in Colusa and Glenn counties in 2003. Over the next 10 years, reports of infestations were sporadic and not well documented. In 2016, five more biotypes were found infesting over 4,000 ha of rice fields in eight counties. By 2019, weedy rice was present in over 100 fields, totaling 5,600 ha. Because this weed constitutes a serious threat to the rice industry in California, a survey of infested fields was conducted in 2020 and 2021 so that baseline infestation data is available to the industry. Over 4,000 ha of rice were inspected, identifying infested basins within each field, their acreage, infestation severity, and weedy rice biotype. Infestation severity was rated using a system that ranged from 0 to 6, with 0 being the absence of weedy rice, and 6 being 25% or more of the basin infested

Of the total surveyed acres, 1,373 ha constituted basins confirmed to be infested with weedy rice. Most infestations were rated not higher than level 3 and only 16% of infested acres were rated as level 4 or higher. Biotype 1 was most common (70% of the basins) followed by biotype 2 (20%). Of the total area surveyed, no basins were found to contain biotype 5. The survey showed that some biotypes are geographically aggregated. Type 3 is found only in the northwest part of the Sacramento Valley, while type 2 is found mostly in the southeast. The survey also showed that type 3 infestations have not expanded but the type is still present in some of the fields identified in 2003, confirming its persistence and weediness. Type 4 is only found in one field, but it has persisted there for more than 5 years. Type 1 is the most widely distributed, and it is present across the Sacramento Valley and in some locations of the San Joaquin Valley. Coincidentally, type 1 is the most difficult type to identify and has very strong weedy characteristics.

Rice Tolerance to Postemergence Applications of Herbicides Mixed with Fluridone

Godar, A.S., Norsworthy, J.K., Souza, M.C., Piveta, L.B., Barber, L.T., and Butts, T.R.

Fluridone is being evaluated as a potential rice herbicide for the mid-southern United Stats. It has activity on a range of annual grasses and small-seeded broadleaf weeds. A field experiment was conducted in 2022 at Pine Tree Research Station near Colt, Arkansas, to evaluate the tolerance of rice to early postemergence applications of fluridone when mixed with other rice herbicides: bispyribac-sodium, fenoxaprop-p-ethyl, penoxsulam, propanil, quinclorac, quizalofop, or saflufenacil. Treatments of fluridone alone or fluridone mixed with these herbicides were applied to 2- to 3-leaf rice. The experiment was conducted on Max-Ace® (quizalofop-resistant) rice, and all plots were treated with clomazone (preemergence) followed by quizalofop (preflood) for weed control. Fluridone was applied at a rate of 168 g ha^{-1}, and all other herbicides were applied at the recommended rate. The experiment was arranged in a randomized complete block design with four replications. Data were collected for injury 7, 21, and 35 days after fluridone application (DAT) and for crop yield at maturity.

Injury from rice herbicides in the absence of fluridone ranged from 7% (with fenoxaprop-p-ethyl) to 79% (with saflufenacil) 7 DAT. Fluridone alone caused an average of 7% injury 7 DAT. When mixed with rice herbicides, fluridone caused little to no additional crop injury 7 DAT, except when mixed with bispyribac-sodium, penoxsulam, or quinclorac, (8, 13, or 6 percentage point additional injury, respectively). Except for saflufenacil, the injury from all treatments disappeared by 35 DAT. On average, 5% of the injury was still present in rice with saflufenacil treatment 35 DAT, regardless of the presence or absence of fluridone as a mix partner. Fluridone when mixed with saflufenacil increased crop yield by 25% compared to the stand-alone application of saflufenacil, indicating that fluridone as a mix partner may help reduce potential crop yield loss from early postemergence application of saflufenacil. Fluridone did not cause any significant positive or negative response in crop yield when mixed with other rice herbicides. Based on this single study, fluridone may offer flexibility as a mix partner for early postemergence weed control in drill-seeded rice on a silt loam soil.

Response of Selected *Glutathione-S-Transferase* Genes in Rice to a Fenclorim Seed Treatment and Exposure to Acetochlor

González-Torralva, F., Norsworthy, J.K., and Avent, T.H.

Fenclorim has been demonstrated in previous research to safen rice (*Oryza sativa* L.) to acetochlor. Information regarding the role of *glutathione-S-transferases* (*GST*s) in rice treated with fenclorim under acetochlor treatment is still unknown. In this research, seeds treated with fenclorim (2.5 g ai kg^{-1}) under acetochlor treatment (1,050 g ai ha^{-1}) were used to quantify the expression levels of *GST*s relative to *actin* gene. A total of nine specific *GST*s were evaluated. Preliminary results have demonstrated that at 24 h after acetochlor treatment, differences in gene expression exists between seedlings with and without fenclorim. Genes *GSTF2*, *GSTF5*, *GSTF12*, and *GSTU35* were up-regulated in rice seedlings with fenclorim. However, other *GST* genes (e.g., *GSTU16*) showed no alteration in gene expression in either seedlings with and without fenclorim. Interestingly, gene expression in *GSTL1* was approximately 2-fold lower in seedlings with fenclorim compared to that without fenclorim. Further experiments are needed to fully understand the role of these *GST*s on safening of rice to acetochlor when using fenclorim.

Responses of Multiple-Resistant Barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] to Cyhalofop-butyl and Florpyrauxifen-benzyl

Hwang, J.I., Norsworthy, J.K., Piveta, L.B., Barber, L.T., and Butts, T.R.

Cases for herbicide resistance evolution in barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] which is the most troublesome species in rice production have been globally reported for several decades. In 2018 to 2019, >300 barnyardgrass seed samples were collected from the mid-southern USA rice fields where the weed survived herbicides.

Offspring from these samples were evaluated for resistance to seven rice herbicides having different modes of action, and then three putative-resistant biotypes (R1, R2, and R3) to both florpyrauxifen-benzyl (FPB) and cyhalofop-butyl (CyB) were selected for dose-response experiments to characterize the herbicide resistance. The dose-response experiment was conducted by evaluating reduction in biomasses of susceptible (S) and resistant barnyardgrass biotypes following treatment of FPB alone, CyB alone, or a formulated premix (PM) of both herbicide active ingredients. The biomass reduction results were used to calculate the herbicide dose rates giving 50% plant responses (ED_{50}) of each biotype, and resistance-to-susceptibility (R/S) ratios were obtained by comparing the ED_{50} values between S and R biotypes. R/S ratios following treatment with FPB alone were the highest for R2 (150) biotype, followed by R3 (100) and R1 (50) biotypes. Similarly, R/S ratios following treatment with CyB alone were higher in the order of R2 (21), R3 (18), and R1 (7) biotypes. Treatment with PM reduced the R/S ratio of R1 (12) and R2 (7) biotypes. However, the R/S ratio of the R3 biotype (214) significantly increased by the PM treatment, which indicates the potential that the mixed use of CyB and FPB can cause an antagonism in barnyardgrass for some cases. Further studies are needed to investigate mechanisms of herbicide resistance evolution in R biotypes and causes of antagonism in the R3 biotype.

Herbicide-Coated Urea Efficacy in U.S. Midsouth Rice

Kouame, K.B.J., Butts, T.R., Davis, B.M., Collie, L.M., Dillon, T.W., Reed, N.H.,
Norsworthy, J.K., and Barber, L.T.

An integrated weed management approach is crucial under the current conditions of herbicide resistance evolution. Among the best management practices is the use of multiple herbicide modes of action (MOAs) that are effective against the most troublesome weeds or those most prone to herbicide resistance. At the same time, the use of auxin mimic herbicides such as florpyrauxifen-benzyl for the control of these weeds has raised multiple herbicide drift injury concerns to neighboring sensitive vegetation and crops. Therefore, strategies that can help maintain a good level of weed control while mitigating herbicide drift concern are essential. Understanding the impact of fertilizer-coating with different herbicides on weed control can improve herbicide application decisions. Field experiments were conducted in 2022 at the University of Arkansas at Pine Bluff Small Farm Outreach Center near Lonoke, AR, to evaluate the impact of coating fertilizer with herbicides on weed control efficacy. The first study consisted of three herbicide programs [florpyrauxifen-benzyl (Loyant), a premixture of florpyrauxifen-benzyl + penoxsulam (Novixid), a tank-mixture of halosulfuron (Permit) + florpyrauxifen-benzyl (Loyant)] applied either as directly coated on urea or sprayed foliarly following urea application, leading to a total of six treatments. Urea (46%), Loyant, Novixid, and Permit were applied at 77,300, 29.3, 65, and 15.8 g ai/ha, respectively. A nontreated control that received an application of urea was also included for weed control evaluation purpose. In a second study, the effect of coating urea with the 4-hydroxyphenylpyruvate dioxygenase-(HPPD-) inhibiting herbicide benzobicyclon (Rogue^{SC}) was evaluated for weed control. Benzobicyclon sprayed versus coated on urea was applied preflood, flood, or post-flood (2 weeks after flood) at 381 g ai ha^{-1}. In the first study, barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and rice flatsedge (*Cyperus iria* L.) control were affected by treatments at 7, 14, and 22 DAA while yellow nutsedge (*Cyperus esculentus* L.) and hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh] control were affected only at 7 DAA. In most cases, Novixid sprayed foliarly and Novixid-coated urea provided similar levels of control of barnyardgrass, rice flatsedge, yellow nutsedge, and hemp sesbania control. In the second study, hemp sesbania and sprangletop (*Diplachne* spp) control were numerically improved with herbicide programs applied at flood. Also, benzobicyclon-coated on urea at flood provided numerically greater control of both weeds, 15 and 29 days after flood, than did the herbicide when sprayed. As a result, Novixid-coated and Rogue^{SC}-coated fertilizer may be viable options to maintain high levels of weed control on some of the most problematic Arkansas rice weeds, while mitigating off-target herbicide movement.

Evaluation of Pyraclonil in an Herbicide Program Approach in California Water-Seeded Rice

Lombardi, M.A., Lynch, M.J., Reyes, S., and Al-Khatib, K.

A limited list of available herbicides and an increase of herbicide-resistant weed populations provides a challenge for California rice growers. The development of pyraclonil, a new broad-spectrum herbicide, can help California rice growers control weeds and retain their high yields. Pyraclonil is a PPO inhibiting herbicide with no evidence of resistant weeds in California rice fields. This 2022 pyraclonil trial was conducted at the Rice Experiment Station in Biggs, California, with a randomized complete block design with three replications.

The objective of the trial was to evaluate the efficacy of seven pyraclonil herbicide programs, a treatment of pyraclonil applied alone, and an untreated check for comparison. Partner herbicides used with the base application of pyraclonil included propanil, benzobicyclon plus halosulfuron, clomazone, thiobencarb, bispyribac-sodium, penoxsulam, and florpyrauxinfen-benzyl applied at their respective timing and rate stated on the label. In each of its applications, pyraclonil was applied on day of seeding at a rate of 0.299 kg/ha (0.267 lb a.i./acre). Weed control was rated at 14, 28, and 42 days after seeding. Response was rated at 7, 14 and 21 days after treatment. Grain yield and moisture were determined at harvest. ANOVA was used to analyze data and means were separated using LSD (p=0.05).

Pyraclonil herbicide programs effectively controlled watergrass (*Echinochloa* spp.), ricefield bulrush (*Schoenoplectus mucronatus*), smallflower umbrella sedge (*Cyperus difformis)* and ducksalad (*Heteranthera limosa)*. Although this year's treatments of pyraclonil program showed significant crop injuries of stunting, stand reduction, and minimal chlorosis, these injuries could have been a result of abiotic factors, specifically colder weather during the first week of planting. The rice later nearly fully recovered at 28 days after treatment. Yields were measured for all treatments; the highest preforming treatment was treatment 4 with an average yield of 9,629 kg/ha (8,591 lb/ac) compared to the untreated control's 3755 kg/ha (3,350 lb/ac). This season's study showed pyraclonil is a promising herbicide for weed control in California water-seeded rice cropping systems.

Impact of Early Season Applications of Dicamba on Rice

Piveta, L.B., Norsworthy, J.K., Castner, M.C., Avent, T.H., Arnold, C.H., and Smith, T.

Dicamba, a synthetic auxin herbicide, is currently labeled in Arkansas for weed control in Roundup Ready Xtend® and XtendFlex® soybean, XtendFlex® cotton, corn, grain sorghum, pasturelands, and non-crop systems. Research conducted in the Midsouth has shown that when timely and accurately applied, dicamba alone or in mixture with other herbicides can control key glyphosate-resistant broadleaf weeds such as Palmer amaranth [*Amaranthus palmeri* (L.) Watson]. In fact, dicamba could potentially serve as an additional herbicide for broadleaf weed control in rice if proven safe to the crop. A field trial was implemented in 2021 at the Rice Research and Extension Center near Stuttgart, AR, to determine the level of rice tolerance to early season applications of dicamba. Dicamba at 560 (1X) and 1120 g ae ha^{-1} (2X) was applied at three timings (preemergence, 1-leaf stage of rice, and 5-leaf stage of rice). At 2 weeks after application, the preemergence application of dicamba at a 1 and 2X rate resulted in 71 and 91% injury to rice, respectively. The injury observed from the preemergence application was partly a result of delayed emergence as evident by stand counts being 17 and 36% less than the nontreated for the 1 and 2X rates of dicamba, respectively, at 3 weeks after treatment. Injury to rice caused by dicamba deceased as applications were delayed, as evident by there being only 39 and 48% injury 2 weeks after applying dicamba to 1-leaf rice at the 1 and 2X rates, respectively. Injury to 5-leaf rice 2 weeks after treatment caused by the 1X rate of dicamba was 8% and was 12% when applied at a 2X rate. By 4 weeks after flooding, rice recovery from the earlier herbicide application was apparent with <3% injury observed, except for the 2X rate of dicamba applied preemergence or at the 1-leaf stage of rice. Even though dicamba has been registered in some crops for more than 60 years, it has never been registered in rice likely because of the negative effect of the herbicide on the crop as seen in this research.

Tank-Mix Options with Highcard™ for Weedy Rice Control

Smith, D.A., Norsworthy, J.K., Piveta, L.B., Barber, L.T., and Butts, T.R.

Weedy rice, *Oryza sativa* L., continues to be a problematic weed in Arkansas rice, *Oryza sativa* L., fields. Max-Ace™ rice varieties are tolerant to Highcard™, quizalofop-P-ethyl. Research was conducted at the Rice Research and Extension Center near Stuttgart, AR, to evaluate crop response and weed control in response to applications of Highcard™ in various combinations with pendimethalin, clomazone, quinclorac, thiobencarb, halosulfruon-methyl, saflufenacil, bentazon, and florpyrauxifen-benzyl in Max-Ace™ rice. Herbicide programs consisted of an early-postemergence application (1- to 2-leaf rice) followed by a pre-flood application (4- to 5-leaf) rice. Crop injury and weedy rice control were evaluated at 1 and 2 weeks after the early-postemergence application and 1, 2, and 4 weeks after the pre-flood application. There was no apparent antagonism caused by any herbicide added to quizalofop at the early-postemergence timing based on weedy rice control at 1 and 2 weeks after initial treatment. All herbicide combinations resulted in 95% or greater control of weedy rice at 4 weeks after pre-flood treatment. Maximum crop injury, 21%, was observed 1 week after the early-postemergence application. There was no more than 6% crop injury caused by any treatment by 4 weeks after the pre-flood application, and rice yields were statistically similar among all herbicide treatments. These results indicate that the various herbicide combinations are all effective options for control of weedy rice when growing Max-Ace™ rice varieties.

California Weedy Rice and Grasses Response to Clethodim

Unan, R., Galvin, B., Alvarez, A., Inci, D., and Al-Khatib, K.

Weedy rice (*Oryza sativa* f. *spontanea* Roshev.) that struggle with cultivated rice which is its closest relative, is an important weed of rice. California *O. sativa spontanea* accessions, determined five accessions, are likely the result of wild, weedy and cultivated rice parentage from within and outside of California. In most regions where rice is farmed, weedy rice is a significant agricultural weed, and it is the most problematic weed in the all USA production area. On the other hand, barnyardgrass (*Echinochloa crus-galli*), late watergrass (*Echinochloa oryzicola*), early watergrass (*Echinochloa oryzoides)* and sprangletop (*Leptochloa fascicularis*) are important weeds and are difficult to control with herbicides. The aim of this study was to determine the response of California weedy rice accessions and grasses to clethodim herbicide applications.

Weedy rice materials were accession 1, 2, 3, 4, and 5. The other weeds materials were jungle rice, barnyardgrass, late watergrass, early watergrass, and sprangletop. Rice variety, M105, was used as a cultivated rice. Clethodim is an ACCase-inhibiting cyclohexanedione herbicide and resistant weeds to clethodim is very limited. Clethodim application rates were 0, 9.4, 18.8, 37.5, 75, 150, 300, and 600 g ai ha^{-1}. The experiment was conducted on complete randomized block design with five replications in the greenhouse. The herbicide was applied with 0.25% nonionic surfactant (% v/v). Dose–response curves based on the log-logistic model were used to determine the effective dose that provides 90% control (ED_{90}). Sprayer chamber application pressure was set to 75 PSI and herbicide mixture was prepared with 187 L ha^{-1} of water. Observations were taken 28 days after herbicide treatment.

The clethodim rate that cause 90% plant injury (ED_{90}) were 58, 61, 59, 50, and 74 g ai ha^{-1} for weedy rice type 1, 2, 3, 4, and 5, respectively. All weedy rice had different response to herbicide treatment. Clethodim ED_{90} doses ranged from 51-74 g ai ha^{-1} for weedy rice. Accession 5 was the most tolerant, and accession 3 the most susceptible to clethodim in the Californian weedy rice population. On the other hand, M105 variety ED_{90} was 87 g ai ha^{-1} for cultivated rice.

Clethodim ED_{90} values were 54, 43, 46, 75, and 80 g ai ha^{-1} for jungle rice, barnyardgrass, late watergrass, early watergrass, and sprangletop, respectively. All weeds had different response to herbicide treatment. Clethodim ED_{90} doses ranged from 43-80 g ai ha^{-1} for weed. Sprangletop was the most tolerant and barnyardgrass was the most susceptible to clethodim in rice-weeds.

In summary, clethodim was successful to control weedy rice and weed. Clethodim is able to control the between 43-80 gr ai ha^{-1} and average of 60 gr ai ha^{-1} dose by an 90% for both weedy rice and grasses. Sprangletop was determined as the most resistant in tested plants. These results indicated that clethodim has a great potential to be used as a spot treatment for the management of weedy rice and grass

Bed Width and Drill Spacing Effect on Weed Management in Furrow-Irrigated Rice

Davis, B.M., Butts, T.R., Reed, N.H., Norsworthy, J.K., Barber, L.T., Hardke, J.T., Bond, J.A., Bowman, H.D., Dillon, T.W., Arnold, C.H., and Kouame, K.B.J.

Furrow-irrigated rice, often referred to as row rice, has grown in popularity in the Mid-South over the past few years. Although this practice has reduced some labor and tillage operations for growers, it can have a negative impact on weed management efforts as the cultural practice of flooding is removed as a viable control option. Alternative management strategies and production practices need to be evaluated to determine effective weed management tactics in this production system. As a result, the objective of this research was to investigate the impact of drill row spacing and bed width on weed control in furrow-irrigated rice.

In 2021 and 2022, an experiment was established in Lonoke, AR, Pine Tree, AR, Rohwer, AR, and Stoneville, MS, in a randomized complete block split plot design with four replications. Treatments consisted of three bed widths (whole plot factor) (76-, 97-, and 152-cm) and four drill row widths (subplot factor) (13-, 19-, 25-, and 38-cm). Hybrid rice cultivar RT7521 FP was drill seeded and standard practices for fertility and irrigation were followed. Barnyardgrass density was assessed at the 5- to 6-leaf rice stage (preflood) and preharvest. Rice was harvested with a plot combine at maturity, and rough rice yield was adjusted to 13% moisture.

Across locations and years, barnyardgrass density at both the 5- to 6-leaf rice stage and preharvest stage was influenced by bed width and drill row spacing. In general, as drill row spacing increased, barnyardgrass density also increased. However, as bed width increased, the beneficial effects observed of narrower drill row spacings (13- and 19-cm) were minimized or negated completely. Rough rice yield was impacted less by bed width and drill row spacing than barnyardgrass density. However, in general, smaller beds (76-cm) and narrower drill row spacings (13- and 19-cm) tended to have slightly greater yields compared to larger beds and wider drill row spacings.

This research demonstrated that to aid in weed management efforts in a furrow-irrigated rice production system, a narrower drill row spacing (13- and 19-cm) paired with a narrower bed width (76-cm) could provide the greatest weed suppression while optimizing rough rice yield. If growers were to adopt wider drill row spacings due to the commercial availability of precision planters with rice seed plates, other alternative weed management efforts and additional input costs would likely be required to maintain equivalent levels of weed control.

California Weedy Rice and Grasses Response to Glufosinate

Unan, R., Galvin, B., Alvarez, A., and Al-Khatib, K.

Weedy rice (*Oryza sativa* f. *spontanea* Rochev.), which struggle with cultivated rice, its closest relative, is an essential rice weed. California weedy rice accessions has five accessions, likely from wild, weedy and cultivated rice parentage from within and outside California. Barnyardgrass (*Echinochloa crus-galli*), late watergrass (*Echinochloa oryzicola*), early watergrass (*Echinochloa oryzoides),* and sprangletop (*Leptochloa fascicularis*) troublesome grass weeds beyond the weedy rice and are challenging to control. This research aimed to determine the responses of California weedy rice accessions and grasses to glufosinate herbicide application.

M206 cultivated rice, weedy rice (1, 2, 3, 4, and 5), barnyardgrass, late watergrass, early watergrass, and sprangletop were grown in the greenhouse. The experiment was designed as a complete randomized block design with five replicates. Glufosinate fractional rates were applied 0, 61.5, 123, 246, 492, and 984 g ai ha^{-1} for weedy rice experiment and glufosinate application rates were 0, 61.5, 123, 246, 492, 984, 1,968, and 3,936 g ai ha^{-1} for grass experiment, respectively. Dose–response curves based on the log-logistic model were used to determine the effective dose that provides 90% control (ED_{90}). A spray chamber at 75 PSI delivering 187 L ha^{-1} was used. The visual injury was rated at 28 days after treatments.

Glufosinate at 307, 381, 590, 371, and 466 g ai ha^{-1} caused 90% injury (ED90) for weedy rice accessions 1, 2, 3, 4, and 5, respectively. All weedy rice had different response to herbicide treatment. Glufosinate ED_{90} doses ranged from 307-590 g ai ha^{-1} for weedy rice. Weedy rice accession 3 was the most tolerant, however, accession 1 the most susceptible to glufosinate in the Californian weedy rice population. ED_{90} for the M206 rice variety was observed at 695 g ai ha^{-1} glufosinate.

ED_{90} for barnyardgrass, late watergrass, early watergrass and sprangletop was obserwed at for 509, 458, 693, and 566 g ai ha^{-1} glufosinate, respectively. Glufosinate ED_{90} doses ranged from 458-693 g ai ha^{-1} for grasses. Early watergrass was the most tolerant, late watergrass the most susceptible to glufosinate in tested grasses.

In summary, glufosinate were successful to control weedy rice and grasses. Glufosinate might be controlled up to 90% for both weedy rice and grasses between 307-693 gr ai ha^{-1} dose. Early watergrass was determined as the most resistant in tested plants. These findings indicated that glufosinate has a great potential to be used as a spot treatment for the management of weedy rice and grasses.

Abstracts of Papers on Rice Culture
Panel Chair: Trent Roberts

Long-Term Greenhouse Gas Emission Impacts of Changing Irrigation Practice in Rice-Rice Rotation

Adviento-Borbe, M.A.A., Karki, S., Runkle, B.R.K., Moreno-Garcia, B., Anders, M., and Reba, M.L.

Rice paddies are one of the major sources of anthropogenic methane (CH_4) emissions. The alternate wetting and drying (AWD) irrigation management has been shown to reduce CH_4 emissions and total global warming potential (GWP) (CH_4 and nitrous oxide, N_2O). However, there is limited information about utilizing AWD management to reduce greenhouse gas (GHG) emissions from commercial-scale continuous rice fields. This study was conducted for five consecutive growing seasons (2015-2019) on a pair of adjacent fields in a commercial farm in Arkansas (USA) under long-term continuous rice rotation irrigated with either continuously flooded (CF) or AWD conditions. The cumulative CH_4 emissions in the growing season across the two fields and five years ranged from 41 to 123 kg CH_4-C ha^{-1} for CF and 1 to 73 kg CH_4-C ha^{-1} for AWD. On average, AWD reduced CH_4 emissions by 73% relative to CH_4 emissions in CF fields. Compared to N_2O emissions, CH_4 emissions dominated the GWP with an average contribution of 91% in both irrigation treatments. There was no significant variation in grain yield (7.3-11.9 Mg ha^{-1}) or growing season N_2O emissions (-0.02-0.51 kg N_2O-N ha^{-1}) between the irrigation treatments. The yield-scaled GWP was 368 and 173 kg CO_2 eq. Mg^{-1} $season^{-1}$ for CF and AWD, respectively, showing the feasibility of AWD on a commercial farm to reduce the total GHG emissions while sustaining grain yield.

Seasonal variations of GHG emissions observed within fields showed total GHG emissions were predominantly influenced by weather (precipitation) and crop and irrigation management. The influence of air temperature and floodwater heights on GHG emissions had high degree of variability among years and fields. These findings demonstrate the use of GHG emission datasets could better capture variability of GHG emissions associated with rice production and could improve field verification of GHG emission models and scaling factors for commercial rice farms.

Methane and Nitrous Oxide Emissions from Furrow-Irrigated Rice Systems with and without Cover Crops

Karki, S., Adviento-Borbe, M.A.A., Massey, J., and Reba, M.

Irrigation management is a major factor impacting methane (CH_4) and nitrous oxide (N_2O) emissions from rice cultivation. Mid-South farmers are increasingly adopting furrow-irrigated rice (FR) to save irrigation water. Additionally, FR offers agronomic benefits such as ease of planting and harvesting and greater flexibility in addressing changing market and weather conditions. However, the effect of FR on CH_4 and N_2O emissions is yet to be evaluated. A field experiment was conducted on two commercial farms (Field 1 and 2) and one research field (Field 3) to assess FR irrigation with cover crops (FRCC) and without winter cover crops (FR) relative to continuously flooded irrigation (MIRI). CH_4 and N_2O fluxes were measured using a static chamber at weekly intervals. Across all fields, grain yields varied depending on the site and crop management practices. In Field 1, there was no difference in harvested grain yield between MIRI (12 Mg ha-1) and FR (11.8 Mg ha-1), but the grain yield was decreased in FRCC (8.5 Mg ha-1). The reduction of yields in FRCC was due to the delayed termination of cover crops. In Fields 2 and 3, grain yields were similar across all treatments (11.3 Mg ha^{-1} -11.7 Mg ha^{-1}). In all fields, FR and FRCC reduced the average seasonal CH_4 emissions but increased seasonal N_2O emissions. Nevertheless, in terms of global warming potential, the increase in N_2O emissions was offset by the decrease in CH_4 emissions. There was no difference in global warming potential among the treatments in Field 1, but in Fields 2 and 3, FR and FRCC reduced the total GWP relative to GWP from MIRI. These results suggest that furrow-irrigated rice can be a more environmentally sustainable way of rice production, provided that proper crop management practices are implemented to avoid damage to the rice growth.

Evaluation of Greenhouse Gas Emissions from Rice Ratoon Crop in Louisiana

Kongchum, M., and Harrell, D.L.

Ratoon cropping has long been used for rice production in south Louisiana. It has been an effective practice for improving producers' income. However, recent studies revealed that this practice could increase methane emission. Three-consecutive year research on the effects of water management practices in rice cultivation on methane and nitrous oxide emissions has been conducted at the Louisiana Agricultural Center – Rice Research Station, near Crowley, Louisiana. The research was compared methane and nitrous oxide emissions from four water management practices; delayed flooding, alternate wetting and drying, furrow irrigated or row rice system, and semi-aerobic water management.

Rice was drill-seeded in a 1.42 m X 4.88 m with four replications. Nitrogen fertilizer was applied at a rate of 168 kg N ha^{-1}, and phosphorus and potassium at the rate of 75 kg P_2O_5 or K_2O kg ha^{-1} in the main crop. Nitrogen fertilizer for ratoon crop was applied at a rate of 100 kg ha^{-1}. Methane and nitrous oxide flux were measured from both main and ratoon crops using a diffusion chamber technique. The diffusion chambers were composed of a base and a removable top, each constructed of clear Plexiglas and measuring 30 cm × 30 cm × 30 cm. The headspace gas was mixed each time before collecting a sample. A 15 mL gas sample was withdrawn from the septum at the top of the chamber using a 20 mL gas-tight syringe at intervals of 0, 30, and 60 minutes, twice a week. The gas samples were analyzed for CH_4 and N_2O using the Shimadzu 2010 *plus*. The data recorded from the GC results was converted from parts per million by volume (ppmv) to mass per unit volume (mg m^{-3}).

The highest methane emissions in the main crop was observed in the delayed flooding system, which was approximately three times higher than other water management systems. The result was consistent over three years monitoring. In contrast, nitrous oxide emissions were higher in the row rice and semi-aerobic systems. In ratoon crop, methane emissions in the delayed flooding system was two times higher than the main crop. There were no differences of nitrous oxide emissions between the main and ratoon crop.

A Midseason Drain to Reduce GWP and Arsenic Uptake

Linquist, B.A., and Perry, H.

Flooded rice systems produce an important staple crop but are a source of methane (CH_4) and arsenic (As) exposure. Introducing soil aerobic events can decrease seasonal CH_4 emissions and grain As concentration. Previous on-station research showed that a midseason drain (MD) accomplished these goals without yield reduction, but the degree of benefit depended on soil-drying severity. A MD fits well within the current management practices for rice in California; but has not been tested across different soils or at a scale that farmers manage. Therefore, in this three-year study, seven on-farm trials were implemented to compare MD grain yields, greenhouse gas emissions, and grain As and cadmium (Cd) concentration to the farmer practice (FP). Grain yields were similar between treatments. The MD decreased seasonal CH_4 emissions by 20-77%, with the magnitude of reduction being related to soil-drying severity similar to on-station findings. Combining previous on-station data with this data, indicates that for every 1% reduction in soil gravimetric water content (GWC), seasonal CH_4 emissions were reduced by 2.5%. With MD, N_2O emissions increased (average = 0.25 kg N_2O-N ha^{-1}), but accounted for only 3% of the global warming potential. The MD decreased grain As concentration by 20% on average but did not affect Cd concentrations. These results indicate that a MD is a viable on-farm management practice for GHG mitigation and reducing grain As concentration with limited risk of yield reduction. The relationship between soil GWC and reduction in CH_4 emissions is potentially useful for on-farm monitoring.

Water, Greenhouse Gas, and Energy Savings Under Conservation Rice Irrigation Practices in the U.S. Mid-South

Moreno-García, B., Henry, C.G., Reba, M.L., and Runkle, B.R.K.

Globally, rice is a large water consumer and is responsible for 8% of the anthropogenic methane emissions. In the United States, Arkansas is the largest rice producer, and the associated water demand is triggering groundwater depletion in some critical areas.

In this context, alternative irrigation practices need to be adopted by rice farmers. While reducing the water delivered to the field, greenhouse gas (GHG) emissions associated to the pumping energy are reduced. In addition, some of these practices allow the soil to oxidate, creating aerobic conditions and thus reducing methane emissions.

In the present study, three conservation irrigation practices were implemented in eight farms in Arkansas during two consecutive growing seasons (2021-2022): Alternate Wetting and Drying (AWD), where fields are under wetting-drying cycles; Furrow Irrigated Rice (FIR) where rice is grown in beds and irrigated down furrows; and Multiple Inlet Rice Irrigation (MIRI), where a polypipe is used to deliver water in each paddy of a field with levees instead of the traditional cascade down paddies through levee gates.

In each farm, two fields were chosen to compare the conservation irrigation practice to the conventional practice. The FIR and MIRI practices were compared to paired fields under the cascade irrigation system. The AWD was practiced in zero-grade fields (precisely graded in all directions with little or no grade) and was compared to a continuously flooded zero-grade system. Soil type, planting dates and other management practices where the same in each pair of fields. Flowmeters were installed to record the water applied and yield values were reported through yield monitors or farmer estimations based on truck load weights. Management practices were input in the Fieldprint© Platform, an online decision support tool to assess farm sustainability, to model GHG emissions and energy use.

Data from the 2021 growing season showed water saving reductions (measured from flowmeter data) ranging between 6 and 38%. The MIRI system showed an average of 753 mm-ha ha^{-1} of irrigation water applied (four replicates), which represented 21% of water savings compared to the average of the cascade system paired fields (962 mm-ha ha^{-1}). The FIR water application (only one replication) was 871 mm-ha ha^{-1}, representing a 38% water savings compared to its cascade paired field (1,410 mm-ha ha^{-1}). The AWD system (only one replicate) achieved 6% of water savings compared to its continuously flooded paired field. Total Water Use Efficiency (TWUE), calculated as the yield divided by the irrigation water applied plus rainfall, ranged between 0.79 and 1.22 kg m^{-3} across the three conservation irrigation practices. The average increase in TWUE for MIRI was 20%, and FIR and AWD showed increases of 44% and 1.5%, respectively.

Irrigation energy use was modeled by Fieldprint Platform, but not all the paired fields used the same pumping water source which made a direct energy use comparison unfair. For that reason, only the paired fields using same water source were selected. In these cases, the conservation irrigation practices reduced energy use by 4-30% (where water savings had ranged between 6 and 29%), and the GHG emissions associated to that pumping were reduced by 4-35%.

Methane emissions modeled by Fieldprint Platform were reduced by 32-80% for those practices where aerobic soil conditions are created (FIR or AWD). Methane reduction in the FIR practice was estimated with a 78% reduction, similar value than the obtained for an AWD system with two drying downs (79.6%). The AWD system with one drying down showed 32% methane emissions reductions even though an organic fertilizer had been applied to that field. Thus, conservation irrigation practices including aerobic periods in the soil can help to mitigate the increase in methane emissions due to practices such as the application of organic fertilizers. As the methane emissions represent a large percentage of the total farm GHG emissions, the whole farm emissions were reduced by 20-43%.

These results show the potential of these conservation practices to achieve water savings, reductions in GHG emissions associated to pumping, and methane emissions reductions from changes to flooded soil conditions. Data from more years and/or more replicates is needed to derive robust conclusions since water applications show high variability across sites and years due to differences in soil types even inside the same farm, weather conditions depending on the year, and different farm management techniques.

Field-Scale Nitrous Oxide Measurements in Rice: Initial Findings

Reba, M., Reavis, C., Chiu, Y., Adviento-Borbe, A., Massey, J., and Runkle, B.R.

Rice contributes to greenhouse gas emissions due to the amount of rice grown in the world and the manner in which it is grown. Globally, rice contributes between 9 to 11% of anthropogenic methane. Water management in rice production is known to reduce methane production by 20 to 60%. However, these gains made in methane emission reductions could be negated by increases in nitrous oxide emissions which have approximately 230 times the global warming potential of carbon dioxide. Historically difficult to measure, nitrous oxide is typically measured using static flux chamber methods. Nitrous oxide emissions have been low when nitrogen and water are managed effectively and extremely high when managed poorly. Measurement of field-scale nitrous oxide is challenging due to equipment costs and site requirements. In response, we deployed a tunable-diode laser absorption spectroscopy sensor (TGA 200A, Campbell Scientific, Inc.), a sensor capable of measuring field-scale N_2O, in a production rice field in northeastern Arkansas during the 2022 production season. We compared the field-scale automated measurements with static flux chamber measurements. We found general agreement between the field-scale and chamber-based measurements of N_2O. We also found trends in N_2O related to atmospheric conditions and will share findings in response to specific events, namely N application and irrigation. These measurements will be important in light of interest in climate smart commodities, especially those related to rice management.

Rice Husk Amendment and Irrigation Management Impacts on Rice Growth, Greenhouse Gas Emissions, and Grain Quality

Runkle, B.R.K., Moreno-García, B., Karki, S., Limmer, M.A., Sang, Y., Yoon, H., Linam, F., Adviento-Borbe, M.A.A., Reba, M.L., Reid, M.C., and Seyfferth, A.L.

Rice, *Oryza sativa* L., is a staple food crop whose cultivation creates atmospheric greenhouse gas emissions and requires high water use. Rice is also a dietary source of toxic metal(loid)s to humans. Thus, increasing the sustainability of its cultivation may reduce natural resource use and improve grain quality and health characteristics. We recently proposed that a combination of silicon (Si) management and conservation irrigation techniques can improve the sustainability of rice production in the field. In particular, the use of rice husks as a field amendment is attractive due to their high Si content, as well as other nutrients (e.g., potassium). Sustainable rice outcomes are hypothesized to include a reduction in arsenic and cadmium accumulation in rice, lower greenhouse gas emissions from rice production, lower irrigation water requirements, and improved nutrient use efficiency. The use of rice husk as a field amendment also utilizes a waste product from rice processing streams and maintains plant-accessible soil Si levels.

Here we show initial results from an experiment in the summer of 2022 where we amended several production-scale, zero-grade rice fields in Lonoke County, Arkansas, with different amounts of rice husk. We amended two pairs of adjacent fields – one with a higher clay fraction (Perry silty clay) and the other with higher sand fraction (Calhoun silt loam). The husks were amended in November 2021 using a drop spreader on plots that were 6 m by 8 m in size, located within the 6.5–16 ha production fields. The amendments were added equivalent to one or two years of husk removed from a site given a typical yield of 10 t ha^{-1}. This addition was 400 g m^{-2} for the "1yr" treatment and 800 g m^{-1} for the "2yr" treatment. Each field had two plots for each amendment as well as two control plots that received no amendment but were raked and tilled in the same manner as the amended plots.

The fields were also treated either with continuous irrigation or with the alternate wetting and drying (AWD) technique to assess interactions between husk amendment and irrigation treatment. In the silty clay fields, one field received continuous floodwater cover while the other received an AWD treatment with a short drainage event in mid-July and a second prior to the final pre-harvest dry-down. In the silt loam soils, both fields received AWD treatment, with a ~4-day drainage event in mid-July. Our measurements targeted outcomes such as grain yield and plant biomass, pore water quality characteristics, and greenhouse gas emissions (from the silty clay fields only). Further analysis will elucidate effects on grain quality (i.e., metal(loid) and nutrient content).

Initial results show that the husk treatment had no significant effect on straw biomass. There was a slight increase in grain biomass (i.e., hand-harvested grain yield) for the silty clay fields with increasing husk amendment, but the effect was not significant due to high inter-plot variability. In the silty clay fields, low soil permeability was a challenge for consistent pore-water sampling, so additional tests are being performed by spinning down the soil water. Pore-water sampling from the silt loam fields demonstrated no clear or systematic effect of the 1yr or 2yr amendments on orthosilicate or dissolved organic carbon (DOC) concentrations, or oxidation-reduction potential (ORP) compared to the two control plots, or on three samples collected outside the amended areas.

Greenhouse gas emissions from the silty clay fields were measured by the vented closed chamber technique on a weekly basis. The results demonstrate greater methane (CH_4) and respiratory carbon dioxide (CO_2) fluxes and lower nitrous oxide (N_2O) fluxes under continuous flood conditions than in AWD conditions. The 2-yr treatment showed 4-6x higher CH_4 fluxes than the control plots (no rice husk amendment) in both fields. The control plot CH_4 emissions averaged 2.5 kg CH_4-C ha^{-1}, which is significantly lower than reported CH_4 emissions from nearby silty clay fields under long-term rice-rice rotation using the eddy covariance technique (7.1-141.6 kg CH_4-C ha^{-1}). This difference is likely due to lesser crop residues in rice-soybean rotation compared to 15+ years of rice-rice rotation.

A holistic perspective on the experiment awaits further laboratory analysis for porewater and grain quality characteristics, modeling interactions of the husk and irrigation treatments, and modeling interactions of the amendments with soil type.

Benefits of Silicon in Rice Culture

Seyfferth, A.L., Limmer, M.A., and Linam, F.

Silicon (Si) is an essential nutrient for rice production yet is often overlooked in nutrient management. Adequate Si nutrition benefits rice in many ways, including increased resistance to rice blast, increased use efficiency of water and nitrogen, and alleviation of arsenic (As)-induced stress and toxicity. Despite these benefits, Si is often not included in nutrient management analyses nor supplied in rice fertilization. While most soils contain ~30% Si, this Si is mainly tied up in secondary soil minerals and is largely unavailable to plants. As soil minerals weather dissolved, Si is lost via leaching. Rice plants demand high quantities of Si, higher than N, P, and K, and up to 10% of the dry matter of rice straw and husk (hull) is comprised of Si. This high demand for Si and removal of Si-rich rice residues from the field accelerate potential Si insufficiency for rice, particularly in well-weathered soils.

We posit that decreased plant availability of Si may contribute to enhanced As uptake by rice in some areas. Arsenic poses a double threat by lowering rice yields and directly impacting human health via the consumption of As-laden grain. The flooded soil conditions under which most rice is grown facilitate As mobilization through the reductive dissolution of As-bearing Iron (Fe) (oxyhydr) oxide minerals in the soil. This mobilized As can be re-adsorbed by soil minerals, including Fe plaque, methylated by soil microbes, or taken up by rice roots and eventually transported to grain. One strategy to limit As concentrations is through soil Si management due to the competitive interaction between As and Si for plant uptake. Most of the As entering plant roots in flooded soils is present as the reduced inorganic form, arsenite, which is carcinogenic and is fully protonated under circumneutral conditions. Under these conditions, arsenite is chemically similar to dissolved Si (as silicic acid), and both are transported into rice roots via the same pathway.

In this talk, we will explore the many benefits of Si for rice that affect rice production and quality, including reversing As-induced straight head disorder, improving N-use efficiency, and disease resistance. We will show data from hydroponic, pot, and mesocosm field studies where Si has been manipulated. We will also discuss how different sources of Si amendments vary in their ability to benefit rice, including synthetic fertilizers and return of rice residues (straw and husk) both in unaltered and charred forms. We will show data on the impacts of different forms of Si on As uptake by rice and its effects on grain yield.

Nitrogen Fixation in Rice Systems: How Much and What Affects It?

Linquist, B., Geise, A., Ladha, J.K., and van Kessel, C.

Rice cultivation is a nitrogen intensive process. While most of the nitrogen (N) deficit is resupplied through fertilizer addition, biological N fixation (BNF) represents an important N input into the system. Diazotrophs in the root zone and paddy water have non-symbiotic associations with plants or are present as free-living N_2-fixers represent a source of fixed N. Diazotrophs can be heterotrophs or phototrophs. Heterotrophs can grow in the dark and rely on a supply of reduced carbon from root exudates or derived from materials such as plant residues. Phototrophs use light as a source of energy to reduce CO_2 and include N_2-fixing systems such as cyanobacteria (blue-green algae) in floodwater and the soil–water interface of lowland rice. Studies estimate that the contribution of BNF may be up to 28-50 kg N/ha. However, estimates of BNF are highly variable and are often studied using indirect methods, pointing to a need for a more accurate method of quantifying nitrogen fixation. In addition, economic and environmental costs of fertilizer application support the importance of better understanding what drives BNF and how current management practices may positively or negatively influence rates of BNF. The practice of alternate wetting and drying (AWD) is often promoted for its multi-fold benefits while N fertilizer addition remains the standard worldwide. But, by adjusting important drivers of BNF including oxygen and nutrient availability, these management practices have the potential to influence seasonal rates of BNF. Here we use novel $^{15}N_2$ techniques to begin to directly quantify how potential water and nutrient management, cultivar, and soil type influence both autotrophic and heterotrophic N fixation in rice.

The study utilized a fully enclosed growth chamber (~1,200L) located in a greenhouse. The chamber was designed to maintain $^{15}N_2$ gas enrichment levels (~3%) while also monitoring and controlling temperature, humidity, pressure, CO_2, O_2, and other trace gases. Treatments were carried out in 12x12x24 cm pots and included: control (0N, flooded, M-210), shaded control, aerobic cultivation, alternate wetting and drying (AWD) cultivation, N addition (180 kg N/ha), shaded N addition, flooded fallow, Koshihikari, and a second soil type treatment. Plants were seeded and grew outside of the chamber for 30 days and were then transferred to the enrichment growth chamber until maturity as a completely randomized design. At harvest, soil cores were taken and separated into two layers (0-1 cm, 1cm+). Plant biomass was separated into roots, straw, and panicles while algae and weeds were also collected separately. All samples were subsequently analyzed for total N and 15N ratios to calculate total N fixation and percent of N derived from the atmosphere (%Ndfa).

In the rice treatments, biological N fixation contributed between 3-15 kg N/ha to the system when extrapolated. On average, ~58% of the fixed N remained in the soil while ~40% was found in rice biomass. Relative to the control, shade treatments significantly reduced the percent of total fixed N found in the soil and increased the percent of fixed N found in rice biomass. Overall, the addition of N increased biomass weight, total N, and total fixed N within rice biomass but had no significant effect on total N fixed within the whole system. While aerobic cultivation reduced total fixed N in the system, fallow treatments, Koshikari, and soil type did not significantly influence total N fixation rates.

Environment and N Rate Effect on Rice Quality Parameters of California Calrose Varieties and ROXY Lines

Harrell, D.L., Zhang, Z., DeLeon, T., Maulana, F., Sharma, N., Zaunbrecher, G.,
McKenzie, K., Shelton, C., and Linquist, B.

Previous research has shown that genetics and environment are two major factors that can affect rice grain characteristics like milling potential, taste, protein and amylose content. Agronomic practices like nitrogen (N) fertilization rate can also influence these characteristics. Previous research has shown that increasing the N fertilization rate will also increase the protein content of rice grain and subsequently reduce the taste value. These parameters are often evaluated by rice marketers and buyers of Calrose varieties using the Satake taste instrument. Limited data exists on the extent of variation that can be expected of California Calrose and ROXY lines when grown under variable environments or agronomic practices. The objectives of these studies were to evaluate milling potential, taste value, protein content and amylose content of Calrose varieties and ROXY lines varieties when: 1) they are grown in multiple environments; or 2) a single variety is grown, and the N fertilization rate is varied.

The first trial evaluated six Calrose rice varieties and ROXY lines for quality across seven environments (locations) in California in 2022. Varieties included M-105, M-206, M-209, M-210, M-211, and 19Y4000. The second trial evaluated M-206 when grown using six different N fertilization rates at the Rice Experiment Station in 2022. Nitrogen fertilization rates evaluated were 0, 90, 120, 150, 180, and 210 kg N ha^{-1}. Results of both trials are pending and will be discussed.

Zinc Fertilizers Modified the Formation and Properties of Iron Plaque and Arsenic Accumulation in Rice (*Oryza sativa L.*) in a Life Cycle Study

Dou, F., Ma, X., Wang, X., Jiang, J., Li, X., and Sun, W.

Rice is the staple food for around 50% of the world's population and is also much more efficient at assimilating arsenic (As) into its grain than other staple cereal crops. This study examined the effect of three forms of zinc (Zn) fertilizers on 1) As accumulation and speciation in rice tissues and 2) the formation and properties of iron plaque on rice roots over the life cycle of this cereal crop in a paddy soil. Elevated As at 5 mg/kg markedly lowered the rice yield by 86%; however, 100 mg/kg Zn fertilizers significantly increased the rice yield by 354−686%, regardless of the Zn form. Interestingly, only Zn^{2+} significantly lowered the total As in rice grains by 17% to 3.5 mg/kg and As(III) by 64% to around 0.5 mg/kg. Zinc amendments substantially hindered and, in the case of Zn oxide bulk particles (ZnOBPs), fully prevented the crystallization of iron oxides (Fe_3O_4 and Fe_2O_3) and silicon oxide (SiO_2) and altered the composition of iron plaques on rice roots. SiO_2 was first reported to be a significant component of iron plaque. Overall, ZnOBPs, ZnO nanoparticles, and Zn^{2+} displayed significant yet distinctive effects on the properties of iron plaque and As accumulation in rice grains, providing a fresh perspective on the potentially unintended consequences of different Zn fertilizers on food safety.

Excess Magnesium (Mg) Effect and Mitigation in Rice

Lamichhane, S., Dou, F., and Tarpley, L.

Recent soil analysis reports of rice field in Texas indicated elevated levels of magnesium (Mg) level. High Mg supply may impair nutrient uptake and photosynthesis, ultimately reducing crop growth and productivity. However, the impact of excess Mg supply on rice production and associated physiological processes has been rarely reported. Using two Mg sources ($MgSO_4$ and $MgCl_2$) and five Mg levels (0, 500, 1,000, 1,500, and 2,000 ppm), we characterized the impact of Mg salinity on a hybrid rice variety ("XP753"). A dose dependent reduction in plant growth, biomass, and grain yield was observed under the application of Mg salts on soil substrate. Furthermore, this study showed that the application of Mg salts on soil interfered with the uptake and translocation of minerals, and significantly increased Reactive Oxygen Species (ROS), malondialdehyde (MDA), and proline levels, indicating the toxic effects of excess Mg salts to rice plants. Currently, we are evaluating the effect of potassium fertilizer in mitigating excess Mg salinity stress in rice. Rice morphological and physiological parameters, and yield components will be evaluated.

Effects of Fertilizer Selection and Variety Response on Crop Outcomes in Organic Rice Agriculture

Lloyd, A., Lamichhane, S., Dou, F., and McClung, A.

With growing consumer and industrial concern for ecologically sustainable agricultural practices, organic farming remains a sector of great interest and development. Critical to this sector are organic nitrogen (N) fertilizers, which exist in many forms including composts, manures, and preformulated commercial products. Here, we present data on yield and milling quality outcomes in response to treatment by preformulated organic fertilizers.

Using data from a 2010 organic fertilizer trial, we discuss the effects of six different organic fertilizer formulations on rice yield and milling quality and analyze the effect of different fertilization rates, in which it was determined that NatureSafe led to significant increase in grain yield relative to other organic fertilizers tested. In 2015, two rice varieties (XP 753 and Tesanai II) were grown treated NatureSafe, in which it was determined that fertilizer application rate had a significant positive effect on grain yield, while variety did not have a significant effect. While N rates alone did not impact whole grain percentage, there was a significant interaction between N rate and variety. These results were compared to a trial conducted in 2017 in which Tesanai II was again grown with NatureSafe. The findings of 2017 support those of 2015, with the overall crop yields not differing significantly between the two years, and with significant increases in crop yields corresponding to increases in N application rates for both years. In both years, whole milling percentage demonstrated a significant positive correlation to increased N rates. However, the rate at which whole milling percentage increased in response to N application rates differed significantly between the two years. Our study provided critical information on appropriate organic N fertilizer source and rate for organic rice production.

How Low Can We Go: Rice Seeding Rate Considerations

Chlapecka, J.

Over time, recommended seeding rates in direct-seeded, delayed-flood rice have been reduced due to various factors. These factors can include better seed treatments, seed placement potential, and tillering capability. What was a 40 seeds/ft^2 (90-100 lbs/acre) recommendation for inbred varieties 20 years ago has evolved into 30 seeds/ft^2 (near 70 lbs/acre). However, many Missouri farmers and consultants are planting less, even on heavier clay soils where an increase may be recommended. Thus, seeding rate trials were initiated in the Missouri bootheel region in 2022 under both flood-irrigated and furrow-irrigated production systems to explore the potential of reducing recommendations even further. Three inbred varieties were sown at five rates from 10 to 50 seeds/ft^2 (approximately 25-120 lbs/acre) and one hybrid was sown at 4 to 20 seeds/ft^2 (9-44 lbs/acre). The resulting final plant stand for inbred varieties ranged from 3 to 28 plants/ft^2, meaning that near 50% emergence was obtained. While average grain yield of Diamond and CLL16 was maximized at 20 seeds/ft^2, consistent maximization did not occur until 30 seeds/ft^2 were sewn with an effective plant stand of 12-15 plants/ft^2. However, DG263L grain yield was consistently maximized with the lowest seeding rate tested, 10 seeds/ft^2 and an average of 6 plants/ft^2 final stand. Results suggest that one should be careful in reducing seeding rate and that the potential will be variety dependent. While we are not ready to reduce recommended seeding rates, results will help to develop a sound guide for replant decisions in the upper Mid-South.

Comparing Levels of Rice Irrigation Automation in NE Arkansas

Massey, J., Jardim, T., Payne, G., Reba, M., and Adviento-Borbe, A.

At least three issues warrant interest in rice irrigation automation: increasing farm size, chronic labor shortages, and groundwater depletion. The first two can negatively impact a producer's ability to refine irrigation practices at scales necessary to address regional water issues. Moreover, a growing number of opportunities to participate in corporate- and/or government-sponsored sustainability programs feature alternate wetting-and-drying flood management. Such efforts would benefit from the refined irrigation control and digital documentation offered by automation technologies.

Field trials on three NE Arkansas farms compared different levels of pump-control and water-sensor automation to their respective manual controls. Irrigation savings and yields were measured along with time to install/remove sensors and observations of automation reliability. Irrigation savings were shown in some but not all cases. Farmers noted that automation improved their 'quality of life' as related to irrigation-related stressors. The recommended entry point for irrigation automation is remote pump control on electric motors. This can be readily coupled with a single water-level sensor to manage flood-based and non-flooded irrigation practices.

Monitoring Water Management Using IRIS Devices

Limmer, M.A., Hanrahan, R., and Seyfferth, A.L.

Water management is a critical factor in rice production, affecting yield, pest pressure, and sustainability. Alternative water managements to the traditional delayed flood include alternate wetting and drying (AWD) and row rice. These alternative water management strategies reduce water usage and affect soil biogeochemistry, resulting in decreased methane emissions and grain arsenic concentrations. When rice soils are flooded, the soil oxidation-reduction potential (i.e., redox) becomes more reduced as microbes use electron acceptors other than oxygen, such as manganese oxides, iron (Fe) oxides, sulfate, and carbon dioxide for respiration. The use of these "alternative" electron acceptors controls important facets of rice production. The reduction of Fe oxides results in the mobilization of arsenic (As), resulting in increased grain As concentrations. The reduction of carbon dioxide produces methane, a potent greenhouse gas, that is emitted from rice paddies. Therefore, measuring the exact redox state of the rice paddy soil is important to determine the severity of As mobilization and methane emission. However, measuring soil redox requires expensive equipment and specialized knowledge. Here we describe the use of low-cost films painted with Fe or manganese oxides to indirectly measure rice paddy soil redox. Indicator of reduction in soils (IRIS) films were developed to identify reduced soils for wetland delineation and benefit from their low cost, ruggedness, and ease of interpretation. However, their application in rice paddy systems to measure redox has not been intensively studied.

We deployed IRIS films in rice paddy mesocosms at the University of Delaware to determine associations between paint removal from the IRIS films and biogeochemical measurements. The films were 30 cm long and painted with either manganese oxides or iron oxides. We deployed the films for different amounts of time to first identify the appropriate deployment time to observe sufficient paint removal under flooded conditions. The rice paddy mesocosms were operated under different water managements, including four different intensities of AWD, a flooded control, and a nonflooded control. IRIS films were deployed throughout the growing season. Porewater was collected weekly and analyzed for redox using a calibrated probe and for elemental composition by ICP-MS. Methane emissions were measured weekly using the closed-chamber technique. At harvest, plants were separated into various plant parts, finely ground, microwave-digested with nitric acid, and analyzed for elemental composition by ICP-MS.

The amount of paint removal on IRIS films was correlated with water management and several redox-sensitive measurements. Paddies under more flooded conditions had more extensive paint removal on both manganese- and Fe-coated IRIS films. The amount of paint removal was positively correlated with porewater As and Fe. Because porewater As drives plant accumulation of As, paint removal was also positively correlated with rice grain concentrations of As. Methane emissions were also positively correlated with paint removal on IRIS films. These results suggest that IRIS could be used to measure redox chemistry in rice paddies, although additional trials are needed on other soil types. Additionally, IRIS may be a useful measurement technique to determine if alternative water managements have been sufficiently aerobic to avoid substantial paint removal, and thus avoiding methane emissions and arsenic accumulation.

The Changing Paradigm of Furrow Irrigated Rice

Henry, C., Clark, G.T., Blankenship, N.R., and Parker, R.E.

Furrow irrigated rice has many limitations, but improving its water use efficiency is the key for it to be a viable production practice. A well instrumented 37-acre field at the Rice Research and Extension Center has been developed for the purpose of evaluating furrow irrigation efficiency. The field is equipped with a low cost novel type of tail water collection system. Previously, it has demonstrated an over 90% irrigation efficiency or about a 30% increase in irrigation efficiency using this system over conventional furrow irrigation system.

The novel system consists of a pit-less pump system, a small electric 2 KW high flow, low head pump, flow control, a perforated sump, backflow prevention, and high head lay-flat return pipe to return tailwater continuously in the field. The system allows for soil moisture to be more consistently maintained near saturation and field capacity between the top and bottom of the field. A small amount of tailwater water is ponded in the bottom of field for return.

In 2021, the pit-less continuous irrigation system yielded 201 BPA (Ricetec FP7321), 25 BPA higher than the 3-day irrigation treatment, although not significantly different. Year 2020 (13.8 inches) was more wet and 2021 (8.5 inches) was slightly drier and data suggested allowable depletions of 40% did not result in significant yield penalties with irrigation frequencies of between 3- and 5-day irrigation intervals and application depths of at least 381 cu. meters/ha (1.5 ac-in/ac.).

In 2022, Ricetec FP7521 was used and treatment were irrigated every 0, 3, 7, 10, and 14 days. The growing season was extremely dry, experiencing only 3.86 inches of rain during the growing season and irrigation of 19.7, 11.1, 11.6, and 9.5 ac-in/ac for the 3-, 7-, 10-, and 14-day irrigations, respectively. The 3-, 7-, 10-, and 14-day irrigation treatments were fertilized with 201.7 kg/ha (180 lb N/ac) of coated urea whereas the continuous irrigation, no-till and cover crop treatments were fertilized with liquid UAN at a rate of 138.9 kg/ha (124 lb N/ac). Fifty ac-in/ac of irrigation was applied in the continuous, but most of this was re-circulated, it was not possible to determine the consumptive water use of the continuous irrigation treatments (0 day). Soil moisture of the 0-day was maintained just above field capacity or negative allowable depletion, during the season, where the 3-, 7-, 10-, and 14-day average allowable depletion just before an irrigation was 77, 90, 93, and 93%. A significant yield penalty of 18 BPA was found between 3- and 7-day irrigations and 10- and 14-day irrigation. A significant yield penalty of between 23.7 BPA was found between no-till continuous fertigated irrigation and 3-day irrigation. Bed height may also play a role, a non-significant difference of 10.4 BPA was found where old beds were used compared to refreshed no-till beds. The data set may explain why yield penalties of FIR exist, because even with a very high agronomic rate of N fertilizer and frequent irrigation intervals, inadequate soil moisture resulted in a significant yield penalty of 23.7 BPA. Another conclusion that can be gathered from the 3-year study is that the pit-less system appears to conserve N compared to a traditional furrow irrigated system. In 2021, very high yields were achieved with only 134.5 kg/ha (120 lb/ac) of fertigated N that was not uniformly applied across the field due to uneven and washed-out beds.

In 2020, UAN was applied in three irrigation events to all of the irrigation treatments. In 2021, liquified urea was applied to all of the irrigation treatments in four irrigation events. In 2022, the interval irrigation treatments received urea at 3- to 5-leaf rice, but the continuous irrigation system applied N every week between 5-leaf rice until boot and about 11.2 kg/ha (10 lb/ac) N were applied up until grain-fill 138.9 kg/ha (124 lb N/ac) total.

No yield penalty has been found between tillage and no-till treatments (p=0.52) after the first year of no-till, and the pit-less pump system appears to negate dry furrows problems that plague conventional interval irrigation. Additionally, the furrow irrigated system has opportunity to use other forms of N successfully, with the opportunity to match fertilizer delivery to crop demand either thought fertigation or sustained released fertilizers such as Environmental Safe Nitrogen. No significant difference in yield has been found between 2020 and 2022 between treatments with Environmental Safe Nitrogen and coated urea. Very high efficiencies and water use efficiencies gained from the pit-less system, cover crops and different N delivery and forms provide opportunities for a climate smart production system and improved profitability for rice farmers.

Arkansas Irrigation Yield Contest

Henry, C.G., Parker, R.E., and Clark, T.

Groundwater withdraws are not sustainable in the mid-south region. Previous research and Extension programs in the region have focused on demonstration and paired comparisons to promote the adoption of Irrigation Water Management Practices in rice. There is almost no data that documents water use efficiency (WUE) of rice, from working farms, a metric for sustainability. Additionally, Natural Resource Conservation Service incentive programs are available for structural and management practices, but education about how to alter water management is lacking in the region. The "Most Crop per Drop" contest was developed to promote awareness of irrigation water management using contest winners to promote their own ideas and successes to their peers.

In 2018, a crop irrigation contest was developed to document WUE and practices that farmers utilize to conserve water. This integrated research and Extension program works with producers through a contest format. Water use is measured with propeller flow meters, rainfall is estimated with computer models and a yield check of 3 acres is done to document WUE for each entrant. The goal of the contest is to document irrigation water management practices and provide a platform for irrigators to share their own success and approaches to irrigation water management. The contest is supported by the industry. In the five years of the program, Ricetec, McCrometer, Seametrics, Irrometer, Delta Plastics, Agsense (Valmont Industries), Trellis, Crop X, Farm Logs, the Arkansas Soybean Promotion Board, and the Arkansas Corn and Grain Sorghum Board provided cash or product prizes for the winners upwards of around $20,000 for the first place winner. Each contestant is provided a report card anomalously showing their performance with respect to yield and WUE relative to the other contestants. This report card provides feedback to each irrigator.

Contestants enter a 30-acre or larger field and request for a meter to be installed before any irrigation. Portable tube, propeller style meters are installed on the field so it cannot be removed without tampering. Rainfall is estimated using rainfall estimation software for each field from emergence to crop maturity. A minimum yield of at least 9,078 kg/ha (180 bushels/A) is required for winners to ensure realistic yield goals are being entered into the contest. Thus, both a high yield and high WUE must be obtained to win the contest.

Average WUE for all rice contestants for the years 2018 through 2021 was 5.1 bushel/inch, while the average yield was 10,037 kg/ha (199 bu/A). First place winners used the flooded rice production system in 2018, 2019 and 2020. In 2021, the highest WUE was achieved using furrow irrigation utilizing a novel pit-less tailwater recovery system. The 4-year average WUE for flooded rice was 5.7 bushels/ac-inch and the average WUE for furrow irrigated rice was 4.82 bushels/ac-inch. The lowest WUE for any individual rice field was a furrow irrigated field with 2.8 bushels/ac-inch. The highest yield for all rice recorded during the study period in furrow irrigated rice was 13,416 kg/ha (266 bu/A), and the lowest yield for any rice entry came from a furrow irrigated rice field with a yield of 6,304 kg/ha (125 bu/A). The 4-year average WUE of all recorded cultural practices are: alternate wetting and drying 6.71, Flood 6.43, Furrow 4.82, and multiple inlet rice irrigation 4.86. Support from and participation by Extension agents as well as NRCS staff has helped the contest to develop in Arkansas. Results of winners, practices, and management styles observed have indicated that the level of management applied plays a key role in the success of the winners.

Analysis of the Effects of High Night Temperature on Arkansas Rice Varieties

Hemphill, C.C., DeGuzman, C.T., Esguerra, M.Q., and Counce, P.A.

Susceptibility of rice cultivars to high night temperature (HNT) results in reduced grain yield, head rice yield, and grain quality. Minimum night temperatures in Arkansas have increased by approximately 1°C since 1980. Investigation into the mechanism of deleterious HNT effects and development of new rice varieties tolerant to HNT are areas of research receiving increased focus by Arkansas rice producers and processors as a part of efforts to address the impact of environmental effects on rice grown in the state.

This paper presents results from field experiments conducted by the High Night Temperature Project at the Rice Research and Extension Center in Stuttgart, Arkansas. A selection of 26 genotypes, including elite Arkansas varieties and candidate lines from the breeding programs, were tested in an advance yield trial in 2021 and 2022. Each genotype was planted in three replications in a randomized complete block design. Dates were recorded for each plot at growth stages R2 (booting) through R9. Ten panicles were collected from each plot to measure panicle length, number of branches, percent filled grains, and seed weight. Check genotypes N22 and Zhe733 were harvested early by hand and threshed in a combine; all other genotypes were harvested by combine which measured plot weight and harvest moisture. The samples were equilibrated to 12% moisture content then two samples were taken from each plot and milled using a McGill Number 2 to measure head rice and total white rice yield. The head rice samples were then assessed using a SeedCount instrument to measure chalkiness and kernel dimension properties.

Weather data from a local station maintained by the HNT project was collected and used to calculate average, minimum and maximum hourly temperatures. Daily sun rise and sun set times recorded by the NOAA were used to separate temperature data by day and night. Temperatures in 2022 were higher in general and reached maximums earlier in the season than in 2021. During a 2-week period in June 2022, average day temperatures stayed above 30°C and reached maximum temperatures of 37°C compared to the same period in 2021 when average temperatures never reached 30°C and reached maximum temperatures of 33°C. Maximum night temperatures exceeded the 28°C critical threshold much earlier in the 2022 growing season (June 12, 2022 compared to July 22, 2021).

Higher temperatures in 2022 lead to reduced grain yield for most varieties, especially Diamond, Lagrue and advance line RU1801145. Varieties with the highest increase in chalk were CLL15 and advance line 19AYT57, while varieties Kaybonnet, Roy J, and Templeton showed tolerance to chalk formation. Head rice yield was greatly affected with most varieties showing a significant reduction in 2022 compared to 2021. Varieties Aroma17, CLL16, Cybonnet, Cypress, Diamond, Kaybonnet, Lagrue, Presidio, and Rondo all exhibited extreme reductions in head rice yield up to a maximum of 43%.

Rice Crop Response to Heat Stress and Management Options

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

Rice is a major world food crop. Rice yield and quality are sensitive to elevated air temperature; heat stress, especially at night, has been shown to cause yield losses in studies performed across the world's major rice-growing regions. Furthermore, the likelihood of damaging hot spells is increasing in rice-growing areas of the Southern United States and elsewhere. For example, at Beaumont, Texas, over the last 25 years, the incidence of nighttime minimum temperatures of 25 °C or higher has increased from an average of two per season (1991-1995) to an average of 13.6 per season (2016-2020). Both genetic improvement and crop management options are needed to improve rice crop resilience to heat stress. This paper discusses rice crop response to heat stress and management options for minimizing the heat stress effects.

The rice flowers are the most sensitive part of the rice plant to heat stress so can be used to describe how heat stress affects rice crop yield. Rice flowers occur in the panicles, which are near the top of the canopy. Under relatively dry conditions, the flowers can be kept cool by evapotranspiration from the leaves of the surrounding canopy. But in humid conditions, especially in dense plantings, the temperatures in the canopy where the flowers are can be warmer than the air just above the crop. This is because the wind speed is decreased and the air is humid.

The evapotranspiration to cool the flowers is not available at night because the leaves are not transpiring. However, rice flowers open fairly early in the morning and are influenced by the temperatures at night because these set the stage for temperatures experienced during flowering. Studies have shown night temperatures are more closely associated with rice yield losses than day temperatures.

Heat stress hurts yield in several interrelated ways, all of which affect flower fertilization thus seed set thus yield. Many involve oxidative stress. Oxidative stress of the developing flower parts can disrupt the fertilization process by affecting growth of the different flower parts. This decreases seed set and decreases yield. Oxidative stress of the developing pollen can lead to nonviable pollen, thus poor fertilization, seed set and decreased yield. Oxidative stress of the leaves can lead to poor nutrient transfer to the developing plant parts, such as pollen grains and flowers.

Management options to decrease heat stress losses include planting early and applying certain plant growth regulators. Planting early can improve the chances of flowering before the hottest periods of summer. The plant growth regulators can partially block an injurious stress response; these plant growth regulators can be cost effective but must be applied as preventatives.

Heat stress, especially high night temperature stress, is an increasing threat to rice crop yield and quality in the Southern United States and other regions of the world. Although efforts are underway to improve heat tolerance in rice cultivars, management options, including planting early and applying certain plant growth regulators, are needed to minimize heat stress effects on yield in current and near-future rice production.

This paper involves studies conducted with other scientists. These include Dr. Abdul Razack Mohammed (Texas A&M AgriLife Research & Extension Center at Beaumont, currently with BASF), Drs. Mayumi Yoshimoto (IAES, NAFRO), Minehiko Fukuoka (IAES, NAFRO), and Kazuhiro Kobayasi (Shimane University) from Japan, and scientists from the AgroFresh and Valent BioSciences companies.

Do Daytime and Nighttime Temperatures Affect Rice Yield and Quality?

Su, Q., Rohila, J.S., and Karthikeyan, R.

Increased heat stress during cropping season poses significant challenges to rice production. We conducted a meta-analysis using data from published peer-reviewed literature (greenhouse and field trials) to evaluate rice phenotype plasticity to high daytime temperature (HDT) and high nighttime temperatures (HNT) and compared heat stress tolerance of studied rice varieties. The analysis showed that rice production was highly affected by HDT as well as HNT, with considerable differences among rice varieties. Seed setting was found to be the most sensitive trait to HDT and HNT, accounting for major portion of the yield losses. The optimum daytime and nighttime temperatures for grain yield were estimated to be around 29°C and 22°C, respectively. Rice grain yield declined by about 4% for every 1°C increase when exceeding the optimum daytime temperature, mainly due to the decreased seed set percentage. The analysis also indicated that the rice grain yield was more sensitive to HNT than HDT, with approximately a 5% reduction per °C beyond the optimum nighttime temperature. In addition to declined seed set percentage, yield loss under HNT was also attributed to reduced grain weight, spikelet number, and biomass production. Both HDT and HNT affected grain quality by increasing chalkiness and decreasing head rice rate, negatively affecting overall rice production. HNT was also found impacting the protein content significantly. Our meta analysis suggest that current estimations of the economic implications of yield loss under high ambient temperatures during rice cropping season are likely to be underestimated without adequately considering their additional impacts on rice quality. Selection and breeding of high-temperature tolerance rice varieties should consider both the rice yield and quality in responses to HDT and HNT.

Abstracts of Posters on Rice Culture
Panel Chair: Trent Roberts

Effects of Different Nitrogen Rates on Nitrogen Use Efficiency, Rice Physiology, and Agronomy Under Organic Management

Lasar, H.G.W., Gentry, T., Dou, F., Lamichhane, S., and Zhou, X.G.

Nitrogen (N) is critical to optimize rice yield potential and quality. However, improper N management remains a key issue in achieving high-yielding organic rice production. Greenhouse and field experiments are conducted to determine the effects of different N sources and rates on organic rice growth, yields and nitrogen use efficiency (NUE) at Texas A&M AgriLife Research Center, Beaumont, TX. Three levels of N (0, 50, and 150 kg N ha^{-1}) from organic soil amendments (chicken litter pellet and nature safe) are assigned in a complete randomized design (greenhouse) and a complete randomized block design (field) with four replications. This study hypothesized that applied nitrogen from organic amendments will enhance rice tillering, biomass, chlorophyll and N content, grain yield, numbers of panicles and 1000-grain yield. This research aims to provide an improved understanding of how appropriately apply N from organic sources to optimize rice production.

Influence of Water Management on Iron Phosphorus Interaction in Rice Rhizosphere

Martinengo, S., Martin, M., Schiavon, M., Romani, M., Said-Pullicino, D., Seyfferth, A., and Celi, L.

The availability of phosphorus (P) to rice plants is influenced by the extent of flooding of the paddy soils because of its strong relationship with iron (Fe) dynamics. The interaction between dissolved Fe(II) and root oxygen loss causes the formation of Fe-plaque on and near rice root surfaces. The newly formed Fe-plaque can retain porewater components, such as P, which can be subsequently released following the partial dissolution of the plaque. Such Fe-P dynamics have been described in paddy soils managed with the traditional continuous flooding technique, adopted in Northern Italy up to present. However, climate change is resulting in increasing water scarcity, thus imposing water saving strategies. The new water management are characterized by shorter flooding periods, with a possible consequence on Fe dynamics in the rhizosphere. Particularly, the Fe plaque formation and composition could be affected by the dry periods, with an unknown consequence on P retention/release mechanisms.

In order to assess the impacts of the emerging water-saving techniques on the rhizospheric Fe-P dynamics and P availability to rice, a macrocosm experiment was conducted to compare the effects of three different water management practices and P fertilization. The compared water management practices were continuous water flooding (WFL), alternated wet and dry (AWD), and delayed flooding (DFL). In WFL and AWD treatments the soil was submerged just before rice sowing. Subsequently, WFL macrocosms were maintained flooded until rice maturity, while AWD macrocosms were dried at the beginning of tillering until the redox potential (Eh) rose above 105 mV. In the DFL macrocosms rice was dry seeded, then the soil was flooded at the beginning of tillering and maintained under continuous flooding up to maturity. Three P fertilization levels were tested per each water management strategy: natural soil supply (no P), 20 kg P ha^{-1} fertilization (medium P), and 40 kg P ha^{-1} fertilization (high P). The concentrations of Fe and P in porewater were monitored until rice harvesting. The plant tissues were analyzed for P concentration, and the contents of amorphous and crystalline Fe (hydr)oxide in root plaque was estimated via oxalate and dithionite extractions at 30 (mid-tillering stage), 60 (stem elongation), 90 (heading), and 120 (harvesting) days after sowing (DAS).

The preliminary results showed a different molar P/Fe ratio in porewater as a result of the combination between water management and P fertilization. Because of the presence of phosphate during Fe(III) precipitation is reported to affect characteristics of the newly formed Fe-P association, a different trend in Fe plaque formation and crystalline ratio was observed. With all the water management strategies, the Fe precipitation on rice roots was higher in "no P" treatment than in the two fertilized ones. During the earlier development stages, Fe plaques were mainly composed of amorphous Fe (hydr)oxide, while the proportion of crystalline Fe (hydr)oxide increased with plant development. Despite this, the total amount of Fe plaque decreased in the last development stages. Thus, indicating a consumption of the poorly ordered fraction of Fe plaque. Such an effect was particularly evident in "no P" treatment, as a possible consequence of the plant responses to P-limiting condition on Fe plaque dissolution. Indeed, rice plants are able to release H^+ and organic acids to enhance the solubility of sparkling available P (i.e. the P bounded to metal oxides). The principal component analysis (PCA) applied to investigate the relationship between relevant variables, underlined the positive correlation between plant P uptake and P concentration in porewater. Additionally, a negative correlation was observed between porewater P concentration and the crystalline ratio of Fe plaque, meaning that decreasing value of poorly ordered fraction of Fe plaque correspond to higher P concentration in porewater. Thus, corroborating the hypothesis of enhanced P release after Fe plaque dissolution promoted by the plant responses to P-limiting conditions.

The relationship between P and Fe dynamics in porewater with P uptake by plants over time will provide insights into the mechanisms controlling P availability under different water management. The amount of Fe plaques formed on the root surface and their crystallinity degree can help to estimate the mechanism that regulate their potential in P retention/release and the consequent effects on plant uptake. However, only synchrotron radiation techniques (bulk X-ray diffraction and bulk X-ray absorption spectroscopy, micro x-ray fluorescence imaging and spectroscopy) will allow to fully elucidate Fe plaque mineralogy and P retention mechanisms in the different water management scenarios, and the subsequent impacts on P availability to rice plants.

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Field-Scale Evaluation of Cover Crops in Rice Production

Vickmark, H.E., Roberts, T.L., Drescher, G.L., and Hardke, J.T.

The use of cover crops suffered a major decrease in use during the mid-20th century but is gaining more interest as farmers are seeking ways to improve soil health. A cover crop can be described as a non-cash crop grown between the harvest and planting seasons of the cash crops. Reduced soil erosion, increased water infiltration, improved soil fertility, and nutrient availability are just some of the benefits that a cover crop may confer to a given field. However, the cover crop must be complementary to the characteristics of the site and the successive cash crop. Significant yield increases following the implementation of cover crops are most often reported in rainfed or non-irrigated production systems. Successful implementation of cover crops in irrigated crops will often result in input reductions such as fewer irrigation events, lower irrigation water use, lower fuel and labor costs, and reduced fertilization. In a continuous, zero-grade rice cropping system on a poorly drained silt loam soil, the success of a non-rice crop may be low, due to reduced nutrient cycling, low water infiltration, and ponded or saturated soil conditions. Therefore, field-scale research was conducted in 2021-2022 on a Henry silt loam soil to determine how winter annual cover crop(s) impacted rough rice yield. Five treatments were tested in this study: Winter fallow (no cover crop), Austrian winter pea (*Pisum sativum)*, hairy vetch (*Vicia villosa)*, black oats (*Avena 129trigose)*, and a combination (50:50) of Austrian winter pea and black oats. Following cover crop termination, the rice cultivar CLL16 was no-till drilled into the cover crop residue. Grain yield of the following rice crop was measured in each treatment via harvest with a commercial combine and weigh wagon, with three replications per treatment. The LS means of yields in each treatment ranged from 9,689.6 kg/ha (142.3 bu/A) to 10,254.8 kg/ha (150.6 bu/A). Mean comparison using a student's t-test determined that there was no significant difference ($\alpha = 0.05$) between the five cover crop treatments and their effects on rough rice yield in a field-scale, continuous rice system. Therefore, the addition of a cover crop in a zero-grade rice cropping system may not enhance rice grain yield. However, further research on the effect of these cover crops on grain yield and soil characteristics is warranted over a longer period to observe both the short- and long-term effects of cover cropping on a continuous zero-grade rice production system.

2022 Arkansas Rice Performance Trials

Amos, L.R., Frizzell, D.L., Wright, A., Hartley, H., Castaneda-Gonzalez, E., Clayton, T.L., and Hardke, J.T.

The 2022 Arkansas Rice Performance Trials (ARPT) evaluate commercial rice cultivars across the rice growing region of Arkansas. Locations include research stations and on-farm locations in grower fields. Performance related to grain yield, milling yield, and agronomics will be presented.

To test cultivars' ability to perform across a vast array of environmental conditions and management styles, research stations and on-farm commercial fields are utilized to evaluate each cultivar. Annually, the Arkansas Rice Performance Trials (ARPT) make use of these locations found throughout riceproducing areas of Arkansas. Evaluating the performance of commercial rice cultivars through yearly trials provides critical information. Each cultivar is tested across varying environmental conditions, soil types, and management styles providing agronomic factors, such as lodging, plant stand, plant height, disease resistance, grain yield, and milling yield. This information informs growers to make the best decision on which cultivar will suit their needs. The opportunity for this year's on-farm locations was in Clay, Desha, Greene, Jackson, Lawrence, and Lonoke counties. Research stations used were in Arkansas, Mississippi, Poinsett, and St. Francis counties. The average grain yield across all locations was 175 bu/ac. The location with the highest average grain yield was Arkansas Co. at 9,633 kg/ha (191 bu/ac) while St. Francis Co. was lowest at 7,767 kg/ha (154 bu/ac). The cultivars with the highest average grain yield across all locations were RT XP780, RT XP753, RT 7401, RT 7521 FP, RT 7302, RT 7331 MA, Ozark, DG263L, and RT 7421 FP. Cultivars with the highest head rice yields were Leland, DGL2065, Addi Jo, Jupiter, CLM04, Ozark, Avant, CLL17, and CLL19.

Influence of Nitrogen Rate on Performance of Selected Varieties in Arkansas

Castaneda-Gonzalez, E., Clayton, T.L., Frizzell, D.L., Amos, L.R., Wright, A.,
Hartley, H., Roberts, T.L., and Hardke, J.T.

The variety by nitrogen (N) studies conducted by the University of Arkansas System Division of Agriculture are designed to analyze the response of new rice cultivars to N fertilization to determine N fertilizer rate recommendations across soils and environments. In 2022, studies were conducted at four locations in Arkansas, the Northeast Research and Extension Center (NEREC) near Keiser (clay soil), the Pine Tree Research Station (PTRS) near Colt (silt loam soil), the Northeast Rice Research and Extension Center (NERREC) near Harrisburg (silt loam soil), and the Rice Research and Extension Center (RREC) near Stuttgart (silt loam soil). Eight varieties were evaluated across a range of N fertilizer rates: 0, 67, 101, 135, 168, 202, and 235 kg N ha^{-1} (67 kg N ha^{-1} treatment omitted on clay soil and replaced with 235 kg N ha^{-1} treatment). The N rate response of the varieties Diamond, DG263L, Taurus, and Ozark are presented. These results will be used to validate or modify current rice N recommendations for Arkansas.

Mizzou Rice Agronomy Program

Chlapecka, J.L.

For over a decade, the University of Missouri lacked a program devoted exclusively to rice. Created in 2021 and located in the bootheel area, the MU Rice Agronomy Program's primary focus is to serve as an advocate for diverse stakeholders in Missouri by providing reliable and unbiased recommendations for growing rice. Missouri averages approximately 80,937 hectares (200,000 acres) of rice production annually, which ranks us 4th in the United States in rice production. While the state as a whole is not known as a rice state, the bootheel region is home to five counties which produce 90-95% of the rice in the state. One aspect that makes our program unique is the heavy focus on furrow irrigation, with over half of our research work being in furrow-irrigated rice. Approximately 30% of Missouri rice acres are furrow-irrigated, which is a larger percentage than any other U.S. state. A primary goal of the program for the first five years after establishment is to produce the general agronomic recommendations that other states are accustomed to but have been absent in Missouri for quite some time. These include cultivar trials, planting date studies, seeding rates, and basic fertility. While the program currently has a total of two full-time employees and one part-time employee, we have plans to grow with one more full-time position posted and graduate student opportunities available. Long story short, look for much more rice data to come out of Southeast Missouri in the future!

Rice Grain Yield Response to Planting Date in Arkansas, 2020-2022

Clayton, T.L., Castaneda-Gonzalez, E., Frizzell, D.L., Amos, L.R., Wright, A., Hartley, H., and Hardke, J.T.

In Arkansas, the rice planting window ranges from late March through June and exposes cultivars to an array of different environmental conditions that affect plant growth and ultimately grain yield. From 2020 to 2022, from late March through early June, four to six plantings were made in two locations each year, the University of Arkansas

System Division of Agriculture's Rice Research and Extension Center (RREC) near Stuttgart, AR; Pine Tree Research Station (PTRS) near Colt, AR for 2020-2021; and the Northeast Rice Research and Extension Center (NERREC) near Harrisburg, AR in 2022. The cultivars grown in 2020 were ARoma17, CLL15, CLL16, CLL17, CLM04, DG263L, Diamond, Jewel, Jupiter, Lynx. ProGold1, ProGold2, PVL02, and Titan, and the hybrids RT7301, RT7321 FP, RT7401, RT7501, RT7521 FP, RT7801, and RTXP753. The cultivars grown in 2021 were the purelines ARoma17, CLL15, CLL16, CLL17, CLM04, DG263L, Diamond, Jewel, Jupiter, Lynx, ProGold1, ProGold2, PVL02, PVL03, RTv7231 MA, and Titan, and the hybrids RT 7301, RT 7321 FP, RT 7401, RT 7521 FP, and RTXP753. The cultivars grown in 2022 were the pureline varieties Addi Jo, ARoma22, Avant, CLL16, CLL17, CLL18, CLM04, DG263L, Diamond, Ozark, PVL03, Taurus, Titan, and RTv7231MA, and the hybrids RT 7302, RT 7321 FP, RT 7331MA, RT 7401, RT 7421 FP, RT 7521 FP, and RT XP753. In 2020 at RREC and PTRS, the optimum planting dates were late April and early March. In 2021 at RREC the optimum dates were late March and early June, while at PTRS the optimum dates were early and late April. In 2022, late March through mid-April were optimal at RREC while early April through late April were optimal for NERREC. While all cultivars follow these general trends, it should be noted that individual cultivars do respond differently to planting date, particularly with late planting dates.

Potash Rate Calculator and Rice Y-Leaf Critical Potassium Concentration: Decision-Support Tools to Assist with Potassium Fertilization Decisions

Drescher, G.L., Slaton, N.A., Popp, M.P., Roberts, T.L., Gruener, C.E., and Smartt, A.D.

Knowledge of how accurately soil testing and plant analysis identify nutrient-deficient soils and recommend the proper fertilizer rate is important to ensure farmers are profitable. Profit-maximizing fertilizer-K rate recommendations rely not only on the yield response to soil-test K and applied fertilizer-K but also on the crop value and fertilizer cost. Information from multiple K fertilization studies over the last two decades was combined to develop an economic metanalysis and define profit-maximizing K rates for rice (*Oryza sativa* L.). This groundwork led to the development of a support tool coined the Potash Rate Calculator (PRC). The PRC defines profit-maximizing fertilizer-K rates based on the yield potential of a field, the field's soil-test K, the crop's value, and the cost of fertilizer, and is an important tool to assist producers in K fertilization decisions, especially in years with high fertilizer costs and/or low commodity prices. Potassium fertilization is paramount on soils with sub-optimal K availability to prevent K deficiency and maximize rice yield. Potassium deficiency symptoms of rice are, however, difficult to visually diagnose during reproductive growth, and critical tissue–K concentrations may change across time, which makes tissue sampling timing a key aspect of K nutrition diagnosis. Recently, critical Y-leaf-K concentrations were defined for pure-line rice cultivars in Arkansas and allow the assessment of the plant's K nutritional status and yield potential. Rice Y-leaf-K concentrations above 16.0 g K kg^{-1} between R1 and R2 maximize pure-line cultivars' yield production. The critical Y-leaf-K concentrations decline between R2 and R3 and are less accurate for diagnosing K deficiency than samples collected before R2. The critical Y-leaf-K concentrations can be effectively used to diagnose the adequacy of the K fertilization program in pure-line rice cultivars. The PRC and critical Y-leaf-K concentrations are novel decision support tools available for Arkansas rice producers that define K fertilization needs, diagnose rice K deficiency, and maximize farming profitability.

Influence of Nitrogen Strategy on Performance of Selected Hybrids in Arkansas

Hartley, H., Clayton, T.L., Castaneda-Gonzalez, E., Frizzell, D.L., Amos, L.R., Wright, A., Roberts, T.L., and Hardke, J.T.

The effect of nitrogen (N) has proven to be an essential nutrient on growth of plants. However, it is not found readily available within crop production. Previous studies have found that a two-way split application (preflood and boot) increases grain and milling yields combined with a reduction in lodging. These studies aim to build on that previous research by evaluating new hybrids in their response to N rate strategy. In 2022, studies were conducted at four locations in Arkansas, the Northeast Research and Extension Center (NEREC) near Keiser (clay soil), the Pine Tree Research Station (PTRS) near Colt (silt loam soil), the Northeast Rice Research and Extension Center (NERREC) near Harrisburg (silt loam soil), and the Rice Research and Extension Center (RREC) near Stuttgart (silt loam soil). Three hybrids were evaluated across a range of N fertilizer rates: 0, 67, 101, 135, 168, and 202 kg N ha^{-1} applied preflood. Each of these treatments also received a 34 kg N ha^{-1} application at late boot. Two additional treatments were also included of 101 and 135 kg ha^{-1} with no N applied at late boot to compare the boot N response. Hybrids evaluated included RT 7321 FP, RT 7302, and RT 7421 FP. Results indicate that the hybrids evaluated achieved optimal yields at currently recommended fertilizer N rates. Additionally, boot N applications resulted in improved performance compared to no boot application. Additional analysis is needed to determine economically optimal fertilizer N rates.

Evaluation of N Rates and Time of Applications on Grain Yield of Furrow Irrigated Rice System

Kongchum, M., and Harrell, D.L.

Furrow irrigated rice (row rice) often requires higher nitrogen (N) rates as compared to flooded rice systems. Preliminary research indicates that 33.6 to 56.0 kg/ha (30-50 lb/A) of N required more than delayed flood rice due to the frequent wetting and drying results in lower N fertilizer efficiency. Field experiments were conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, Louisiana, from March-August for cropping season of 2021 and 2022 to determine the best practice for optimum rate and time of N application on rice yield. The treatments were included two rates of N fertilizer (135 and 185 kg N ha^{-1}) with four different time of applications (single application at 4-leaf stage, two-split (4-leaf, and 4-leaf + 7 days), two-split (4-leaf, and 4-leaf + 14 days), and 3-split (4-leaf, 4-leaf + 7 days, and 4-leaf + 14 days). The experiments were arranged in 2 x 6 factorial in randomized complete block design with four replications. Two rice varieties, CLL17 and RT7521FP, were used in a parallel trial.

The highest yield was observed in the higher N rate of 185 kg N ha^{-1} in the single application treatment (10,123 and 7,743 kg ha^{-1} for RT7521FP and CLL17, respectively). However, yield differences were 2.7 and 4.1% as compared to the treatment with 135 kg N ha^{-1}. Among the split-application methods, two-split N applications at 4-leaf and 4-leaf + 14 days showed highest yield regardless of N rates but not statistically significant from other split application methods in both rice varieties. The results indicated that the single application was the best option, and the two-split applications at 4-leaf and 4-leaf + 14 days was an alternative.

Evaluation of Delayed Flood and Furrow-Irrigated Rice System on Rice Growth and Yield

Kongchum, M., Harrell, D.L., and Baisakh, N.

Delayed flood rice system has been a major rice production system in Louisiana. Recently, a great interest has turned to rice produced in furrow-irrigated fields or row rice in the southern region of the United States. Field experiments were conducted in 2021 and 2022 to evaluate rice growth and yield from both cultivation systems. Rice was drill-seeded with 7-row seeder of 20.3 cm apart and the plot size was 1.42 m x 4.88 m. The trials were conducted in a randomized complete block design with four replications. Six nitrogen fertilizer rates of 0, 100, 135, 168, 202, and 235 kg N ha^{-1} were used for evaluating agronomic data and grain yield. Nitrogen fertilizers in form of urea were applied one-day before flooding at about 4- to 5-leaf growth stage. Phosphorus and potassium fertilizer were applied at planting at the rate of 67 kg P_2O_5 ha^{-1} and 67 kg K_2O ha^{-1}, respectively. Two similar trials were conducted at the same time, one with delayed flooding system, and another with furrow irrigation system. Nitrogen fertilizer for furrow irrigation system was applied at 4- to 5-leaf growth stage. Two separate trials in each water management system using rice variety CLL17 and a hybrid RT7521FP. Seed rate for CLL17 was 355 seeds m^{-2} and 151 seeds m^{-2} for hybrid RT4521 FP.

Higher N rates could delay maturity by 2-3 days in both CLL17 and RT7521FP. Average maturity dates in furrow irrigation system were 5-8 days longer than the delayed flood. Average plant heights over all N rate treatments in delayed flood were taller than the furrow irrigated rice about 10-20 cm. Grain yield for RT7521FP in delayed flood was higher than the furrow irrigated rice by 33.8% in 2021, and 26.2% in 2022. This difference was similar for the grain yield of CLL17, which was 33.8% in 2021, and 29.8% in 2022.

Effect of Water Management Practices on Rice Arsenic Uptake

Kongchum, M., and Harrell, D.L.

Recent research indicated that rice grown in some environmental conditions can contain harmful levels of arsenic (As). Anaerobic soil conditions of flooded rice fields can make the soil As more mobile and available for plant uptake compared to aerobic condition. Field experiments were conducted in drill-seeded rice system to evaluate the effect of water management practices and three soil amendment materials (rice husk as, silica slag, and Ag lime) on As uptake. Arsenic uptake in different plant tissues were compared in three water management practices: delayed flood (DF), alternate wetting and drying (AWD), and semi-aerobic rice system (SA). Plant tissue samples were collected at 50% heading stage (above ground samples), rough rice, brown rice, and milled rice.

The highest concentration of total As was observed in rough rice (0.33 mg kg^{-1}) with delayed flooding system, followed by tissue samples at 50% HD (0.13 mg kg^{-1}), brown rice (0.98 mg kg^{-1}), and the lowest concentration was in the milled rice (0.07 mg kg^{-1}) samples, when averaged over three water management practices. Water management practices showed significantly impacted on the total As concentration. The As concentration in rough rice with delayed flood was 0.61 mg kg^{-1}, followed by AWD (0.30 mg kg^{-1}), and 0.08 mg kg^{-1} in SA water system. However, the soil amendment materials did not alter total As concentration in plant tissues.

Application of Drone in Rice Seeding and Pollination

Manangkil, O.E., and Abdula, S.E.

In recent years, the world has seen massive automation in rice crop establishment. Drones are a force to be reckoned with in agriculture. Direct-seeding and supplemental pollination are among the relatively newer and less common uses of drones. Two studies were conducted to determine the best seeding rate in direct-seeding, and the possibility of supplemental pollination in hybrid rice seed production. Drone direct-seeding was conducted and compared with manual broadcasting and transplanting in the irrigated lowland fields at the Philippine Rice Research Institute (PhilRice) in Nueva Ecija province. The seeding rates used were of 20, 40, and 60 kg ha^{-1}, each seeded in 1,512 m^2 plot size. Both manual broadcasting and transplanting used 40 kg ha^{-1} seeding rate each in 756 m^2 plot size. On the other hand, another experiment was conducted for 7 days to test the efficiency of supplemental pollination using drone in hybrid seed production. It was compared with the usual manual pollination using sticks. DJI Agras T16 model equipped with seed spreader was used in seeding while DJI Matrice 600 Pro was used in pollination. In terms of seeding rate, results show that highest grain yield was obtained from the 40 kg ha^{-1} drone-seeded (9.62 t ha^{-1} crop cut; 6.44 t ha^{-1} actual) setup. The same setup also outyielded the two other manual methods. Manual seeding yielded the least (8.31 t ha^{-1} crop cut; 6.38 t ha^{-1} actual). In hybrid seed production, supplemental pollination using drone yielded higher at 2.50 t ha^{-1} than manual supplemental pollination at 2.13 t ha^{-1}. Drawing from the results of this study, it is therefore concluded that the 40 kg ha^{-1} drone seeding rate yielded the best result. As regards the supplemental pollination experiment, the drone technology also proves better than the manual method.

A Five-Year Summary of the University of Arkansas Rice Research Verification Program

Mazzanti, R.S., Hardke, J.T., and Watkins, K.B.

Rice (*Oryza sativa, L.*) production is constantly changing as new cultivars are released and new production challenges arise. Producers continue to request the University of Arkansas System Division of Agriculture field-test existing technology to determine the profitability of rice production based on recommended practices. In 1983, the Arkansas Cooperative Extension Service and the Arkansas Rice Research and Promotion Board initiated the Rice Research Verification Program (RRVP). The RRVP is an interdisciplinary effort between growers, county Extension agents, Extension specialists, and researchers. The RRVP is an on-farm demonstration of all the research-based recommendations required to grow rice profitably in Arkansas. The trends in yields, management decisions, and impacts will be presented.

The specific objectives of the program are:

1. To verify research-based recommendations for profitable rice production in all rice producing areas of Arkansas.
2. To develop a database for economic analysis of all aspects of rice production.
3. To demonstrate that consistently high yields of rice can be produced economically with the use of available technology and inputs.
4. To identify specific problems and opportunities in Arkansas rice production for further investigation.
5. To promote timely implementation of cultural and management practices among rice growers.
6. To provide training and assistance to county agents with limited expertise in rice production.

Methods used:
Each RRVP field and cooperator was selected prior to planting. Cooperators agreed to pay production expenses, provide crop expense data for economic analysis, and implement Extension recommended production practices exclusively in a timely manner from seedbed preparation to harvest.

Summary:
Since the program's inception 39 years ago, RRVP yields have averaged 0.9 ton/ha (18 bu/acre) above the state average. The most recent 5-year RRVP average stands at 1.35 ton/ha (20 bu/acre) above the state average. The consistently higher yield averages of the program in comparison to the state average can mainly be attributed to intensive cultural management and integrated pest management.

Drill Row Spacing in Rice, Does it Affect Yield?

McCarty, D.L., Northcutt, C.H., Fruge, A.J., Hardke, J.T., and De Guzman, C.T.

This study was conducted to determine if the drill row spacing have a significant effect on yield of rice cultivars in Arkansas. Six cultivars planted in three different row spacings were chosen for use in this study. Five of the cultivars are commercially available while the sixth is an experimental line. The cultivars are Diamond, CLL16, Titan, RTXL 753, Jewel, and STG18P-01-231. Each of these were planted in three different row spacing as treatment with four replications: 190.5 mm (7.5 in), 254 mm (10 in), and 304.8 mm (12 in) row spacing. This study was conducted in two years (2021 and 2022) with the same management practices and equipment each year.

The test was conducted under conventional tillage practices with the soil being prepared at a 50.8 mm (2 in) depth. The seed was prepared for planting using a 78.43 kg/ha (70 lbs/ac) seeding rate. The plots were planted in a 6 row wide by 4.752 m (15 ft) configuration while being randomized in each replication. After the emergence and growth of the cultivars, each of the plots was trimmed back to a length of 3.658 m (12 ft) to ensure the uniformity of the plot size. The test was then fertilized with approximately 328.81 kg/ha (135 units/ac) of nitrogen and flooded to a depth of 101.6 mm (4 in) for the remainder of the growing season. Once the cultivars had matured, in approximately 85 to 90 days, the flood was removed and the plots were left to dry down. Upon reaching a moisture content in the 18 to 22% range, the plots were reduced to four rows wide by removing the outer row on each side of the plot and harvested. The removal of the outer rows was done to eliminate border effect that will inflate the yield dramatically. Yield was calculated and adjusted at 12% moisture content. Data were analyzed using Analysis of Variance (ANOVA) to detect significant yield differences in mean yields among treatments. Data in 2021 showed that although the 254 mm (10 in) row spacing has the highest mean yield of 15,242.09 kg/ha (226.64 bu/ac) compared to 190.5 mm (7.5 in) and 304.8 mm (12 in) spacing with 14,915.09 kg/ha (221.78) and 14,321.95 kg/ha (212.96 bu/ac), respectively. No significant differences in yield were detected among the three row spacing treatments. In 2022, significant differences were detected where 190.5 mm (7.5 in) spacing has the highest yield of 14,346.28 kg/ha (213.32 bu/ac) followed by the 254 mm (10 in) spacing with 13,243.03 kg/ha (196.92 bu/ac) and 304.8 mm (12 in) spacing with 11,968.53 kg/ha (177.97 bu/ac). Mean comparison for two years showed that the largest difference in yield was between the 190.5 mm (7.5in) and 304.8 mm (12 in) spacing with a 1,485.44 kg/ha (22.09 bu/ac) difference in the two-year average.

Automation for Furrow Irrigated Rice

Blankenship, N.R., Henry, C.G., and Clark, T.

A pit-less tailwater system for furrow irrigated rice, offers many benefits for rice farmers, including improved yields over traditional furrow irrigated rice, reduced water use, no-till, cover crop adoption, reduced labor and equipment, reduced fertilizer usage, and reduced global warming potential. A fertigated and automated system has been developed to meet the needs of climate smart rice.

The automation is composed multiple components. A tailwater pump is optimized for low power consumption and is located at the lowest elevation of the field. A hub controller is the brains of the tailwater system and coordinates the operation of the tailwater pump and pressure compensating valve using a LoRaWAN radio system and a proprietary data packet protocol. The pressure compensating valve maintains the manifold pressure for the water entering the field while also adding irrigation water to the field as needed by monitoring the water level in the bottom of the field at the hub.

In operation, the tailwater pump monitors the water level at the lowest elevation of the field. As the water rises the pump provides increasing flow to recycle the return water to the poly pipe delivering water to the furrows. The pressure compensating valve is modulated to maintain a constant head pressure compensating for the combined variable flow of the tailwater pump and the irrigation water from the irrigation water source. The system provides additional benefit of less labor required to manage irrigation inflows, constant level of water (soil water and return volume) maintained in the field and storage for rainfall in the field, and reduced risk of bursting irrigation pipe.

In addition, a pump timer has been developed for the needs of local farmers. The user can enter the pump delay, pump run time, and the maximum allowable rainfall before the pump is stopped using a display and interface that is waterproof. This device is inexpensive, easy to install, electrically isolated for high voltage safety, restarts upon interruption, and requires little to no maintenance.

Early Cascade Rice Irrigation Shutoff (ECIS) for Improved Cascade Irrigation Management

Jardim, T.M., Massey, J.H., Smith, M.C., Payne, G.K., Reba, M.L., and Henry, C.G.

A conservation-of-mass model was used to simulate early cascade rice irrigation shutoff (ECIS), an approach that aims to improve the efficiency of cascade (levee-gate) flood distribution commonly used in the Lower Mississippi River Basin. With ECIS, a water-level sensor is used to trigger early shutoff of irrigation, allowing one or more downfield paddies to act as "catch basins" for excess irrigation and uncaptured rainfall. The catch basin paddy(s) is managed using agronomics developed for alternate wetting and drying rice irrigation, i.e., supplemental irrigation is added to ensure that a shallow flood is always maintained for 10-day post flood initiation and at early rice reproduction. The model was used to assess how field size and irrigation discharge rate impact irrigation application and field runoff under conventional cascade flood distribution (control), multiple-inlet rice irrigation (MIRI) and ECIS. Results suggest that ECIS uses less irrigation water than conventional cascade flood distribution and can approach the water savings of MIRI, even when accounting for supplemental irrigation added at critical times of rice growth. Key ECIS management strategies are to (a) ensure that after flood initiation, the catch basin paddy(s) is filled before initiating early shutoff and (b) size the catch basin area based on available irrigation delivery rate (L min^{-1} ha^{-1}).

Cascade flooding is used to irrigate approximately half of the rice area in Arkansas. While irrigation water efficiency is increased using MIRI, the continued use of cascade indicates there is a need for innovative management strategies built around cascade irrigation. Using modeling, new cascade management strategies such as ECIS can be evaluated for their potential as a water saving tool and practices refined prior to initiating field trials.

Assessing the Impact of Alternative Management on U.S. Rice Methane Emissions

Reavis, C.W., Reba, M.L., Runkle, B.R.K., Shults, D., Massey, J.H., and Chiu, Y.L.

Rice is a food staple that accounts for 20% of global caloric intake annually. With a growing global population, rice production must continue to improve to meet future demand. Key challenges to the future of rice production include a limited irrigation water supply and increasing methane emissions associated with an expanded production area. Additionally, studies comparing methane emissions globally still indicate a large amount of uncertainty. Thus, there is a need for methods to quantify rice methane emissions across large production regions while also accounting for differences in regional and adapted management practices.

The Intergovernmental Panel on Climate Change (IPCC) has proposed a set of tiered methods that can be used to estimate rice methane emissions in different global regions. In particular, the IPCC Tier 2 method is able to estimate methane emissions under both baseline and sustainable management conditions across different regions. In the United States, we estimated 11 years of emissions in the U.S. Mid-South and California rice producing regions using regional scaling factors for both residue and water management. We also evaluated the recommended regional scaling factors against direct observations made at the field scale in the Arkansas. We found that U.S. rice methane emissions during the growing season ranged between 0.27 and 0.42 Tg annually. Additionally, we found that introduction of a single or multiple aeration event(s) can reduce methane emissions by an average of 0.12 and 0.26 Tg yr^{-1}, respectively. In addition to the inventory estimates, we also developed a spatial representation of methane reduction potential for the U.S. Mid-South and California, which can be used to target or promote the application of sustainable growing practices.

Alternate Wetting and Drying Technique in Italian Rice Cropping Systems

Romani, M., Miniotti, E.F., Noè, D., Celi, L., Said-Pullicino, D., Vidotto, F., Vitali, A., Martinengo, S., and Facchi, A.

The decreasing availability together with the high demand of water resources has strongly evidenced the need to identify and implement rice irrigation techniques which allow to achieve high grain yields per unit of water used, without compromising the hydrological balance of the territory. Rice cropping systems are also asked to reduce greenhouse gases (GHGs) emissions in order to mitigate the impacts on climate change and to improve rice grain quality by decreasing cadmium and arsenic concentrations. In this respect, the adoption of Alternative Wetting and Drying (AWD) can represent a possible solution for Italian rice cultivation.

The research was carried out over two cropping seasons (2021 and 2022) in a 1 ha temperate experimental platform (mean annual temperatures and precipitation of 12.7°C and 700 mm) located within the Rice Research Centre of Ente Nazionale Risi at Castello d'Agogna (45°14'47.7"N; 8°41'55.3"E, NW Italy). Soils are loamy to silty loamy with a pH of 6.3, an organic C content of 9.0 g kg^{-1} and a CEC of 10.0 $cmol_{(+)}$ kg^{-1}. The experimental design comprised a split-plot 3×3 factorial arrangement representing: (i) three water management practices: (a) water seeding and continuous flooding (WFL), (b) water seeding and AWD with a water blade threshold of about 10 cm below the ground level (AWDsafe), (c) water seeding and AWD with threshold of about 20 cm below the ground level (AWDstrong); (ii) three early rice varieties, corresponding to the main Italian grain types (Selenio and Cammeo as subspecies temperate japonica; CL26 as tropical japonica). Two hydrologically isolated 22×68 m plots for each water treatment were setup. All plots were ploughed in spring, laser levelled, rotary harrowed and water seeded (150 kg ha^{-1}) in the second half of May. Urea fertilization was differentiated for each variety (140 kg N ha^{-1} for Selenio and Cammeo; 160 kg N ha^{-1} for CL26), and split between basal, tillering and panicle differentiation stages (30-30-40% for Selenio and Cammeo; 40-30-30% for CL26). Water management in WFL plots involved continuous flooding for most of the growing season, except for a 4–6 d after sowing to allow for plant establishment, and two 4 days mid-season drainage periods for fertilizer and herbicide application. AWD management started after tillering and involved field flooding up to a water level of 10-12 cm whenever the water depth, monitored by means of water tubes, reached the critical thresholds for AWD (10 or 20 cm below the surface). In all treatments, final field drainage was carried out around 20–30 d before harvest. Crop yields, yield components and N contents at harvest, as well as As and Cd contents in white rice were determined. Before harvesting, fungal diseases incidence was evaluated (IRRI, Standard Evaluation System for Rice). CH_4 and N_2O emissions were monitored regularly over the cropping season for Selenio variety by the non-steady-state closed chamber technique. Cumulative annual fluxes of both CH_4 and N_2O were used to calculate the overall GWP and the GHG Eco-Efficiency.

Mean grain yields of around 9.7, 9.7 and 8.6 t ha^{-1} were obtained for Selenio, Cammeo and CL26 respectively, with no significant differences between water managements in both years. Although adoption of AWD did not affect rice yield and yield components, a higher rice sterility was observed in 2021 for Selenio and CL26 varieties (average of 10.7 and 12.5% for Selenio and CL26) with respect to WFL (8.1 and 10.2% for Selenio and CL26, respectively). However, higher spiklets/panicle was observed in 2022 for Cammeo variety in AWDstrong (74.3) with respect to AWDsafe and WFL managements (69.2 and 66.6, respectively). Selenio and CL26 milling head rice yield were nonetheless positively affected by AWD in both years. Conversely, a significant reduction in milling head rice yield was observed for Cammeo under AWDstrong in 2021. Adoption of AWD also reduced the risk of infections by *Sclerotium oryzae*, compared to WFL where higher damages were observed for the Cammeo (in both years) and CL26 varieties (in 2022). Although AWD reduced the total As grain content by 19-26% with respect to WFL (215 ppb), this regime increased the mean Cd grain contents from values around 28 ppb under WFL to 132 and 165 ppm under AWDsafe and AWDstrong, respectively. Both AWD regimes generally reduced CH_4 emissions and slightly increased N_2O emissions with respect to WLF. Compared to WFL that showed a mean GWP of around 8.6 t CO_2-eq ha^{-1} y^{-1}, adoption of AWDsafe and AWDstrong led to a 46 and 71% reduction in GWP, respectively. The decrease in GWP and similar grain yields observed with the adoption of AWD consequently resulted in a higher Eco-efficiency (3.1 and 7.4 kg grain kg^{-1} CO_2-eq for AWDsafe and AWDstrong, respectively) with respect to WFL (1.6 kg grain kg^{-1} CO_2-eq).

The adoption of water sowing in combination with AWD in Italian temperate rice cropping systems mitigated GHG emission while maintaining a high yield performance comparable to traditional WFL management. Furthermore, AWD showed a positive effect by reducing fungal diseases pressure and stresses related to the strongly reducing soil conditions typical of continuous flooding. (This research was supported by Lombardy Region RDP 2014-2020 within the project RISWAGEST- Innovative water management in paddy fields)

Monitoring of the Productive Behavior of Rice Crop at Different Doses of Nitrogen by Remote Sensing in Valencia (Spain)

San Bautista, A., Fita, D., Franch, B., Castiñeira-Ibáñez, S., Tarrazo-Serrano, D., Uris, A., Arizo, P., and Rubio, C.

Crop productivity has been a key factor during the 20th century. Rice yields have increased by 107% in the last 50 years. Genetic improvement and agricultural inputs have played an essential role. Nitrogen can be considered the most critical nutrient in agriculture. Nitrogen is essential for the growth of the rice crop and the achievement of high yields. Spain is an important rice producer within the European Union. In the region of Valencia (N39°16'59.99"; W0°22'0.01"), rice has been cultivated since the 10th century; this region was vital for the crop introduction in Europe. The c'op i" cultivated in a natural park (*l'Albufera de València*) of 21,000 ha; approximately 15,000 ha are used for rice cultivation. This area has no restrictions in years of drought. For example, in 2022, it could represent 8% of rice production in the European Union.

In the first decade of the 21st century, a new, more productive variety (*Jsendra* cultivar) was developed by Spanish scientists; nowadays, it is the most cultivated variety in the region. *Jsendra* has a higher harvest index and crop season than the old varieties and also, is resistant to lodging. To achieve higher yields, the lodging and a shorter crop season was the limiting factor of the old varieties. Therefore, the optimum nitrogen dosage was established at 176 kg N·ha^{-1} (Fertilizers Units, FU). The differences between old and new varieties are evident. For this reason, it is necessary to study the effect of nitrogen and determine the optimum dose in the new *Jsendra* cultivar. In this work, four nitrogen treatments were tested: 130 FU (N1), 176 FU (N2), 243 FU (N3), and 270 FU (N4). N1, N2, and N3 were applied before sowing, while in N4, 220 FU were applied before sowing, and 50 FU were applied 40 Days After Sowing (DAS).

The experiment was carried out in Valencia (Spain) in 2021, each treatment was repeated three times in a completely randomized design, the area of the plots measured 3000 m^2. The crop was flooded during the whole season, except in the interval from 36 to 43 DAS, when the field was dried (nitrogen application). Fifteen days before dry conditions, the Leaf Area Index (LAI) was determined in the field. After the dry conditions, a second LAI measurement was made (47 DAS). The objective was to evaluate the exact moment when nitrogen provoked a positive response in the crop.

For this reason, the experiment was monitored with Sentinel-2 satellite data. The visible (Green and Red) and NIR bands at 10 m spatial resolution were used between the first sampling (21 DAS) and harvest. Finally, the yield of each plot was acquired with a yield monitor equipped on a combine harvester; the main productive parameters were also obtained.

The results show statistically significant differences between the yields of the four treatments ($p<0.05$), the increase in nitrogen dose positively influences yield (N4>N3>N2>N2>N1). In the first 30 season crop days, there was no clear evidence of these differences (there was similar LAI and reflectance measured by satellite). However, after dry conditions (45 DAS), the differences between treatments (LAI and reflectance) appeared. These differences were higher between N1, N2, and N3; but not between N3 and N4. After flowering (85 DAS), significant differences were found between N3 and N4, with N4 showing a higher absorption of visible radiation and a higher reflectance in the NIR band, which resulted in a greater NCMI [NCMI=(NIR-(Green+Red) / (NIR+Green+Red)]. Comparing N3 and N4, the number of filled grains per panicle and the weight of 1000 grains were higher in N4, whereas the number of panicles per m^2 was the same. Thus, grain filling was an important phenological stage for the appearance of differences. Satellite data also showed these differences.

The results of this experiment have been compared with experiments carried out on old varieties (years 1983 and 1987). The new *Jsendra* cultivar showed a better response to the increase in nitrogen dosage. The saturation point of the yield curve could be above 270 FU, while in the old varieties, it was at 176 FU.

In conclusion, Sentinel-2 satellite data could be used to evaluate the three critical moments of rice production (tillering, flowering, and grain filling). Variations in crop management can be analyzed with these data. In this experiment, it was possible to anticipate the positive effect of nitrogen and the application timing.

Summary of N-StaR Nitrogen Recommendations in Arkansas during 2021

Scott, C.L., Roberts, T.L., Williamson, S.M., Drescher, G.L., and Hardke, J.T.

Arkansas has led the nation in rice production since 1973, consistently accounting for over 40% of the country's total rice production. Producers in the state utilize many tools in their efforts to grow rice more efficiently, reduce environmental impacts and increase profitability. One of the tools available is the Nitrogen Soil Test for Rice (N-STaR). The results obtained from direct steam distillation (DSD) of 0-18 in. soil samples from plot-scale N response trials across the state were correlated and used to develop a field-specific, soil-based N test for Arkansas rice. Once comprehensive small-plot and field-scale validations were completed in 2010 by Roberts et al., N-StaR was made available to the public for both silt loam and clay soils. Since then, producers have been able to submit samples to the N-StaR Soil Testing Lab for analysis and to receive N fertilizer recommendations. In recent years, sample submissions have decreased compared to early years of the program's existence. Lower sample submissions were again seen in 2021, perhaps due to consistent precipitation in spring and continued effects of the COVID-19 pandemic. Samples were summarized by county and soil texture and were from nine Arkansas counties. A total of 21 fields were submitted, six of which were clay and 15 were silt loam. The N-rate recommendations generated by N-StaR for samples submitted were compared to the producer's estimated N rate, the 2021 Recommended Nitrogen Rates and Distribution for Rice Cultivars in Arkansas and the standard Arkansas N-rate recommendation of 168 kg N/ha (150 lb N/ac) for silt loam soils and 202 kg N/ha (180 lb N/ac) for clay soils. Each comparison was then placed into one of three designations: a decrease in recommendation, no change in recommended N rate or an increase in the N rate. County, but not soil texture, was a significant factor ($P = 0.04$) in all three comparisons when the N-StaR rate was less than the recommended rate. Reductions exceeding 33.6 kg N/ha (30 lb N/ac) were recommended by N-StaR in 71% of the fields in the standard rate comparison, 50% in the producer's estimated comparison and 74% in the cultivar comparison. These numbers further illustrate the ability of N-StaR to potentially reduce fertilizer input costs for producers.

Yield Responses of Pure-Line and Hybrid Rice to Long-Term Annual Potassium Fertilization

Smartt, A.D., Drescher, G.L., Roberts, T.L., Slaton, N.A., Shafer, J., Hoegenauer, K., Ortel, C., and Followell, C.

Potassium (K) is one of the most limiting nutrients for rice (*Oryza sativa* L.) grown in the direct-seeded, delayed-flood production system common in the U.S. mid-South and substantial yield reductions can occur when produced on soils low in exchangeable K. The likelihood of a positive rice grain yield response to K fertilizer is good when soil-test K is considered Low or Very Low (≤90 mg kg^{-1}). Tissue analysis can also be used to indicate the nutritional status of a crop and help guide nutrient management of U.S. mid-South rice production systems. Rice in Arkansas has shown a positive yield response to fertilizer-K applied to rice as late as flag-leaf emergence, indicating the potential to correct in-season K deficiency with a proper and timely interpretation of tissue-K concentrations. Most previous research in Arkansas has been focused on the response of pure-line rice to K fertilization and inconsistent results of recent studies on the yield response of hybrid rice to K fertilization indicates that additional research is needed. The primary objective of our research was to compare yield responses of pure-line and hybrid rice cultivars to K fertilization in a trial where various K rates (0, 37, 74, 112, and 149 kg K ha^{-1}) have been applied annually for several years. This study was conducted at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS, Colt, Arkansas) in a long-term trial established in 2000 on a Calhoun silt loam. Rice is rotated annually with soybean (*Glycine max*) and both crops are managed according to University of Arkansas Cooperative Extension Service recommendations for pest control and nutrient requirements, except for fertilizer-K management. Composite soil samples from the 0- to 10-cm depth were collected from every fertilizer-rate main plot prior to fertilization and planting, where each main plot was split into sub-plots by drill-seeding a pure-line cultivar (Diamond; 84 kg ha^{-1}; 19-cm row spacing) in one half and a hybrid (RT 7321 FP; 28 kg ha^{-1}; 19-cm row spacing) in the other half. Soil-test K ranged from 49 mg kg^{-1} without fertilizer-K to 84 mg kg^{-1} with 149 kg K ha^{-1} applied annually. With Very Low (<61 mg kg^{-1}) Mehlich-3 K in the no-fertilizer-K control plots, both cultivars responded to K fertilization. Without K application, the pure-line (Diamond) produced 69% of the maximum yield produced when fertilized with K, while the hybrid (RT 7321 FP) produced 56% of the maximum yield. Averaged between cultivars, grain yields of 5.6, 7.3, 8.0, 8.4, and 8.9 Mg ha^{-1} were produced from annual application rates of 0, 37, 74, 112, and 149 kg K ha^{-1}, respectively. Grain yields did not differ from the application of 74 or 112 kg K ha^{-1}, but all other rates resulted in significantly different grain yields from each other. Grain yields were also significantly less from the hybrid (6.9 Mg ha^{-1}) than from Diamond (8.4 Mg ha^{-1}), averaged among fertilizer-K rates, but the interaction of cultivar and K rate did not influence yields. Grain yields of the hybrid cultivar were lower than expected, likely due to lodging at maturity, which was estimated to average 80, 47, 22, 5, and 0% for application rates of 0, 37, 74, 112, and 149 kg K ha^{-1}, respectively, while no lodging was observed for Diamond. Results of this study suggest that RT 7321 FP may be more responsive to K fertilizer than pure-line cultivars, but recent trials observed another hybrid (RT Gemini 214 CL) to be less responsive than pure-line cultivars. Based on inconsistent responses of hybrid rice to K fertilization and the fact that earlier studies predominantly evaluated pure-line cultivars, it is important to continue studying the response of hybrid rice to K fertilization to build a database for proper interpretation of tissue data and potential adjustments to K fertilizer recommendations. Y-leaf tissue samples were collected at the booting growth stage, but analysis of the samples has not yet been completed, so results and interpretation of tissue data will be included when this poster is presented.

Correlation of Post Flood Crop Sensor Readings with Rice Leaf Total Nitrogen and Yield

Williamson, S.M., Roberts, T.L., Drescher, G.L., Smartt, A.D., Hoegenauer, K.A., Ortel, C.C, Followell, C.A., Scott, C.L., and Hardke, J.T.

As technology advances the development of real-time, handheld crop sensors can offer valuable insights on a crop's fertilization response. However, little work has been done to directly correlate values obtained from crop sensors to plant nitrogen (N) content or subsequent rice yields. Two conventional rice cultivars, Diamond and CLL 15, were evaluated using the Trimble GreenSeeker Handheld crop sensor at four weeks and six weeks post flood and at late boot. Plant samples were collected from Y leaves at the four- and six-weeks post-flood timings and flag leaves at the boot timing. All plant samples were dried, ground, and submitted for total N analysis. At the time of rice leaf sample collection Greenseeker readings were taken from the length of each rice plot (5 m) with the sensor held ~1 m above the plant canopy. GreenSeeker readings proved to have a statistically significant (P <0.0001) relationship with plant leaf total N concentrations and rice relative yield. GreenSeeker readings had a significant (P <0.0001) relationship with leaf N concentration at all sample timings, however the four- and six-week post-flood timings had r^2 values of 0.75 and 0.57, respectively, suggesting crop sensor readings at the four- and six-week post-flood timings could be

used as a good predictors of rice N status and potential yield response. Future research should be expanded to other crop sensors that are currently on the market to expand opportunities for producers to monitor rice N status and make in-season applications to maximize rice grain and milling yield.

Influence of Seeding Rate on Performance of New Rice Cultivars

Wright, A., Hartley, H., Frizzell, D.L., Amos, L.R., Clayton, T.L., Castaneda-Gonzalez, E., and Hardke, J.T.

The rice cultivar by seeding rate study objective is to evaluate the response of new cultivars to selected seeding rates to determine the most effective seeding rate throughout the diversity of rice growing environmental conditions in Arkansas. These cultivars were seeded at three locations in Arkansas: the Rice Research and Extension Center (Stuttgart; silt loam soil), the Pine Tree Research Station (Colt; silt loam soil), and the Northeast Research and Extension Center (Keiser, clay soil). The pureline varieties evaluated in 2022 were Ozark, Taurus, PVL03, DG263L, and RTv7231 MA seeded at 54, 108, 215, 323, and 431 seed/m^2; and the hybrids evaluated were RT 7321 FP, RT 7331 MA, RT 7421 FP, and RT 7302 seeded at 43, 65, 86, 108, and 129 seed/m^2. Results indicate currently recommended hybrid seeding rates can produce adequate stands to achieve optimal yields. However, results for varieties indicate that some varieties may achieve optimal yields at lower than currently recommended seeding rates. Additional analysis is needed to determine economically optimal seeding rates. It should be noted that all seed is treated with insecticide, fungicide, and bird repellent seed treatments to achieve and maintain maximum plant stands.

Modelling of Rice Crop Yield Behavior using Remote Sensing

Rubio, C., Fita, D., Franch, B., Castiñeira-Ibáñez, S., Tarrazo-Serrano, D., Uris, A., Arizo, P., and San Bautista, A.

Global food production requires efficient technologies to maintain food security. In this sense, agronomy science needs to adapt its techniques to the current society; sustainable and highly productive agriculture is one of the greatest present and future challenges. Rice is the most essential food for human consumption. Crop modelling is one of the tools that can improve crop productivity and efficiency. Classically, mathematically modelling rice crop yield has been complex, requiring many input parameters, some of which are difficult to obtain. However, there is clear evidence that this tool could change future crop management. With modelling, it is possible to estimate the production value before harvest (up to 3 months before). The yield estimation would be decisive information for crop design and management.

Remote sensing enables the improvement of mathematical models for yield estimation. The new satellite missions (Landsat-9 and Sentinel-2) make it possible to acquire crop information with an incredible spatial (≤30 m), temporal (≤5 days) and spectral (10 electromagnetic bands) resolution. The satellite reflectance measured is related to the crop photosynthetic rate and biomass, essential variables for the achievement of high yields. Thus, it is interesting to obtain models for crop yield estimation with the lowest number of variables. In the present work, mathematical models have been developed with only three solar spectral bands [(Green (555 nm), Red (665 nm) and NIR (840 nm)], for each available date of the Sentinel-2 satellite during the year 2020, and have been validated in the years 2019 and 2021.
The reference yield value was acquired with yield monitors equipped on combine harvesters. Yield data was processed according to scientific literature, and the average value of reference yield was calculated for each Sentinel-2 pixel. The total area studied was 394.38 ha; 249.26 ha were used in the modelling, the fields were located in two rice-producing areas in Spain: Seville (N37°9'42.52"; W5°55'27.59") and Valencia (N39°16'59.99"; W0°22'0.01"). For each available Sentinel-2 date, a linear model was obtained between the three selected bands and the pixel-level reference yield, introducing a dummy variable depending on the area (Seville or Valencia). The total number of models built was nine (for the total number of available dates). The model validation was carried out on 145.12 ha, the model was applied in the years 2019 and 2021. The value of the determination coefficient (r^2) and the mean absolute error (MAE) were used to evaluate the model performance.

The results show that the best yield estimation was obtained 40 days after sowing (tillering phase), the validation MAE obtained was 0.412 t·ha^{-1} in Valencia and 0.248 t·ha^{-1} in Seville. Furthermore, during the entire crop season, the r^2 of the models exhibited a value greater than 0.90. At the field level, a validation MAE of 0.275 t·ha^{-1} was obtained, with an r^2 of 0.95.

Yield differences between the two areas (Seville and Valencia) were evident. Valencia had a lower yield than Seville (a difference of about 2.5 $t \cdot ha^{-1}$). This difference could justify the high value of r^2. However, in the Valencia area, an r^2 of 0.82 (for a total of 52 fields) and a MAE of 0.296 $t \cdot ha^{-1}$ were obtained at the field level. The temporal curve of the NDVI [(NIR-Red) / (NIR+Red)] and NCMI [(NIR-(Green+Red) / (NIR+Green+Red)] indices was obtained for each region and year, showing a high value and initial slope in Seville. Thus, these curves could be presented as a helpful tool to evaluate each region's productive potential, identifying the phenological stages in which the differences are defined. Differences in climatic parameters (range of temperatures and humidity, and the number of sunshine hours) have also been observed between the two production areas. The highest production values correspond to a more significant number of sunshine hours and a wider range of temperatures throughout the crop season, variables that, according to the literature, significantly influence the productive behavior of the crop.

In conclusion, it is worth saying that global modelling is possible for different rice production zones with high r^2 values. According to the results, it would be convenient to include in the modelling the climatic variables. These variables could be necessary to explain the differences between the cultivation zones. Remote sensing could also be a promising tool to optimize crop management within the field and to refine breeding plans. That is, the properties of the crop and its interaction with the weather are manifested in the reflectance satellite value.

Evaluation of Field Sampling Protocols for Measuring Grain Yield in Drill-Seeded Rice

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

Accurate estimation of grain yield is essential when optimizing rice management practices. Techniques based on the number of tillers (breeders' method; BM) or plant area (quadrat method; QM) are often used to estimate grain yield in plot-scale experiments. However, the accuracy of these methods maybe challenged by variations associated with different genotypes and growing environments. In this study, rice grain yields using BM and QM were compared to yields obtained using combine harvester (CH) for two commercial fields and one research field. The field studies were designed to test how irrigation (continuously flooded; alternate wetting and drying; furrow irrigation), winter cover cropping, rice cultivars (hybrids and inbreds) and/or N-rate impact rice yield. Across all fields and management treatments, calculated grain yields ranged from 5.22 to 14.0 Mg hc^{-1}. Grain yields estimates using QM were not significantly different from yields measured by CH (P-value = 0.982) but were significantly different from yields estimated using BM ((P-value = <0.0001). Only the grain yield estimates using QM were highly correlated to yields generated by CH (coefficient = 0.450; P-value = 0.013). For BM estimates, adjusted yields using actual 1000 grain weight of various rice cultivars were similar to grain yields calculated using the default value of 25 number of grains.

These results demonstrate that the quadrat method better predicts plot-scale yield relative to whole-plot results obtained by mechanical harvesters. The less time-consuming breeders' method is more suitable for qualitative yield assessments but does not reliably reflect whole-plot variability better captured by quadrat and mechanical harvest methods.

Effects of Rice and Biomass Sorghum Production on Soil Organic Carbon and Total Nitrogen Contents at Beaumont Field Experiment

Araji, H.A., Bera, T., Dou, F., Yang, Y., and Wilson, L.T.

A replicated field experiment for production of rice and biomass sorghum was conducted at the Texas A&M AgriLife Research Center in Beaumont, Texas, in 2020 and 2021 to determine the effects of year, crop type, timing of sampling, and depth of soil cores on the percentages and total mass of carbon and nitrogen in rice and biomass sorghum soils. A hydraulic Giddings rig was used to collect soil cores to a depth of one meter before planting and immediately after harvest each year. Soil bulk density and soil organic carbon and nitrogen were estimated for 0-10, 10-25, 25-50, and 50-100 cm depths. The percent of the soil comprised of carbon was significantly affected by year and soil depth, but total soil organic carbon was significantly affected by year, crop type, soil depth, and year × soil depth. The percent of soil comprised of nitrogen was significantly affected by year, and soil depth, but total organic nitrogen was significantly affected by crop type, soil depth, year × crop type, and crop type × soil depth. Soil C:N ratio was significantly affected by year, soil sample timing, soil depth, year × soil sample timing, and year × soil depth. For both years, total soil organic carbon and nitrogen storage for biomass sorghum as a C4 crop was higher than rice which is a C3 crop.

Estimation of the Number of Suitable Fieldwork Days Required to Plant the Arkansas Rice Crop

Badarch, B., and Watkins, K.B.

Extreme weather events like excessive rainfall and/or cold weather temperatures in the planting season can negatively affect the number of suitable fieldwork days available for planting. Weather dictates the number of days suitable for planting rice, *Oryza sativa L.*, and can lead to either a shortened planting window or later planting dates. A shorter planting window caused by extreme weather variability can negatively affect rice grain yield potential. A late planting season can also lead to delayed harvest in the fall, where rain and/or dew could lead to reduced rice kernel quality and higher drying costs.

We examine Arkansas' historical rice planting progress by using annual rice planted hectares, weekly rice planting progress data, and the number of suitable fieldwork days per week obtained from the U.S. Department of Agriculture, National Agricultural Statistics Service for the period 1981 to 2022. Based on these data, we seek to answer the following three main questions: 1) what is the maximum daily number of rice hectares that can be planted in Arkansas? 2) what is the minimum number of days required to plant the entire rice crop in the state? and 3) how many days are suitable for fieldwork during the optimal rice planting window for the state? We arrive at answers to these questions using methods for calculating similar statistics for corn in the Corn Belt found in the literature. The procedures we use are as follows:

1) We estimate the maximum Arkansas rice hectares planted per suitable fieldwork day for each year by multiplying each week's rice planting progress percentage for a given year by the total rice hectares planted each year, summing the two peak weekly hectares planted, and dividing them by their respective sum of suitable fieldwork days,

2) we calculate the minimum number of suitable fieldwork days required to plant the rice crop each year by dividing the total state-planted rice hectares by the estimated maximum rice hectares planted per suitable fieldwork day.

3) We calculate a frequency distribution to determine historical probabilities for the number of available suitable fieldwork days per week during the last week of March through the third week of May planting window in Arkansas.

We found the average maximum number of hectares planted per suitable fieldwork day to be slightly over 23,067 ha (57,000 ac). About 22 days is the average minimum number of suitable fieldwork days to plant the entire rice crop in Arkansas for the 42-year period. We then evaluated the distribution of suitable fieldwork days per week for the optimal planting window and found the average number to be 4.5 days for the study period. Probabilities for the number of suitable fieldwork days per week varied from a 19% chance for either two or three suitable fieldwork days occurring per week to a 31% chance of either six or seven fieldwork days occurring per week.

There was no significant trend in the maximum number of rice hectares planted per suitable fieldwork day or the minimum number of suitable fieldwork days over the 42-year period. However, there were significant variations around the means of the previous two statistics resulting from varying weather conditions, with variations being more pronounced over the last couple of decades (2000-2022). Untimely or extreme precipitation events had significant delaying impacts on the timing of rice planting during the 2000 and 2022 period relative to the 1980s and 1990s, and our data results bear this out.

Our findings are informative and helpful for Arkansas rice producers and will provide interesting historical perspectives on the state's rice planting performance. The actual statistics are practical and should be useful for future rice planting decisions.

California Rice Crop Rotation Online Calculator: Development and Demonstration

Brim-DeForest, W.B., Rosenberg, S., Bruno, E., Lam, C., Tooyserkani, B.,
Zorlu, H., Martin, T., and Pittelkow, C.

Over the past year, in response to outcomes from a grower survey about crop rotation in California rice, we developed an interactive decision support tool meant to support rice growers in the Sacramento Valley of California and other interested persons in understanding the possible economic impacts of switching from rice over to a rotation crop. The calculator was developed in collaboration with the University of California Integrated Pest Management (IPM) Team and was supported with a grant through the Western IPM Center and USDA NIFA.

The crop rotation calculator was developed to explore how different production decisions may impact profitability in the year following rice. This is an interactive decision support tool that calculates the short-term profitability of switching from rice over to a rotational crop including tomato, sunflower, safflower, and dry beans. Crop rotations have been shown to support several agronomic challenges related to pests, and resistance issues, by disrupting pest life cycles, as well as allowing for the use of pesticide modes of action not available in a continuous rice system. Rotations may also help to improve long-term soil health functions like improved soil structure and increased nutrient cycling and uptake.

During the summer of 2021, four focus groups were held to evaluate the economic costs and requirements for switching from rice over to a rotational crop. While University of California Cooperative Extension (UCCE) cost of production studies are available for these crops individually, we focused specifically on the experiences of rice growers who rotated with other crops from rice. Our goal was to shed light on the additional time and effort of finding new markets and learning a new crop, as well as required changes in equipment, land preparation, labor, and irrigation that may be expected when switching from a flooded rice system to a rotational crop. Hence, these focus groups were a crucial step for understanding how rice growers' conditions differ from common row crop growers and how these conditions correlated to different economic outcomes for production. To supplement the focus group outcomes, UCCE cost studies and partial budgets were also used to extrapolate prices for relevant cost components for the individual crops. Costs were calculated for each crop ($ per acre). We used the cost-benefit equation, *Profit = Revenue - Costs*. In cost-benefit analysis, any component of revenue or costs that changes as a result from the changing practice can be either a benefit or a cost. For example, if less fertilizer is required because of the new practice (in this case switching to a different crop), this is a benefit.

Prices used for the baseline rice crop may not be representative of every farm or ranch. This cost study also does not include infrastructure costs and may be missing other cost components. Equipment costs were based on UCCE cost assumptions and included overhead and operating costs. Operating costs included fuel and repair costs, while overhead costs for equipment were estimated in each study using Capital Recovery to value annual depreciation and interest rate of capital investments. Annual overhead and operating costs were converted to average hourly rates then scaled to $/acre. With this method, it is important to note that values will be different based on grower's average land size and the total hours of equipment use.

The calculator was presented for review to a group of industry members and growers at a UC Rice Integrated Pest Management (IPM) Workgroup Meeting in February 2022 and was subsequently updated to its current form and was officially launched in November 2022.

Economic Assessment of Rice Quality in Arkansas

Durand-Morat, A., and Nalley, L.L.

Because rice is a field-to-plate crop, unlike wheat, maize and soybeans which are typically processed, visual attributes can often drive demand and price. Globally, consumer preferences for rice are heterogenous, and there is growing evidence that indicates consumers are increasingly aware of rice quality, even amongst low-income households.

The amount of broken rice is one of the main indicators of rice quality and affects not only the visual aspect of rice and, potentially, consumers' willingness to pay but also directly affects the price farmers receive in many countries, including the United States. While it's known that broken rice can affect profitability and affect U.S. export markets, little is known about the actual economic value of rice quality. With that in mind, this study assesses the economic impact of improving milling yields in Arkansas. We built a rice production model for Arkansas from 2004 to 2020 using historical area harvested by rice variety paired with yearly varietal specific yield and milling rates from the Arkansas Rice Performance Trials (ARPT, various years). We used the model to run two scenarios, namely:

1. An across-the-board improvement in milling quality resulting in a 1%-point increase in head rice yield (HRY) and no changes in milling rate yield (MRY) for each variety in each year, which consequently reduces the broken rice rate by 1% point. Paddy rice production was assumed constant, which together with the assumption of no changes in MRY results in no changes in milled rice production (QM) relative to the baseline.

2. A milling quality for each variety at least equal or better than RoyJ, an inbred variety described as having "good milling potential." As such, any variety i in year t which had either an MRY or HRY less than the average milling rate of RoyJ is replaced with the average RoyJ milling values.

For scenario 1, the results suggest that the value of the Arkansas rice crop would increase by an average of $5.54 million annually, or 0.4 percent relative to the baseline average annual value of the rice crop. Moreover, such improvement in rice milling quality generates between 54.75 and 64.41 thousand metric tons (tmt) of additional milled rice a year, which is enough to feed between 895 thousand to 1.05 million people annually at the average global per-capita consumption of 61.2 kg. Under scenario 2, the average economic value of the Arkansas rice crop increases by $24.48 million annually, and result in between 179.76 tmt and 211.48 tmt a year of additional milled rice produced, enough to feed between 2.94 and 3.46 million people a year.

It is important to state that the increase in the value of the rice crop discussed above amounts to the benefit farmers will receive but does not account for changes in the value of the milled rice sold. The value of selling more milled rice across all milling qualities (100% heads to 15% broken) is expected to increase because of the higher milling quality assumed in scenarios 1 and 2 and likely to surpass the value added to the crop.

Consumer Valuation of Rice Quality in Colombia

Phillips, J., Durand-Morat, A., and Nalley, L.L.

Colombia is the third largest rice producer in Latin America, with an average of 1.87 million metric tons (milled basis) produced annually in 2019-21. However, it is around 90% self-sufficient and relies on import to cover a growing demand.

Colombia protects its domestic rice market with a high 80% import tariffs on rice coming from all WTO members but applies preferential rates to Ecuador, Peru and the United States under regional trade agreements. Because of the preferential access granted to U.S. rice under the Colombia-U.S. Preferential Trade Agreement, Colombia has become a top destination for U.S. long-grain rice, ranking 4th in 2021/22 after Mexico, Haiti, and Iraq. As the preferential treatment increases in the coming years, it is expected that more U.S. rice will make it into Colombia.

The goal of this study is to assess consumer preferences for rice quality in Colombia. To our knowledge, this is the first study assessing the economic value of rice quality in Colombia. In particular, we focus on consumer preferences for rice with different broken percentage. Broken rice is considered a sub-product of rice milling and carries a significantly lower price than head rice. Broken rice not only lowers the economic value of the rice crop but also reduces the rice available for food consumption. Broken rice is used as pet food in many countries despite the fact that it has the same nutritional value as head rice.

A choice experiment was implemented in Cali and Palmira, Colombia, in April of 2022. A total of 400 consumers were surveyed. Consumers were presented with five choice sets of three clear-bagged, half-kilo samples of rice with varying levels of broken (5%, 10%, 15%, 20%, and 30%) and prices (varying from 2,500 to 8,500 COP/kg), and a no-buy option. In each choice set, consumers were asked to choose the most preferable option, including the no-buy option. Consumers also answered a socioeconomic questionnaire, which included a number of questions about their rice-eating behavior.

The preliminary result show that Colombian consumers are indifferent about the percentage of broken rice. In other words, consumers are not wiling to pay a premium for rice with low (5%) percentage of broken, despite the fact that "gourmet rice" with low broken percentage seems to be a growing segment of the market in Colombia. The findings are relevant as they show that consumers may have other motivations (e.g., brand loyalty or other credence attributes) to purchase high-quality rice aside the broken percentage.

Economic Analysis of Furrow Irrigated Rice (FIR) and Flooded Rice Production System

Mane, R.U., Mohite, D.B., Henry, C.G., and Watkins, K.B.

Furrow Irrigated Rice (FIR) is an upland rice production system that involves irrigating rice with furrows. Since 2016, FIR production in Arkansas has increased from 16,187 hectares (40,000 acres) to an expected planting of 80,937 hectares (200,000 acres) in 2020. The objective of the paper is to compare the economics of the FIR production system with conventional flooded production systems. There is currently very little information available about the economics of the row rice system, and it is imperative for producers to know the economics of this system before they get involved with it. Actual field trials for this system were conducted from 2016 to 2020, and data with respect to production costs and net revenues are summarized and reported in this paper.

The University of Arkansas 2016 - 2020 Crop Enterprise Budgets are used to study profitability of rice under FIR systems when compared with conventional flooded system from the Rice Research Verification Program (RRVP). Economic data from 10 different FIR plots are compared with conventional flooded production systems using data from four different producers. Producers provided production data sheets listing inputs, equipment used, and timing of operations, and these data were used to develop crop budgets.

The Wilcoxon rank-sum test was utilized to understand better their comparative influence on crop productivity and net returns. Based on producer level data from 2016 to 2020, the research concludes that there was no significant difference in the cost of fertilizer, chemical (herbicide), tillage operation, irrigation cost, and net returns between the flooded and FIR rice cultivation system.

Comparative Economic and Environmental Assessments of Furrow- and Flood-Irrigated Rice Production Systems

Nalley, L., Massey, J., Durand-Morat, A., Shew, A., Rarajuli, R., and Tsiboe, F.

Rice, Oryza sativa L., producers in the Mid-South of the United States face decreasing groundwater availability and increasing pumping depths which may jeopardize sustainable rice production. Recently, producers have started adopting furrow irrigated rice (FIR) which reduces irrigation requirements by approximately 17% compared to conventionally flooded rice (CIR). Although driven by water savings and ease of planting and harvesting, as FIR does not require levees to be built, there are both yield (quantity) and milling (quality) concerns with FIR production. While some view FIR as a more sustainable production practice because of its reduced water usage, a comprehensive Life Cycle Analysis (LCA) has not been conducted to compare the two production systems. This study compares the economic (yield differences, NPV of water conserved, and milling discounts/premiums) and environmental (a stepwise LCA which monetizes the holistic environmental of CIR and FIR on a per kg of rice basis) differences between CIR and FIR. Profitability results indicate that CIR is more profitable and LCA results show that CIR is more environmentally sustainable. These results present a Gordian knot for policy makers and rice stakeholders alike as they struggle between a production practice that has a lower environmental impact (CIR) versus one that conserves water, reduces soil disturbance, and offers more flexibility to respond to market and weather conditions (FIR). Water savings has historically been a key focus of rice production from an environmental sustainability standpoint. Our research indicates that failure to both recognize and quantify holistic environmental metrics besides water savings may provide misleading recommendations.

Impacts of Weather on Rice Grain Yields in Eastern Arkansas

Watkins, K.B., and Badarch, B.

There is currently a need to better understand uncertainty in rice grain yields due to weather. Although rice is an irrigated crop, weather can greatly affect rice grain yields. High summer temperatures and high summer nighttime temperatures can cause stress to rice resulting in lower rice grain yields and reduced milling quality. Excess spring rainfall and cooler than average temperatures can push rice planting to later dates, resulting in significantly reduced rice grain yields. The objective of this study is to determine how precipitation and temperature affects rice grain yields in eastern Arkansas.

Eastern Arkansas county rice yields and county rice planted hectares were obtained from the USDA National Agricultural Statistics Service for the period 1980 to 2021. Quadratic and linear yield trend equations were estimated for each county. If the quadratic term was statistically significant, a quadratic trend was used, otherwise a linear trend was used. Trends were then removed from all county yield data to remove the effects of technological change over time. Monthly weather variables (precipitation, average temperatures, and average minimum temperatures) were obtained for each county for the period 1980 to 2021 using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) interactive tool. PRISM allows the user to obtain spatial climate data for the conterminous United States.

Fixed effects regression models were used to pool time series and cross-sectional data in this study. Fixed effects models assume cross-sectional units can be adequately captured by different intercept coefficients or dummy variables. Counties represent cross-sectional units, and rice grain yields, rice planted hectares, and weather variables represent time series observations. Models were estimated for three regions: 1) Northeast Arkansas (Clay, Craighead, Greene, Jackson, Lawrence, Mississippi, Poinsette, and Randolph counties); 2) East-central Arkansas (Arkansas, Cross, Lonoke, Monroe, Prairie, Phillips, St. Francis, and Woodruff counties); and 3) Southeast Arkansas (Ashley, Chicot, Desha, Drew, Jefferson, and Lincoln counties). Counties with several missing yield observations were excluded. Detrended county rice grain yields (kg/ha) represented the dependent variable for each model. Independent variables included county rice planted hectares (1,000 ha), monthly precipitation (mm) for March through October, monthly average temperatures (°C) for March through July, monthly average minimum temperatures (°C) for August through October, and dummy variables for each county within each region.

Weather variables had both positive and negative impacts on rice grain yields, but weather impacts tended to vary by region. Precipitation had a negative impact on rice grain yields in all three regions during March and April, particularly in East-Central Arkansas and Northeast Arkansas (statistically significant at either the 1 percent or 5 percent levels). March and April precipitation had less impact on rice grain yields in Southeast Arkansas (not statistically significant in March; only statistically significant at the 10 percent level in April). Precipitation in May, June, and July tended to have a negative impact on rice grain yields in all three regions, but impacts were statistically significant during select months when moving south to north (statistically significant in May, Southeast Arkansas; statistically significant in July, East-central Arkansas; statistically significant in June and July, Northeast Arkansas). Precipitation had a positive impact on rice grain yields in all three regions in September, but the positive impact was statistically significant only in Northeast Arkansas and East-central Arkansas. October precipitation tended to have a negative impact on rice grain yields, with the largest negative impact occurring in Northeast Arkansas. Higher average temperatures increased rice grain yields during April and May in all three regions (statistically significant at the 1 and 5 percent levels) but reduced rice grain yields during June and July in all three regions. The negative impact of average temperature on grain yields was significantly larger in July (1 percent level) relative to June (5 percent level) in all three regions. Higher average minimum temperatures during the month of August reduced rice grain yields in all three regions (statistically significant at the 1 percent level). Higher average minimum temperatures during September and October increased rice grain yields in all three regions.

Expected Monetary Payoffs of Planting Rice in Alternative Planting Windows and Different Weather Outcomes

Watkins, K.B., Gautam, T.K., and Hardke, J.T.

The timing of rice planting, the type of cultivar planted, and weather can greatly affect the profitability of rice production. Earlier studies focused on the impacts of rice planting timing on grain yields and/or milling yields and concentrated almost exclusively on public pure-line rice cultivars. The earlier studies also did not evaluate the impacts of planting timing on rice profitability. The main objective of this study is to evaluate the impact of rice planting date and cultivar type on rice net returns per hectare (gross returns less variable and fixed expenses) during dry, wet, and normal rice growing seasons.

Primary data for this study come from Degree-Day 50 (DD50) rice cultivar thermal unit threshold studies conducted annually by the University of Arkansas System Division of Agriculture (UADA) for the purpose of maintaining the DD50 computer management aid used by Arkansas rice producers. Grain yields, whole kernel milling yields, and total milling yields were collected by planting date, cultivar, and year for the period 2012 through 2021. All data come from studies conducted at the UADA Rice Research and Extension Center (RREC) near Stuttgart, Arkansas, and focus exclusively on long-grain cultivars.

Net returns were standardized to contemporary 2019 – 2021 average values for comparison across all ten years. Gross returns were calculated as the product of rice grain yields and milling adjusted rice prices. Milling adjusted rice prices were calculated based on whole kernel and total rice milling yields recorded by cultivar and planting date in the DD50 studies, the three-year average U.S. long-grain harvest price (August through October) obtained from the USDA National Agricultural Statistics Service, and three-year average long grain loan values for whole and broken kernels obtained from the USDA Farm Service Agency for the period 2019 – 2021. Milling adjusted long-grain prices were calculated based on a standard milling yield of 55/70. Production expenses by cultivar type were calculated based on three-year average variable and fixed expenses by rice cultivar type obtained from UADA crop enterprise budgets for the period 2019 – 2021. Three cultivar types were evaluated in the study: 1. Long-grain pure lines; 2) long-grain herbicide tolerant non-hybrid proprietary lines (herbicide-tolerant lines); and 3. Long-grain hybrid proprietary lines (hybrid lines). Hybrid lines included both herbicide non-tolerant hybrids and herbicide-tolerant hybrids.

Planting dates were grouped into planting windows based on the percent of rice hectares planted on a weekly basis by month and year as reported by the USDA National Agricultural Statistics Service, Arkansas Field Office. Three planting windows were created based on these historical data: 1. Early Planting Window (March 11 – April 14); 2. Middle Planting Window (April 15 – May 14); and 3. Late Planting Window (May 15 – June 30). A payoff matrix approach was used to evaluate the economic impacts of different planting windows and cultivar types on rice profitability given different weather outcomes during the growing season. A payoff matrix shows the payoffs (expected net returns per hectare) associated with choosing specific actions (planting different rice cultivar types in different planting windows) given possible states of nature (weather outcomes) for which decision makers have little or no control.

The results of this study demonstrate that weather in the growing season not only dictates when rice can be planted but also has a significant impact on the monetary payoffs associated with the timing of rice planting. Monetary payoffs per hectare in dry and normal growing seasons tend to be greatest when planting early (March 11 – April 14) for all cultivar types evaluated in the study. Alternatively, monetary payoffs per hectare in wet growing seasons tend to be greatest for most cultivar types (long grain pure lines and hybrids) when planted later (April 15 – May 14). Monetary payoffs per hectare for herbicide tolerant non-hybrids are significantly smaller relative to other cultivar types when planting occurs in the middle (April 15 – May 14) and late (May 15 – June 30) planting periods, indicating hybrids and long grain pure lines should be considered rather than herbicide tolerant cultivars when early planting is not feasible. The results of this study are applicable to east-central Arkansas, or more specifically the Grand Prairie region of Arkansas, and may vary for other rice producing regions in Arkansas.

Abstracts of Posters on Economics and Marketing
Panel Chair: Brad Watkins

Variability in Rice Returns using a Representative Farm Approach

Dimas, A.M., and Deliberto, M.

Agriculture is a major contributor to the U.S. economy and vital to the continued availability of a safe and inexpensive food supply. In 2007, the value of products sold was $297 billion (USDA, 2007 Census of Agriculture), a 48% increase over 2002. The total number of farms during this period increased by 4% (75,810 farms) and 291,329 new farms began operation. Representative farms are virtual farms that represent the production practices of a specific crop and region. A unique capability of the representative farm system is the ability to assess how much risk each modeled farm may encounter. The construction of such farms has been accomplished using projected prices, input costs, and policy parameters from the annual baseline and incorporating historical risk components with a whole-farm simulation model that incorporates historical variability, simulates the farm a specified number of times per year of analysis.

The results of these simulations are tabulated, and the probabilities are reported. The probability of a cash flow shortfall, ending cash going negative, and the farm losing real net worth are just a few of the parameters used to determine how much risk farms face. The representative farm approach treats a farm business unit as a unique system characterized by local features and resources and assumes adaptations are made by farm management. Local conditions are internalized in the creation and simulation of each farm. The first phase in the creation of a representative farm begins with a local facilitator coordinating meetings for four to eight producers in each area that are similar in size, structure, and type of farming or ranching operation. Data collection is an iterative process of focus group sessions initiated by a local facilitator collecting data that would be representative of a farm in the region with details collected on farm structure, existing assets and liabilities, input costs, income of the farm and machinery necessary to operate the farm. New data is collected or updated for each of the representative farms on a three-year rotating schedule. This for the purpose of evaluating the impact that alternative rice cultivar selection and competing crops have on producer net returns using stochastic efficiency with respect to a function criterion.

Simulation as an analytical tool continues to gain popularity in industry, government, and academics. For agricultural economists, the popularity is driven by an increased interest in risk management tools and decision aids on the part of farmers, agribusinesses, and policy makers. Multivariate empirical distributions (MVE) is used in this study, it simulates random values from a frequency distribution made up of actual historical data and has been shown to appropriately correlate random variables based on their historical correlation. Parameters for the MVE include the means, deviations from the mean or trend expressed as a fraction of each variable, and the correlation among variables. The MVE distribution is used in instances where data observations are too few to estimate parameters for another distribution. Much of the recent interest in risk analysis in agriculture comes from changes in the farm program that ushered in an era of increased uncertainty. With increased planting flexibility and an abundance of insurance and marketing alternatives farmers face the daunting task of sorting out many options in managing the increased risk they face. Like farmers, decision makers throughout the food industry are seeking ways to understand and manage the increasingly uncertain environment in which they operate. The unique abilities of simulation as a tool in evaluating and presenting risky alternatives together with an expected increase in commodity price risk will likely accelerate the interest in simulation for years to come. The use of farm-level simulation techniques and the use of risk analysis gives managers a better feel for the impacts of alternative marketing strategies and illustrates the inherent uncertainties surrounding an intensely competitive environment.

Stochastic Efficiency with Respect to a Function (SERF) orders a set of risky alternatives in terms of certainty equivalents (CE) calculated for specified ranges of risk attitudes. The use of farm-level simulation techniques and the use of risk analysis gives managers a better feel for the impacts of alternative marketing strategies and illustrates the inherent uncertainties surrounding an intensely competitive environment. This method has been effective for determining profitability of different farm management practices such as tillage methods. The concepts of certainty equivalents (CE) are used to evaluate risky alternatives over a specified range of lower and upper bound absolute risk aversion coefficients. Certain Equivalent values can be described as the value of a particular payoff a decision maker would require for the opportunity of a higher payoff but at an uncertain amount. Graphical mapping of CEs of risky outcomes over a range of absolute risk aversion coefficients (ARAC) facilitates ordinal rankings for decision makers with different risk attitudes. Risk premiums may also be calculated using SERF analysis.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Griffiths Atungulu

Feasibility of Fumigant Reduction Based on Early Detection of Insect Activity in Rice Storage by using Wireless SmartProbe System

Pan, Z., and Khir, R.

Reducing the chemical use for insect control and associated cost is very important for the rice storage. In the past four years, with the support from the California Rice Research Board, we have successfully demonstrated a SmartProbe wireless early detection technology to catch insects in stored rice when insects emerge. It is believed that insect infestation generally starts from the top layer of rice and then gradually moves down to the bottom. Therefore, only the top layer of rice in storage, instead of the entire product, needs to be treated if the insects are detected early. The objective of this study was to investigate the movement behavior and mobility of insects in rice and control method. Insect catching devices equipped with video cameras and the sensors of temperature and relative humidity were designed and built to study the movement behavior and mobility of insects in rice. The devices were used to conduct tests in our laboratory and a commercial storage facility. A top layer treatment practice based on the new smart probe insect detection was applied. The obtained results indicated that the insect infestation and activities started in the top layer of rice mass. The insect infestation can be controlled in the top layer of the rice by applying surface treatment using insecticides. The new practice used only 20% of chemical that was used for fumigating entire product. It was concluded that the adoption of the new SmartProbe system for early detection of insect activity and application of top layer treatment can maintain the product quality, reduce treatment costs, and mitigate food safety, health, and environmental concerns.

Commercial Demonstration of a SmartProbe System for Early Detection of Insect Pests and Environment Monitoring

Pan, Z., and Khir, R.

Insect infestation during the storage of rice is a dire problem leading to spoilage, quality loss, food safety risk, and contamination. At present, insect activities in rice during storage are typically monitored by human visual inspection. Insects can only be found when their population is large and the damage to the rice quality has happened. This can reduce product quality and cause a significant economic loss. Therefore, early detection of insect activity in stored rice can maintain the product quality, reduce the chemical fumigation and associated costs, and mitigate food safety, health, and environmental concerns. The objective of this study was to demonstrate a SmartProbe technology for the early detection of insect pests in commercial rice storage. The SmartProbe system, consisting of insect probe, a cloud server, and a user interface, was developed and demonstrated in nine commercial storage facilities in California. The new detecting system was programmed to take images periodically or on-demand. Data and images were processed in a cloud servicer. The server processed the images and counted the captured insects with an insect-counting algorithm. The system also recorded temperature and relative humidity. The user interface displayed images of insects, insect numbers, temperature, and relative humidity. The results showed that the SmartProbe system was able to early detect insect activities in all tested storage facilities and simultaneously monitor temperature and relative humidity of the rice. The first insect was detected the next day after the system installation in all of the tested storage facilities in late April 2021. The number of insects continued to increase during the test periods. However, the human inspection in all tested storage facilities did not find any insects during the entire test periods until tests were stopped. Additionally, the new smart technology was able to catch and detect different types of insects. The findings of this study confirmed that the new technology provides a novel detection method for insect infestation problems. It can make a significant impact in the rice industry, including eliminating the labor and costs from human inspection, preventing from the product damages and economic losses, and reducing food safety risks, and chemical use and related cost.

On-Farm In-Bin Drying of Rice with Advanced Moisture Monitoring and Automated Fan Control Systems

Atungulu, G., and Luthra, K.

Most on-farm systems use either natural or slightly-heated air to dry freshly-harvested, high-moisture content rice to prevent excessive respiration and mold growth on grains. However, the duration required to achieve drying is greatly affected by weather conditions. The real problem is that the weather may not allow complete drying of the rice, particularly the upper layers, in a timely manner. When this happens, there is a great possibility for mold growth in the grain mass, with potential mycotoxin development, and "quality" deterioration including staining, milling yield reduction, and sensory and functional problems. New technology for use in on-farm drying systems, popularly referred to as "cabling technology" offers a means to utilize the advantages of low-temperature, in-bin drying systems, yet prevent the disadvantages that are sometimes incurred with these systems. The new technology controls drying fan operation by the principle of Equilibrium Moisture Content (EMC). Our research, through lab- and field-based experiments as well as simulations and modeling of the EMC-based in-bin drying, sought to answer primary and practical questions that are needed to successfully implement the new in-bin drying systems.

Abstracts of Posters on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Griffiths Atungulu

Control of *Rhyzopertha dominca* through Stored Grain Protectants

Doherty, E.M., Sun, Q., and Wilson, B.E.

Rice growers are increasingly storing their harvests in on-site grain bins for extended periods, exacerbating the impacts of stored grain pests. Fumigants have been the most common form of pest management in stored grains, but concerns over resistance are driving the development of alternative methods for controlling stored rice pests. Here, we investigated five grain protectant insecticides: methoprene, deltamethrin, a commercial formulation of methoprene with deltamethrin, diatomaceous earth, and beta-cyfluthrin. Treatments and a control were applied to rice stored in 5-gallon trash bins (N=50). Then, 50 lesser grain borers, *Rhyzopertha dominica*, and 50 rice weevils, *Sitophilus oryzae*, were added to each bin every month. To assess product efficacy, each month a grain probe sample was taken from each bin, and beetles were counted. Additionally, vials of rice were removed from each bin each month. Ten *R. dominica* or *S. oryzae* were added to each vial. After 2 weeks, beetle mortality was calculated for each vial, and after 8 weeks, progeny were counted. After 6 months, the frass and beetle biomass of each grain bin was weighed. Control of beetles varied widely between treatments, signifying the importance of using effective insecticides to mitigate rice damage and manage pest populations.

Increasing Resistant Starch in Rice with Three Starch Synthesis Genes

Everette, J.D., Grunden, E., Pinson, S.R.M., and Chen, M.-H.

Resistant starch (RS) is defined as a portion of the starch that, after consumption, resists digestion in the small intestines of healthy humans and instead reaches the colon where it is fermentable by the microbiota. RS is a type of dietary fiber, and its consumption improves gut health, adiposity and insulin resistance, and decreases cardiovascular disease risk factors. Cooked rice high in RS has lower glycemic index than rice low in RS which would improve the consumer's confidence in consuming rice. Fried foods using high RS rice flour maintain rice flour's low oil absorbance property compared with wheat flour, and have acceptable texture. Understanding genes and their interactions in association with RS would help rice breeders in developing rice varieties with health benefit properties for different uses.

The U.S. variety Katy is a long-grain rice with translucent kernels (Tr) and low RS. A Katy mutant line (katym) with opaque grain phenotype (Op) was identified in a M5 Katy mutant population (USDA-ARS Genetic Stocks-Oryza collection). Further analysis showed that katym grains had higher apparent amylose content (AAC), significantly lower paste viscosity and lower gelatinization temperature (GT), relative to those of Katy wild type; while these functional traits of katym were significantly different from those of IR36ae (a high RS *beIIb* mutant) grains suggesting potentially a different starch synthesis related gene mutation in katym. We mapped the novel katym mutation in recombinant inbred lines (RILs) derived from crossing katym with IR36ae. In addition, this mapping population generated the RILs with three starch synthesis genetic variants, *Wx* of intermediate amylose (Wx^{i}) and high amylose (Wx^{a}) alleles, *beIIb* and *BEIIb* alleles, and *Katyw* wild type and *katym* mutant alleles, allowing us to study the interactions of these three genes on RS content.

Using SSRs tagging, all the known starch synthesis genes to evaluate F_2 RILs of Tr and Op grains indicated the katym mutation resides on the short arm of chrom 8 closer to *SSIIIa* and *qChalk* than to *AGPS2*. In F_3, recombination broke linkage between *katym* and all three markers, with RM22559 being most closely linked, followed by RM310. In F_4, F_5 and F_6 recombination in 1980 progeny from heterozygous parents broke linkage between grain Op and all four markers except RM22547, mapping the katym mutation between 5.11 Mb and 5.70 Mb, indicating *SSIIIa* as the candidate gene for *katym*. The effect of +/- *SSIIIa* on RS was shown to be influenced by the growing environment. It was demonstrated from transplanting multiple pairs of Katy and katym across the field both early and late in one growing season resulted in early and late heading pairs of Katy and katym. The RS of the early heading pairs were not significantly different between the two, while later flowering katym had, on average, 59% higher RS than late flowering Katy.

Grains of $F_{4:5}$ near isogenic lines (NILs) based on the three genes showed that, in general, *beIIb* RILs had significantly higher RS than *BEIIb* RILs, and stacking *katym* onto *beIIb* reduced RS. However, sibling lines (NILs) of $Wx^aWx^aBEIIbBEIIb$ having *katym* had significantly higher RS than those having *Katyw*; while RS of $Wx^iWx^iBEIIbBEIIb$ NILs having *katym* and *Katyw* were comparable in 2020 growing environment. These results suggested that maximal RS is obtained by combining the mutant *beIIb* with non-mutant *SSIIIa* and Wx^a, while the *katym* (or *ssIIIa Op* mutant) did not affect the starch structure for RS in non-mutant *BEIIb* and Wx^i genetic background but did increase the RS in progeny having *BEIIb* + Wx^a. While IR36ae contains the desired high-RS combination of *beIIb* + Wx^a, it has weak culms and flowers very late. To make these high-RS genes more readily available to U.S. rice breeders in improved germplasm, we have been selecting *beIIb* + Wx^a cross-progeny with stronger, erect culms, and earlier flowering time.

Culinary and Health Beneficial Properties of Rice Varieties Developed for Niche Markets

McClung, A.M., Chen, M.-H., and Beaulieu, J.C.

Although conventional milled rice dominates the market, many mainstream grocery stores now carry a wide array of rice products that differ in culinary, processing and nutritional properties which indicates consumer interest in diversifying their diets with rice. From the earliest days of the establishment of the U.S. rice industry, breeding programs have endeavored to develop varieties for niche markets. Some of the first aromatic releases, Delitus and Salvo, date back to 1917 and were derived from varieties introduced from other countries. Since then, there has been increasing consumer demand for aromatic jasmine and basmati rice which now make up 87% of U.S. imports. Over the years, varieties have been developed for other specialty markets including, parboiling/canning quality, sweet/waxy rice, special cuisines (e.g. risotto, sushi), brewing/distilling, quick cooking/instantizing, and high protein.

Rice varieties which have unique flavor profiles, grain appearance traits, cooking properties, and enhanced natural nutrition can be sold with a premium price. This is an incentive for farmers in addition to them being directly in control of marketing their own crop. USDA-ARS has conducted research in support of specialty rice markets as this is in alignment with the agency's national goals which include: 1) developing crop plants with enhanced nutritional or product quality to address the needs of producers, processors, and consumers, 2) developing crops with higher profit margins for growers to help stabilize rural economies, and 3) producing new crops that provide alternative markets for farmers and a variety of novel products for domestic and international consumers.

Recently, USDA-ARS released three rice varieties developed for specialty markets that are being commercialized. "Scarlett," released in 2018, was an outcome of a NSF project with Susan McCouch, Cornell University, to explore yield enhancing alleles from the wild species *O. rufipogon* introduced into the *O. sativa* variety Jefferson. It is a high yielding semidwarf long grain with red bran. Another pigmented variety that was released in 2022 is "USDA-Tiara" which derives its aroma and purple bran from IAC600 from Brazil, but it has more acceptable agronomic traits as is expected for U.S. production. A recent analysis of the volatiles from IAC600, USDA-Tiara, and Scarlett grain demonstrated that USDA-Tiara had a very wide aromatic profile and higher levels of 2-acetyl-1pyrroline than IAC600 whereas Scarlett exhibited lower total volatiles than the brown bran variety, Rondo.

Our research has shown that red and purple bran varieties have high levels of phenolic and flavonoid compounds as compared to brown bran. These pigmented rice bran compounds have high anti-oxidant activity and have been shown to decrease cancer cell growth in cell assays and improve intestinal immunity in animal studies. Thus, Scarlett and USDA-Tiara, are examples of new rice varieties that combine consumer desired culinary and nutritional traits with agronomic characteristics resulting in unique rice products that bring greater economic value to rice farmers interested in direct marketing.

In 2022, USDA-ARS also released “Santee Gold” rice. This variety was derived from Presidio crossed with Carolina Gold which is an heirloom variety that is still being grown for a “historically authentic” specialty market and is being marketed directly to restaurant chefs and consumers. The goal of this cross was to reconstitute “Carolina Long,” a variety noted in historical records because of its extra-long grain but which no longer exists. Santee Gold combines the longer grain, higher milling and improved productivity found in Presidio with the same culinary traits and distinctive gold hulls found in Carolina Gold. The product will be sold as whole grain brown rice, whole milled rice, and rice grits or “middlins.”

Development of Instantized Rice Processing Methods for Improved Product Quality and Safety

Atungulu, G., and Luthra, K.

American consumers have become increasingly drawn towards fast, convenient foods. Consequently, the market demand for instant rice – a processed form of rice that is cooked and dehydrated before it is sold – has risen tremendously and become a significant component of the rice industry. However, compared to freshly cooked rice, the quality of instant rice is significantly lowered. The objective of this study was to determine the impacts of modified convective heated air and microwave drying on quality of instantized rice produced from contemporary long-grain hybrid cultivars. Convective heated air drying of cooked rice comprised of drying by stepwise lowering of drying air temp or drying at a constant drying air temperature, under various relative humidity conditions and drying durations. Drying was also conducted by an industrial Microwave (MW) set at 915 MHz frequency with treatments performed at select MW power and heating duration, and as necessary augmented with a final step of convective heated air-drying to get the safe product water activity. Impacts of treatments on percentage points of moisture removed, color, texture, water activity, bulk density, volume increase ratio and rehydration ratio of instantized rice were evaluated. The study has provided crucial information on instantizing potential of new varieties of rice to improve product quality and safety.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2025 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.

Presented Paper, Poster, and Symposia Abstracts

To be published in the printed proceedings, presented paper, poster, and symposia abstracts for the 40th 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 2½ months prior to the 40th RTWG meeting in 2025, or earlier as stated in the Call for Papers issued by the 40th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2025 RTWG meeting and their email and mailing addresses are presented following this section. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Michael Salassi
   Louisiana Agricultural Experiment Station
   LSU AgCenter
   101 Efferson Hall
   Baton Rouge, LA 70803
   Phone: (225) 578-2391
   Email: msalassi@agcenter.lsu.edu

2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
    a. Include a statement of rationale for the study.
    b. Briefly outline methods used.
    c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 40th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 40th 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 40th RTWG meeting and submitted to the 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 2025 PANEL CHAIRS

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IN MEMORY OF

Charles Bollich

Dr. Charlie Bollich, Research Agronomist with the USDA-ARS, passed away on June 16, 2022, in Beaumont, Texas. at the age of 95. He was born on September 9, 1926, in Mowata, Louisiana, and he served in the United States Navy during World War II. His entire career was with the USDA-ARS in rice breeding which began in Crowley, Louisiana, but over 25 years were spent as the Research Leader at the Rice Research Unit, in Beaumont.

He was the developer of 20 rice varieties that were grown extensively along the Texas and Louisiana Gulf Coast. ‘Bluebelle’ rice, released in 1965, was considered the standard for grain quality for many years and is still considered so in South America. ‘Labelle, released in 1972, was an early-maturing variety that was presented as a short-term transition variety, but it was grown for over 15 years. ‘Newrex,’ released in 1979, was the first rice variety developed for the parboiling and canning industry. Rice varieties were also developed for the medium-grain and aromatic markets. He is best known for the development of ‘Lemont’ in 1983, a semidwarf variety that helped to transform rice production in the southern USA. From that point forward, essentially all rice varieties that were developed for that region were semidwarf in height with many having Lemont in their parentage.

Over the course of his career, he received many prestigious awards including: the USDA-ARS Award for Superior Service (1983); Fellow of the American Society of Agronomy (1985); Fellow of the Crop Science Society of America (1986); the 1986 Distinguished Research and Education Team Award from the Rice Technical Working Group; the ASA Agronomic Achievement Award in Crops (1991); the Distinguished Service Award from RTWG (1992); the USDA-ARS Hall of Fame (1994); the C.N. Bollich Endowment Program by Texas A&M University (1994); and the Louisiana State University Alumni Hall of Distinction (1995). He is fondly remembered as a man of short stature, who cast a long shadow.

IN MEMORY OF

Albert Fischer

Dr. Albert J. Fischer passed away on November 22, 2022, at the age of 72, in Davis, California. He was born in Montevideo, Uruguay. He was a world traveler and citizen, and emigrated to Argentina, Mexico, and Colombia before settling in Davis, California. He received an undergraduate degree in Crop Science and Animal Husbandry at the University of the Republic of Uruguay, and Master's and PhD degrees in Crop Science from Oregon State University.

Dr. Fischer had a lifelong passion for ending hunger in developing countries and collaborated extensively with colleagues around the world. He started his career working for the Uruguayan Ministry of Agriculture, after which he went on to work as a professor of Weed Science at the University of Chapingo in Mexico, as a Rice Physiologist at the International Center for Tropical Agriculture (CIAT) in Cali, Colombia, and as a visiting weed biologist at North Dakota State University, before finally joining the Plant Sciences Dept. at UC Davis in 1997.

At UC Davis, Dr. Fischer was honored to hold the Melvin D. Androus Professorship for Weed Science in Rice endowed by the California Rice Research Board and was awarded the California Rice Industry Award in 2017. He served for several years as the president of the International Weed Science Society and was honored with their Outstanding International Achievement Award in 2022.

The breadth and depth of Dr. Fischer's research over the years is extensive. He covered a variety of topics, including weed ecology, population genetics, and herbicide resistance mechanisms. In California, he was among the group of researchers to first find herbicide resistance in weeds of rice and became a leading international expert in several key rice weeds, including weedy red rice and the *Echinchloa* complex.

IN MEMORY OF

Ben Jackson

Dr. Ben Jackson passed away September 23, 2021. Ben was born in Tipton, Oklahoma, on October 17, 1924. After graduating in 1942, Ben moved to Oklahoma City where he attended Draughn's Business College learning typing and other office skills. He enlisted in the Army on April 6, 1944, and was trained as Communications Chief learning Morse Code and was responsible for the use and maintain radio, switchboard and telegraph systems. He fought in three major battles and received three Bronze Service Stars, the Bronze Star Medal for meritorious service at the Siegfried Line, a World War II Victory Ribbon and his unit received the Distinguished Unit Badge.

He met Ella Sue Wood while they were in college, and they later married on December 22, 1946. After completing an Associate's Degree they moved to Stillwater, Oklahoma, where Ben completed his Bachelor's Degree in Botany at Oklahoma A & M (OSU). He accepted a position in the Agronomy Department which enabled him to work and complete a Master's Degree in Genetics. Ben worked at a university in Ethiopia for four years before returning to the U.S. and completing his Ph.D. at the University of Minnesota. He worked with the Rockefeller Foundation in Thailand where he helped develop and improve rice varieties.

After 17 1/2 years in Thailand, Dr. Jackson left to spend a year on study in Fayetteville, Arkansas, to compile his rice research while in Thailand. This gave him the opportunity to travel to the surrounding rice-growing states of Texas, Louisiana, Mississippi, and Arkansas. He retired from the Rockefeller Foundation and worked for Mississippi State University at the Delta Research and Extension Center in Stoneville. He developed a variety from Texas that was named after the state capitol called 'Jackson' rice. Another variety 'Jasmine 85' was from IRRI and developed in Thailand. It was well received in Mississippi.

After five years in Stoneville, he retired to Broken Arrow, Oklahoma, in 1990 but continued to do consultant work in the United States and overseas. He consulted with Uncle Ben's Rice owned by Mars Candy Company in New Jersey and Budweiser beer in Jonesboro, Arkansas. He consulted overseas in Bangladesh, India, Vietnam, Indonesia, Kenya, Nepal, Bolivia, Taiwan, Borneo Mali, Liberia, and Macedonia.

IN MEMORY OF

Gabriel Sciumbato

Dr. Gabe Sciumbato passed away peacefully June 1, 2022, in Rio Communities, New Mexico. Dr. Sciumbato was the research plant pathologist for Mississippi State University at the Delta Research and Extension Center in Stoneville, MS, from 1976 until his retirement in May 2015. Dr. Sciumbato's research program was active in screening fungicide efficacy in numerous crops during his tenure at MSU including rice where he focused his research efforts on managing sheath blight of rice.

IN MEMORY OF

John Scott

John Edward Scott, 93, of Beaumont, Texas, passed away on April 22, 2021. Born in Seymour, Texas, on June 6, 1927, he was the son of William Roy Scott and Ola James (Buffington) Scott. As a young man, he enlisted in the United States Navy during World War II where he served for eight years.

John was a Texas Aggie through and through, first graduating with his Bachelor's degree in horticulture. He then went on to earn his Master's degree in agronomy and began his career as a dedicated agronomist at the Texas A&M Rice Research and Extension Center in Beaumont. There he was part of the rice varietal development team led by USDA-ARS. His career spanned over 39 years and three breeders, Hank Beachell, Charlie Bollich, and Anna McClung, and he was a contributor to the development of many rice varieties starting with the medium-grain 'Gulfrose' in 1960 and the long-grain 'Belle Patna' in 1961.

He was a frequent participant at the RTWG meetings presenting research findings on optimizing cultural management practices for different rice varieties, understanding the response of plant architecture characteristics to management, and developing rapid methods for milling breeding lines to perform selections. John was very active in his church and served as a deacon for many years at Meadows Church of Christ. He was able to do all of this with Betty, his loving wife of 59 years, by his side.

GUIDELINES FOR RTWG AWARDS

1.0 The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

1.1 The Distinguished Rice Research and/or Education Award

1.1a Individual category – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research, (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress and promise technical advances in the rice industry.

1.1b. Team category – Same as the individual category, except that one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

1.2 The Distinguished Service Award - Awards to be made to designated individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2.0 The Awards Committee shall consist of the Executive Committee.

3.0 The duties of the Awards Committee are as follows:

3.1 To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee Members cannot nominate or write letters of support for an individual or team for the RTWG awards.

3.2 To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority (highest number of votes) vote. The Awards Committee Chair (same as the Executive Committee Chair) can only vote in case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

3.3 The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting.

3.4 The Awards Committee shall select appropriate certificates for presentation to the recipients of the Awards.

4.0 Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three (3) recommendation letters. Electronic submissions of the nominations are preferred; these should be submitted as a single pdf file, with the exception of a one-page summary of accomplishments that should be provided at the same time, but as a MS Word file. Hard copies can be submitted, in which case fifteen (15) complete copies of each nomination must be submitted, and a one-page summary of accomplishments included with each nomination. This summary will be published in the RTWG Proceedings for each award participant.

4.1 Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

4.2 A member of an organization, described in 4.1, may nominate or co-nominate two persons.

4.3 Nominations are to be sent to the Awards Committee for appropriate committee consideration.

4.4 The deadline for receipt of nominations shall be three months preceding the biennial meeting.

4.5 Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

Past RTWG Award Recipients

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients
1972	D.F. Houston	L.B. Ellis	None
Davis, CA	R.D. Lewis	H.M. Beachell	
	N.E. Jodon	C.R. Adair	
	E.M. Cralley	W.C. Dachtler	
1974	J.G. Atkins	R.A. Bieber	None
Fayetteville, AR	N.S. Evatt	J.T. Hogan	
	M.D. Miller	B.F. Oliver	
	T. Wassermand		
1976	D.H. Bowman	T.H. Johnston	None
Lake Charles, LA	R.F. Chandler	M.C. Kik	
	J.N. Efferson	X. McNeal	
	J.P. Gaines		
1978	J.W. Sorenson, Jr.	D.T. Mullins	R.K. Webster
College Station, TX	R. Stelly		
1980	M.L. Peterson	W.R. Morrison	B.D. Webb
Davis, CA	L.E. Crane	F.T. Wratten	

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Arkansas 'Get the Red Out' Team	
1982	C.C. Bowling	L. Drew	R.J. Smith, Jr.	B.A. Huey
Hot Springs, AR	J.P. Craigmiles		F.L. Baldwin	
1984	M.D. Morse	E.A. Sonnier	California Rice Varietal Improvement Team	
Lafayette, LA	L.C. Hill	D.L. Calderwood	H.L. Carnahan	J.N. Rutger
			C.W. Johnson	S.T. Tseng
			J.E. Hill	J.F. Williams
			C.M. Wick	S.C. Scardaci
			D. M. Brandon	
1986	D.S. Mikkelsen	J.B. Baker	Texas Rice Breeding and Production Team	
Houston, TX			C.N. Bollich	B.D. Webb
			M.A. Marchetti	G.N. McCauley
			J.E. Scott	J.W. Stansel
			F.T. Turner	A.D. Klosterboer
			E.F. Eastin	M.O. Way
			N.G. Whitney	M.E. Rister

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1988	M.D. Androus	H.L. Carnahan	Arkansas DD-50 Team	
Davis, CA	S.H. Holder	B.A. Huey	N.R. Boston	G.L. Davis
	M.D. Faulkner	W.R. Grant	F.N. Lee	N.P. Tugwell
	C.H. Hu	F.J. Williams	D.A. Downey	G.L. Greaser
			T.H. Johnson	G. Rench
			B.R. Wells	M.S. Flynn
			B.A. Huey	T.C. Keisling
			R.J. Smith	F.J. Williams
			D. Johnson	
1990	H.R. Caffey	B.R. Jackson	None	
Biloxi, MS	O.R. Kunze			
1992	C.N. Bollich	A.A. Grigarick	J.W. Stansel	
Little Rock, AR	B.D. Webb	C.M. Wick		
1994	S.H. Crawford	K. Grubenman	M.C. Rush	
New Orleans, LA	J.V. Halick	R.N. Sharp		
	R.J. Smith			

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1996 San Antonio, TX	P. Seilhan	K. Tipton	D.M. Brandon	
1998 Reno, NV	G. Templeton S.-T. Tseng	B. Wells	S.D. Linscombe	
			Advances in Rice Nutrition Team	
2000 Biloxi, MS	D.M. Brandon J.W. Stansel	R.K. Webster	P.K. Bollich R.J. Norman	C.E. Wilson
			Bacterial Panicle Blight Discovery Team	
2002 Little Rock, AR	F.L. Baldwin R.H. Dilday	M.A. Marchetti J.F. Robinson	M.C. Rush	D.E. Groth A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
2004 New Orleans, LA	P.K. Bollich A.D. Klosterboer F.N. Lee W.H. Brown	J.A. Musick J.E. Street J.F. Williams S.L. Wright	F.N. Lee A.K. Moldenhauer	M.A. Marchetti
			Individual	
			R.D. Cartwright	

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			LSU Rice Variety Development Team	
			S. Linscombe	X. Sha
2006	T.P. Croughan	J.N. Rutger	P. Bollich	R. Dunand
The Woodlands, TX	R. Talbert	F. Turner	L. White	D. Groth
			Individual	
			R. Norman	
			Bakanae Team	
			J. Oster	R. Webster
2008	M.C. Rush	R. Dunand	C. Greer	
San Diego, CA	C. Johnson			
			Individual	
			D. Groth	
2010	T. Miller	J. Thompson	Individual	
Biloxi, MS	J. Kendall		E. Webster	
			Advances in Nitrogen Use Efficiency Team	
2012	E. Champagne	G. McCauley	D. Harrell	N. Slaton
Hot Springs, AR	J. Hill		G. McCauley	B. Tubaña
			R. Norman	T. Walker
			T. Roberts	C. Wilson
			J. Ross	
			Individual	
			A. McClung	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Rice Entomology Team	
			J. Bernhardt	M. Stout
2014	R. Fjellstrom	J. Oster	G. Lorenz	J. Gore
New Orleans, LA			L. Espino	M. Way
			L. Godfrey	
			Individual	
			J. Saichuk	
			Clearfield Rice Technology Research Team	
2016	Rolfe J. Bryant	Lawrence M. White, III	D. Groth	
Galveston, TX	Farman Jodari		D. Harrell	
			S. Linscombe	
			E. Webster	
			Individual	
			Terry Siebenmorgen	
			Rice Irrigation Management Team	
2018	Merle Anders	Johnny Saichuk	Merle Anders	Jarrod Hardke
Long Beach, CA	Randall "Cass" Mutters	Terry Siebenmorgen	Michelle Reba	Arlene Adviento-Borbe
	Steven D. Linscombe	Lloyd T. "Ted" Wilson	Benjamin Runkle	Bruce Linquist
			Chris Henry	Steve Linscombe
			Joe Massey	Dustin Harrell
			Individual	
			Michael Orrin "Mo" Way	

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Genomics Team	
			Christine Bergman	Melissa Jia
2020	Don Groth	Karen Moldenhauer	Ming-Hsuan Chen	Yulin Jia
Orange Beach, AL	Kent McKenzie	Michael "Mo" Way	Jeremy Edwards	Anna McClung
			Robert Fjellstrom	William D. Park
			Individual	
			N/A	
			Arkansas Weed Science Rice Team	
2023	Ming-Hsuan Chen	Bob Scott	Jason Norsworthy	Thomas R. Butts
Hot Springs, AR	Gus Lorenz	Eric Webster	Tom Barber	
	Zhongli Pan			
			Individual	
			Dustin Harrell	

RICE TECHNICAL WORKING GROUP HISTORY

Meeting	Year	Location	Chair	Secretary	Publication Coordinator(s)
1st	1950	New Orleans, Louisiana	A.M. Altschul		
2nd	1951	Stuttgart, Arkansas	A.M. Altschul		
3rd	1951	Crowley, Louisiana	A.M. Altschul		
4th	1953	Beaumont, Texas	W.C. Davis		
5th	No meeting was held.				
6th	1954	New Orleans, Louisiana	W.V. Hukill		
7th*	1956	Albany, California	H.T. Barr	W.C. Dachtler	--
8th	1958	Stuttgart, Arkansas	W.C. Dachtler	--	--
9th	1960	Lafayette, Louisiana	D.C. Finfrock	H.M. Beachell	--
10th	1962	Houston, Texas	H.M. Beachell	F.J. Williams	--
10th	1964	Davis, California	F.J. Williams	J.T. Hogan	--
11th	1966	Little Rock, Arkansas	J.T. Hogan	D.S. Mikkelsen	--
12th	1968	New Orleans, Louisiana	M.D. Miller	T.H. Johnston	--
13th	1970	Beaumont, Texas	T.H. Johnston	C.C. Bowling	--
14th	1972	Davis, California	C.C. Bowling	M.D. Miller	J.W. Sorenson*
15th	1974	Fayetteville, Arkansas	M.D. Miller	T. Mullins	J.W. Sorenson
16th	1976	Lake Charles, Louisiana	T. Mullins	M.D. Faulkner	J.W. Sorenson
17th	1978	College Station, Texas	M.D. Faulkner	C.N. Bollich	O.R. Kunze
18th	1980	Davis, California	C.N. Bollich	J.N. Rutger	O.R. Kunze
19th	1982	Hot Springs, Arkansas	J.N. Rutger	B.R. Wells	O.R. Kunze
20th	1984	Lafayette, Louisiana	B.R. Wells	D.M. Brandon	O.R. Kunze
21st	1986	Houston, Texas	D.M. Brandon	B.D. Webb	O.R. Kunze
22nd	1988	Davis, California	B.D. Webb	A.A. Grigarick	O.R. Kunze
23rd	1990	Biloxi, Mississippi	A.A. Grigarick	J.E. Street	O.R. Kunze
24th	1992	Little Rock, Arkansas	J.E. Street	J.F. Robinson	M.E. Rister
25th	1994	New Orleans, Louisiana	J.F. Robinson	P.K. Bollich	M.E. Rister
26th	1996	San Antonio, Texas	P.K. Bollich	M.O. Way	M.E. Rister M.L. Waller

Continued.

RICE TECHNICAL WORKING GROUP HISTORY
(Continued)

Meeting	Year	Location	Chair	Secretary	Publication Coordinator(s)
27th	1998	Reno, Nevada	M.O. Way	J.E. Hill	M.E. Rister M.L. Waller
28th	2000	Biloxi, Mississippi	J.E. Hill	M.E. Kurtz	P.K. Bollich D.E. Groth
29th	2002	Little Rock, Arkansas	M.E. Kurtz	R.J. Norman	P.K. Bollich D.E. Groth
30th	2004	New Orleans, Louisiana	R.J. Norman	D.E. Groth	P.K. Bollich D.E. Groth
31st	2006	The Woodlands, Texas	D.E. Groth	G. McCauley	D.E. Groth M.E. Salassi
32nd	2008	San Diego, California	G. McCauley	C. Mutters	D.E. Groth M.E. Salassi
33rd	2010	Biloxi, Mississippi	C. Mutters	T.W. Walker	M.E. Salassi
34th	2012	Hot Springs, Arkansas	T.W. Walker	C.E. Wilson, Jr.	M.E. Salassi
35th	2014	New Orleans, Louisiana	C.E. Wilson, Jr.	E.P. Webster	M.E. Salassi
36th	2016	Galveston, Texas	E.P. Webster	L. Tarpley	M.E. Salassi
37th	2018	Long Beach, California	L. Tarpley	B. Linquist	M.E. Salassi
38th	2020	Orange Beach, Alabama	B. Linquist	J. Bond	M.E. Salassi
39th	2023	Hot Springs, Arkansas	J. Bond	J. Hardke	M.E. Salassi

- 1972 was the first year that an official Publication Coordinator position existed within the RTWG. Prior to that, the Secretary assembled and coordinated the publication of the meeting proceedings.

Rice Technical Working Group

Manual of
Operating Procedures

2023

I. Purpose and Organization

The Rice Technical Working Group (RTWG) functions according to an informal memorandum of agreement among the State Agricultural Experiment Stations and the Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, and the Agricultural Research Service (ARS), the Economic Research Service (ERS), the Cooperative State Research, Education, and Extension Service (CSREES), and other agencies of the United States Department of Agriculture (USDA). Membership is composed of personnel in these and other cooperating public agencies and participating industry groups who are actively engaged in rice research and extension. Since 1960, research scientists and administrators from the U.S. rice industry and from international agencies have participated in the biennial meetings.

The RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by the States, Federal Government, and other members. The current disciplines or Panels represented are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization & Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Each Panel has a Chair who, along with the Secretary/Program Chair, solicits and receives titles, interpretive summaries, and abstracts of papers to be presented at the biennial meeting. The papers are presented orally in concurrent technical sessions or via poster. Each Panel over the course of the meeting develops proposals for future work, which are suggested to the participating members for implementation.

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

Other members of the Executive Committee are elected biennially by the membership of the RTWG; they include the Chair who has served the previous term as Secretary/Program Chair, a Geographical Representative from each of the seven major rice-growing states (Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas), the Immediate Past Chair, and an Industry Representative. The rice industry participants elect an Executive Committee member from one of following areas: i) chemical, ii) seed, iii) milling, iv) brewing industries, v) producers, or vi) consultants. The Publication Coordinator also is on the Executive Committee. The Coordinator of the RTWG website is an ex-officio member of the Executive Committee.

Standing committees include: i) Nominations, ii) Rice Crop Germplasm, iii) Rice Variety Acreage, iv) Awards, and v) Location and Time.

II. Revised Memorandum of Agreement

The previous Memorandum of Agreement is published in the 33rd RTWG Proceedings in 2010. The following is a revised Memorandum of Agreement accepted by the 34th RTWG membership in 2012.

REVISED MEMORANDUM OF AGREEMENT

FEBRUARY 2012

INFORMAL UNDERSTANDING

among

THE STATE AGRICULTURAL EXPERIMENT STATIONS

and

THE STATE AGRICULTURAL EXTENSION SERVICES

of

ARKANSAS, CALIFORNIA, FLORIDA, LOUISIANA, MISSISSIPPI, MISSOURI, AND TEXAS

and

THE AGRICULTURAL RESEARCH SERVICE,
THE ECONOMIC RESEARCH SERVICE,
THE COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

and

OTHER PARTICIPATING AGENCIES

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

and

COOPERATING RICE INDUSTRY AGENCIES

Subject: Research and extension pertaining to the production, utilization, and marketing of rice and authorization of a Rice Technical Working Group.

It is the purpose of this memorandum of agreement to provide a continuing means for the exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by State Agricultural Experiment Stations, State Agricultural Extension Services, the United States Department of Agriculture, and participating rice industry groups. It is believed this purpose can best be achieved through a conference held at least biennially at the worker level of those currently engaged in rice research and extension. Details of the cooperation in the seven states are provided in formal Memoranda of Understanding and/or appropriate Supplements executed for the respective state.

The agencies represented in this memorandum mutually agree that overall suggestions of cooperative review and planning of rice research and extension in the several rice producing states and the United States Department of Agriculture shall be developed by a Rice Technical Working Group (henceforth designated RTWG), composed of all personnel actively engaged in rice investigations and extension in each of the agencies, as well as participating rice industry groups.

It is further agreed that there shall be a minimum of three Administrative Advisors to the RTWG to represent the major agencies involved, including:

1) A director of an Agricultural Experiment Station from a major rice-growing state elected by the Station Directors of the rice-growing states,

2) A director of a State Cooperative Extension Service from a major rice-growing state elected by the Extension Directors of the rice-growing states, and

3) A USDA Administrative Advisor from ARS named by the Administrator of Agricultural Research Service.

The RTWG shall convene <u>at least biennially</u> to review results and to develop proposals and suggested plans for future work. It is understood that the actual activities in research and extension will be determined by the respective administrative authorities and subject to legal and fund authorizations of the respective agencies.

Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (chair and secretary), subject to consultation with the remainder of the Executive Committee.

The Executive Committee shall consist of 15 members:

<u>Officers</u> (2):

<u>Chair</u> -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

<u>Secretary/Program Chair</u> -- (normally moves up to Chair).

<u>Geographic Representatives</u> (7):

One active rice worker in state or federal agencies from each of the major rice states -- Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas.

These Geographic Representatives will be responsible for keeping all governmental rice workers and administrators in their respective geographic areas informed of the activities of the RTWG.

<u>Immediate Past Chair</u> -- provides guidance to incoming chair to facilitate a smooth transition between biennial meetings.

Administrative Advisor (one from each category) (3):

State Agricultural Experiment Station
State Agricultural Extension Service
USDA - Agricultural Research Service

Publication Coordinator -- serves to handle matters related to the publication of the RTWG Proceedings.

Industry Representative -- to be elected by industry personnel participating in the biennial meeting of the RTWG; represents all aspects of the U.S. rice industry and serves as liaison with other rice industry personnel; and is responsible for keeping all interested rice industry personnel informed of the activities of the RTWG.

The Officers, Geographic Representatives, and the Publication Coordinator of the Executive Committee shall be elected on the first day of each biennial meeting to serve through the close of the next regular biennial meeting.

A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the active subject matter panels. Such election shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the panel program in close cooperation with the Secretary-Program Chair and for seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective panel sessions.

Participation in the panel discussions, including presentation of rice research findings by rice industry representatives and by representatives from National or International Institutes, is encouraged.

At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund,' established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

This type of memorandum among the interested state and federal agencies provides for voluntary cooperation of the seven interested states and agencies.

III. Description of Committees, Positions, Duties, and Operating Procedures

A. Executive Committee

The Executive Committee conducts the business of the RTWG, appoints standing committees, organizes and conducts the biennial meetings and presents the awards. Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (Chair and Secretary), subject to consultation with the remainder of the Executive Committee. A quorum (i.e., eight members, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. A simple majority vote is needed to pass any motion and the Chair only votes in the case of a tie. The Executive Committee is composed of the following 15 members: i) three officers—Chair, Secretary/Program Chair, and Immediate Past Chair; ii) seven Geographical Representatives from each major rice producing state; iii) three administrative advisors from the major agencies of Agriculture Experiment Stations, State Agricultural Extension Services, and the USDA; iv) a Publication Coordinator; and v) a Rice Industry Representative. The Officers, Geographical Representatives, and the Publication Coordinator shall be elected to the Executive Committee at the Opening Business meeting of each biennial meeting to serve through the close of the next regular biennial meeting. Industry personnel participating in the biennial meeting elect the Industry Representative.

1. **Chair**
   The Chair provides leadership to the RTWG by organizing the agenda and presiding over the Business and Executive Committee meetings, presiding over the Awards process, appointing temporary or ad hoc committees to explore and address RTWG interests, and being the official spokesperson for the RTWG during his/her period of office. If the nomination process for selecting geographical representatives and members of the Nominations committee fails to produce a candidate, then it the responsibility of the Chair to work with the state delegation in selecting a candidate from that state. The Secretary/Program Chair is usually nominated by the Nomination Committee to be Chair at the next biennial meeting. If the Chair nominated cannot serve or complete the full term of office, it is the responsibility of the Executive Committee to appoint a new Chair.

2. **Secretary/Program Chair**
   The Secretary/Program Chair serves a two-year term and is responsible for organizing, conducting and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair appoints a Local Arrangements Committee and Chair from their home state to help with organizing and conducting the biennial meeting. The Secretary/Program Chair is responsible for the minutes of all Business and Executive Committee meetings, the publishing of the minutes of these and other committees (i.e., Rice Crop Germplasm, Rice Variety Acreage, and Nominations) at the RTWG in the Proceedings and ensuring the Panel Chairs correctly publish their minutes and abstracts in the Proceedings. The Secretary/Program Chair is responsible setting up the RTWG website. The Secretary/Program Chair is responsible for the resolutions pertaining to the biennial meeting and for the Necrology Report when appropriate. The Secretary/Program Chair authors the Resolutions section of the RTWG Proceedings that expresses appreciation to individuals and organizations that contributed to making the biennial RTWG meeting a success. The Secretary/Program Chair is a member of the Executive Committee and usually resides in the state the biennial meeting is conducted. The Secretary is usually chosen by active rice workers from the meeting host state and the candidate identified to the Nominations Committee for election. If the Secretary/Program Chair nominated cannot serve or complete the full term of office, it is the responsibility of the member on the Nominations Committee of the hosting state to appoint a new Secretary/Program Chair.

3. **Immediate Past Chair**
   Provides guidance to the incoming Chair to facilitate a smooth transition and lend continuity between biennial meetings. The Immediate Past Chair assists the Publication Coordinator in editing the nontechnical sections of the proceedings and revises the MOP as required. The Chair is nominated by the Nominations Committee to be the Immediate Past Chair at the next biennial meeting. The Immediate Past Chair will incorporate the changes approved by the Executive Committee in the MOP.

4. **Geographical Representatives**
   There are currently seven geographical representatives representing each of the major rice producing states, Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, on the Executive Committee. Each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to serve a two-year term on the Executive Committee. If the Geographical Representative nominated cannot serve or complete the full term of office, it is the responsibility of the delegate on the Nominations Committee from that state to appoint a new Geographical Representative.

5. **Administrative Advisors**
   The Administrative Advisors provide advice and lend continuity to the Executive Committee. A minimum of three Administrative Advisors will be appointed to the RTWG to represent the major agencies involved. They shall consist of: i) a Director of an Agriculture Experiment Station from a rice-growing state elected by the Station Directors of the rice-growing states; ii) a Director of a State Cooperative Extension Service from a rice-growing state elected by the Extension Directors of the rice-growing states; and a USDA Administrative Advisor from the ARS named by the Administrator of the Agricultural Research Service. No term limit is established.

6. **Publication Coordinator(s)**
The Publication Coordinator is responsible for assembling, editing, and publishing of the RTWG Proceedings from the biennial meeting. The Coordinator is assisted in the editing the nontechnical session portions of the proceedings by the Immediate Past Chair. The Coordinator serves on the Executive Committee to handle all matters related to the publication of the RTWG Proceedings. Currently, one publication coordinator serves this position. This is a voluntary position requiring the approval of the RTWG Executive Committee to serve. No term limit is established.

7. **Industry Representative**
The Industry Representative represents all aspects of the U.S. rice industry to the Executive Committee and serves as liaison with other rice industry personnel. Responsibilities include keeping all interested rice industry personnel informed of the activities of the RTWG. Industry personnel participating in the biennial meeting elect the Industry Representative. If the Industry Representative nominated cannot serve or complete the full term of office, it is the responsibility of the Industry members of the RTWG to appoint a replacement.

B. Standing Committees
The Executive Committee has appointed the following Standing Committees.

1. **Nominations Committee**
The purpose of the Nominations Committee is to nominate the Secretary/Program Chair, Chair, Immediate Past Chair, and Geographical Representatives to the Executive Committee, and the members or delegates to the Nominations Committee. The Nominations Committee is composed of eight members. Seven of the members represent each of the seven major rice-producing states and one delegate is from the U.S. Rice Industry. As with the Executive Committee, each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to be their delegate on the Nominations Committee and the Rice Industry is responsible for designating who their delegate is on the committee. The Chair of the Nominations Committee is from the next state to hold the RTWG biennial meeting. If a delegate on the Nominations Committee cannot serve or complete the term of office, it is the responsibility of the Geographical Representative from that state to appoint a replacement. Each delegate is responsible for polling the active rice workers in their state or industry to determine who their Geographical Representative is on the Executive Committee and who their delegate is on the Nominations Committee. The Chair of the Nominations Committee is responsible for obtaining the results from each delegate on the Nominations Committee, compiling the results, and reporting the results to the RTWG at the Opening Business meeting for a vote. When a state is next in line to host a biennial meeting, it is the responsibility of the delegate from that state to nominate the Secretary/Program Chair. Since the Secretary/Program Chair moves up to RTWG Chair and the RTWG Chair to Past Chair, it is the responsibility of the Chair of the Nominations Committee to nominate them to the RTWG members.

2. **Rice Crop Germplasm Committee**
The Rice Crop Germplasm Committee functions not only as an RTWG committee but also as the Rice Crop Germplasm Committee for the National Plant Germplasm System. In this capacity, it is part of a specific national working group of specialists providing analysis, data and recommendations on genetic resources for rice and often-related crops of present or future economic importance. This committee represents the user community, and membership consists of representation from federal, state, and private sectors; representation from various scientific disciplines; and geographical representation for rice. There are also ex-officio members on the committee from the National Plant Germplasm System. The Rice Crop Germplasm Committee, along with the other Crop Germplasm Committees, is concerned with critical issues facing the NPGS including: i) identifying gaps in U.S. collections and developing proposals to fill these gaps through exchange and collaborative collecting trips; ii) assisting the crop curators in identifying duplications in the collections, and in evaluating the potential benefits and problems associated with the development and use of core subsets; iii) prioritizing traits for evaluation and developing proposals to implement these evaluations; iv) assisting crop curators and GRIN personnel in correcting passport data and ensuring that standardized, accurate, and useful information is entered into the GRIN database; v) assisting in germplasm regeneration and in identifying closed out programs and other germplasm collections in danger of being lost and developing plans to

rescue the important material in these programs; vi) working with quarantine officials to identify and ensure new techniques for pathogen identification that will assist in the expeditious release of plant germplasm; and vii) maintaining reports on the status of rice for Congress, ARS National Program Staff and Administrators, State administrators, and other key individuals involved with the NPGS. The Committee members serve six-year terms. They rotate off of the Committee in two-year intervals. The Rice Crop Germplasm Committee Chair appoints a committee who nominates a slate of members. This committee maintains the diversity of the membership. Nominations also are requested from the floor and elections take place among the voting members to fill the six-year terms of office. A Chair is then elected from the voting membership for a two-year term. The Chair can only be elected to two consecutive terms of office unless completing the term of a previous Chair.

3. Rice Variety Acreage Committee

The purpose of the Rice Variety Acreage Committee is to collect and summarize data on varieties by acreage for each state and publish the summary in the RTWG Proceedings. The Committee consists of the rice specialists from each of the seven major rice-producing states and one other representative, usually a breeder or a director of an experiment station. No more than two members can represent any one state. The Chair of the Rice Variety Acreage Committee solicits information from each of the states then compiles it for the Committee report published in the RTWG Proceedings. Members of the Rice Variety Acreage Committee solicit their own members, first based on state and then on knowledge and interest expressed by active members of the RTWG to be part of the Rice Variety Acreage Committee. The Chair of the Rice Variety Acreage Committee is elected by the members of the Committee and may serve more than one term. No term limits have been established for members of the Rice Variety Acreage Committee. English units of measure should be used for the acreage tables for continuity.

4. Awards Committee

The Awards Committee is composed of the Executive Committee. See section IV. C., 'Guidelines for RTWG Awards' for details regarding responsibilities and duties of the Awards Committee.

5. Location and Time Committee

The Location and Time Committee is made up of three individuals, two from the state next to hold the biennial meeting and one from the state following the next host state. This Committee explores when and where the next biennial RTWG meeting will be held. The incoming Chair appoints the Location and Time Committee members.

C. Website Coordinator

A third-party website host and developer will be used to maintain a permanent RTWG website. A permanent (100 years from 2010) address (www.rtwg.net) has been purchased through www.networksolutions.com. The Chair and Secretary Program Chair are to meet and transfer responsibilities no later than one year after the preceeding meetings to ensure a smooth transition from one host state to the next.

D. Revisions to the Manual of Operating Procedures

The Executive Committee with a majority vote has approved this 'Manual of Operating Procedures' for use by the Rice Technical Working Group. This 'Manual of Operating Procedures' is a working document that should be amended or modified to meet the needs of the Rice Technical Working Group. Amendments or modification to this 'Manual of Operating Procedures' can only be made by a quorum of the Executive Committee with the approval of the majority of the Executive Committee. The RTWG Chair can only vote in the case of a tie. The Immediate Past Chair will incorporate the approved changes in the MOP.

IV. Biennial Meeting Protocols

A. Biennial Meetings

The biennial meetings are hosted by the participating states in the following rotation: Arkansas, Louisiana, Texas, California, Missouri, and Mississippi. A state is allowed to host a biennial meeting if the state is deemed by the Executive Committee to have a sufficient number of rice scientists to properly conduct a biennial meeting. The Secretary/Program Chair is responsible for organizing, conducting, and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair is responsible for setting up the RTWG website. The Chair organizes the agenda and presides over the Business and Executive Committee meetings and the Awards process. Panel Chairs coordinate the oral and poster presentations in their discipline with the Secretary/Program Chair, editing of abstracts with the Publication Coordinator, updating of panel recommendations, and choosing their successor. Detailed information on the business meetings; detailed responsibilities of the Publication Coordinator, Panel Chairs, and the Local Arrangements Committee; timeline of preparation for the biennial meeting; instructions for preparation of abstracts; and guidelines for the RTWG awards are listed in this section.

1. Executive Committee Meetings

The agenda for the Executive Committee meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Executive Committee meetings. Following is a typical agenda.

a. Opening Executive Committee Meeting (held on day prior to start of meeting)

Old Business

i) The Chair opens the meeting
ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

New Business

The Necrology Report read by Chair.
The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.
The Chair leads a discussion of any New Business that has developed since the last RTWG meeting. Several months prior to the RTWG meeting the Chair should solicit any New Business items from the Executive Committee.

b. Closing Executive Committee Meeting (held on last day of meeting)

Old Business

i) The Chair opens meeting
ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. Opening General Session and Business Meetings

The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

a. Opening General Session and Opening Business Meeting (begins the RWTG meeting)
   i) The Chair opens the meeting and thanks the host state delegation for preparing the program.
   ii) The Secretary welcomes the RTWG membership to their state.
   iii) The Chair opens the Business Meeting by asking the Secretary to read the minutes of the Closing Business meeting from the previous RTWG meeting and the Chair then entertains a motion for acceptance of the minutes.
   iv) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.
   v) The Chair reads the Necrology Report and asks for a few moments of silence.
   vi) The Nominations Committee Chair reads the nominations for the Executive Committee and Nominations Committee to the RTWG membership. The RTWG Chair then entertains a motion to accept the nominations.
   vii) The Chair calls on the Chair of the Location and Time Committee of the next biennial meeting to report when and where the next RTWG meeting will be held.
   viii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.
   ix) The Chair asks for a motion to adjourn the Opening Business Meeting.
   x) The General Session usually ends with invited speaker(s).

b. Closing Business Meeting (ends the RTWG meeting)
   i) The Chair opens the meeting and calls for Committee reports from Rice Crop Germplasm, Rice Variety Acreage, Rice Industry, and the Publication Coordinator.
   ii) The Chair thanks the Publication Coordinator(s) for their efforts in coordinating, editing, and publishing the RTWG Proceedings.
   iii) The Chair thanks the host state delegation for hosting the RTWG Meeting.
   iv) The Chair then passes the Chair position to the Secretary/Program Chair. The incoming Chair thanks the Past Chair for service to the RTWG and presents the Past Chair with a plaque acknowledging their dedicated and valuable service to the RTWG as the Chair.
   v) The incoming Secretary/Program Chair informs the membership of the time and place for the next RTWG meeting.
   vi) The incoming Chair invites everyone to attend the next RTWG meeting and asks for a motion to adjourn the RTWG meeting.

3. Publication Coordinator(s)

The Publication Coordinator(s) are responsible for providing instructions for manuscript preparation, collecting abstracts from the Panel Chairs, assembling all pertinent information for inclusion in the Proceedings, final review, and publication of the Proceedings upon the conclusion of each RTWG meeting. The Publication Coordinator(s) solicit input from the Executive Committee, Panel Chairs, and the general membership for changes and/or adjustments to the RTWG Proceedings content, style, format, and timetable. It is, however, the Publication Coordinator(s) responsibility to make the final decision on changes appropriate to ensure the Proceedings is a quality product and reflective of the goals and objectives of the organization. This flexibility is needed to ensure that publication of this information through their respective institution is done in accordance with university or other agency requirements. The Publication Coordinator(s) are responsible for updating the guidelines for submitting abstracts as needed and including this information in the published Proceedings and also on the RTWG host website once the call for abstracts is made. The Publication Coordinator(s) are responsible for mailing proceedings in electronic and hardcopy format to the general membership and also placing the Proceedings on the internet.

4. **Panel Chairs**

A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the six disciplines or Panels. The current Panels are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization, and Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Such elections shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the Panel program in close cooperation with the Secretary-Program Chair. Program development involves scheduling of oral and poster presentations, securing moderators to preside at each panel session, editing of abstracts, seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective Panel sessions, and election of a successor. Since the Secretary is from the RTWG host state, the Panel Chairs elected should also be from the host state if possible to facilitate close cooperation with the Secretary and other Panel Chairs. If an elected Panel Chair cannot serve or fulfill the duties, then it is the Secretary's responsibility to replace the Panel Chair with someone preferably from the same discipline.

Each Panel Chair is responsible for collecting all of the Panel abstracts prior to the RTWG biennial meetings. The appropriate due date will be identified in the Call for Papers for the RTWG meeting. Each Panel Chair is responsible for assembling the Panel abstracts into one common MS Word file that is consistent with the above guidelines, with the abstracts appearing in the order presented. Paper abstracts will be presented first and poster abstracts second. A Table of Contents should be included with each panel section. Panel Chairs are responsible for editing all abstracts for their panel. A common file should be developed prior to the beginning of the RTWG meeting and submitted to the Publication Coordinator(s) to accommodate preliminary preparation of the Proceedings prior to the meeting. The Panel Chairs are strongly encouraged to edit the abstracts for content clarity and RTWG format to expedite publication of the Proceedings. These materials will be merged in the final Proceedings in the format submitted. Final editing will be performed by the Publication Coordinator(s), Rice Research Station secretarial staff, and the incoming Chair.

In addition, Panel Chairs are to prepare and submit both a paper copy and MS Word computer file version of the (1) final Panel Recommendations and (2) a list of panel participants by the conclusion of the meeting. A copy of the previous recommendations and panel participants will be provided to each Panel Chair prior to the meeting.

Panel Chairs are to organize the oral presentations in the concurrent Technical Sessions and the posters for the Poster Sessions with the Secretary/Program Chair.

5. **Local Arrangements**

The Local Arrangements Committee and the Chair of this Committee are typically appointed by the Secretary/Program Chair to help with meeting site selection and organizing and conducting the biennial meeting. Thus, they usually reside in the state the biennial meeting is conducted due to logistics. Typical responsibilities include: a survey of possible meeting sites and establishments; working with the hotels for rooms, meeting space, and food functions; securing visual aids; helping with spouse activities; solicitation of donations; and providing speakers and entertainment.

6. **Financing Biennial Meeting, Start-up Money, and the Contingency Fund**

   a. The biennial RTWG meetings are financed through registration fees and donations from industry and interested parties. The Executive Committee established a base amount of $6,000 that is to be transferred from one host state to the next as start-up money to begin preparations for the RTWG meeting prior to when donations or registration fees can be collected.

b. At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund', established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

c. The Contingency Fund was established as a safety net for states hosting the biennial meetings. It is to be used by the host state when the startup money transferred from the previous state to host the biennial meetings is insufficient or when a state goes into debt hosting the biennial meetings.

   i. If the previous host state is unable to provide any or all of the $6,000 in start-up money for the next host state to initiate meeting preparations, the current Chair should be informed of this situation as soon as possible (as the Chair will normally have served as Secretary of the previous meeting, he/she will probably be aware of this situation). The Chair should then communicate to the Executive Committee how much money will be needed from the Contingency Fund to provide the next host state the full $6,000 in start-up funds. The Chair will then ask for approval from the Executive Committee to make arrangements to have the appropriate funds transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the next host state. Providing the next host state adequate ($6,000) start-up funds will be the highest priority for the use of contingency funds.

   ii. If a host state has gone into debt as a result of hosting the annual meeting and will request the use of contingency funds to cover all or part of that debt (over and above the inability to provide the $6,000 in start-up funds to the next host state), it must submit a detailed request for approval of the use of these funds to the Chair, who will than make this request available to the Executive Committee. The request should include a detailed accounting of all financial aspects of the hosted meeting, including all funds received and sources thereof, as well as a detailed accounting of all expenses incurred as a result of hosting the meeting. The Chair will have discretion on how to proceed with polling the Executive Committee (e.g., email or conference call) on approval of the use of contingency funds to cover all or part of the incurred debt. The Executive will then decide through parliamentary procedure whether to use contingency funds to cover all or part of the incurred debt. The Chair will then make arrangements to have the amount of any funds approved by the Executive Committee for this purpose transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the host state. No repayment of these funds will be required.

7. Complementary Rooms, Travel Reimbursements, and Registration Fee Waivers

Complementary rooms (Suite) are provided during the meeting for the Chair and Secretary. Typically, the hotel will provide rooms free of charge in association with a certain number of booked nights. Invited speakers may be provided travel funds, free room, or registration, depending on meeting finances. The Local Arrangement Committee usually does not provide any travel assistance for attendees. Registration can be waived or refunds given on the discretion of the Local Arrangement Committee based on their financial situation. Possibly, a certain amount should be specified non-refundable before registration is begun. Distinguished Service Award recipients usually have their registration fee waived for the day of the Award Banquet if they are not already registered.

8. Biennial Meeting Preparation Timeline

May 1, 2023	Secure Hotel
May 1, 2024	Pre-RTWG planning meeting
June 15, 2024	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 2024	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 2024	First call for papers and a call for award nominations
Sept. 15, 2024	Second call for papers (Reminder; e-mail only)
Oct. 15, 2024	Titles and interpretive summaries due
Dec. 1, 2024	Abstracts due
Dec. 1, 2024	Award nominations due to Chair
Dec. 1, 2024	Registration and housing packet sent
Jan. 3, 2025	Reminder for registration and hotel (e-mail only)
Jan. 29, 2025	Last day for hotel reservations
Jan. 30, 2025	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 2025	Registration due without late fee
February 2025	40^{th} RTWG meeting

9. Program Itinerary

The biennial meetings begin on Sunday afternoon with committee meetings followed by a social mixer in the evening. The meetings end on Wednesday morning with the Closing Business meeting. The Awards presentations are made at dinner Monday or Tuesday evening or at a luncheon on Tuesday. See programs from previous RTWG meetings for more details.

Sunday: Registration usually begins Sunday afternoon and standing committees and ad hoc committees meet Sunday afternoon. A Sunday evening social mixer is hosted by the RTWG.

Monday: Registration continues Monday morning and posters are usually setup prior to the Opening General Session. The Opening General Session starts the biennial meeting with opening remarks from the Chair, a welcome from the Secretary/Program Chair, the opening business meeting, and ends with invited speakers. The concurrent technical sessions (i.e., oral presentations) of the six Panels begins after the Opening General Session on Monday. Posters are on display throughout the meeting or removed Monday evening and new ones placed on display Tuesday morning and removed Tuesday evening, depending on the number of posters and poster sessions.

Tuesday: The concurrent technical sessions continue on Tuesday and extend through Tuesday afternoon, depending on the number of papers. Each concurrent technical session ends with the review of the panel recommendations. If there are a sufficient number of posters, a second poster session is held on Tuesday.

Wednesday: The biennial meeting usually ends on Wednesday with the Closing Executive meeting and then the Closing Business meeting.

10. Symposia

Symposia are welcomed in conjunction with the RTWG biennial meetings. Symposia must not interfere with the RTWG biennial meetings and are to be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting.

11. Functions by Industry and Other Groups

Functions held in conjunction with the RTWG biennial meetings are welcomed as long as they do not interfere with the RTWG biennial meetings. Thus, these functions must be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting. Exceptions are informal, brief functions held at the meal breaks of breakfast, lunch, or dinner.

B. Instructions for Preparation of Abstracts for Biennial Meetings

Beginning with the Proceedings for the 24th Rice Technical Working Group meeting, Desktop Publishing software was chosen for expediting the post-meeting publication process using Microsoft Word (Windows). If individuals do not have access to MS Word, submission of materials in ASCII format (DOS compatibility is essential) is acceptable. Each electronic file should include: i) title of materials, ii) corresponding RTWG Panel, iii) corresponding author's name, daytime telephone number, e-mail address, and iv) computer format (i.e., MS Word and version number). These criteria apply uniformly to i) presented paper abstracts, ii) poster abstracts, iii) symposia abstracts, iv) panel recommendations, and v) list of panel participants. More details with respect to each of these items follow below.

As soon as a web page is established by the host state, a link will be provided to the RTWG web page where current submission instructions will be maintained.

1. Presented Paper, Poster, and Symposia Abstracts

To be published in the printed Proceedings, presented paper, poster, and symposia abstracts for the RTWG meetings must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the Proceedings.

a. Both a paper copy and an electronic file are required. Hard copy and electronic file are to be submitted to the respective Panel Chairs 2 ½ months prior to the RTWG meeting, or earlier as stated in the Call for Papers issued by the RTWG meeting Chair and/or Panel Chairs. Please e-mail the abstract to the Panel Chair by the deadline and mail the hard copy thereafter. If e-mail is not available, mail the electronic file to the panel chair on a IBM compatible CD or floppy disk.

The respective Panel Chairs for each RTWG meeting and their e-mail and mailing addresses are presented in the 'Instructions for Preparation of Abstracts" in each Proceedings. In case of other questions or if unable to access the Call for Papers, contact:

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b. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

c. Type: Do not use any word processing format codes to indicate boldface, etc. Use 10 point Times New Roman font.

d. Heading:
   i) Title: Center and type in caps and lower case.
   ii) Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).

iii) Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

e. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

f. Content is limited to one page.
   i) Include a statement of rationale for the study.
   ii) Briefly outline methods used.
   iii) Summarize results.

g. Tables and figures are not allowed

h. Literature citations are not allowed.

i. Use the metric system of units. English units may be shown in parentheses.

j. When scientific names are used, *italicize* them -- do not underline.

C. Guidelines for RTWG Awards

1. The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

a. The Distinguished Rice Research and/or Education Award

   i) Individual category – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research and (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress, and promise technical advances in the rice industry.

   ii) Team category – Same as the individual category, one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

b. The Distinguished Service Award - Awards to be made to designate individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, or industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2. The Awards Committee shall consist of the Executive Committee.

3. Responsibilities and duties of the Awards Committee are as follows:

a. To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee members cannot nominate or write letters of support for an individual or team for the RTWG awards. If a member of the Awards Committee is nominated for an award in a given category, it is common courtesy to abstain from voting in that category.

b. In the event that a real or perceived conflict of interest regarding award nomination packets exist, the Chair reserves the right to pass the responsibilities of award elections to the immediate past chair, the secretary, or an executive committee member who does not have a conflict of interest.

c. To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority (highest number of votes) vote once a quorum is mustered. A quorum for the Awards Committee is when at least eight members vote, excluding the Chair. The Awards Committee Chair (RTWG Chair) can only vote in the case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

d. The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting. The Chair of the RTWG shall present the awards by speaking briefly about the accomplishments of the award recipient(s) and after presenting the award allow the recipient(s) an opportunity to express their appreciation.

e. The Awards Committee shall select appropriate certificates for presentation to the recipients of the awards.

4. **Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three recommendation letters, pertinent biographies of each nominee, and a concise but complete explanation of the accomplishments. Electronic submissions of the nominations are preferred; these should be submitted as a single pdf file, with exception of a one-page summary of accomplishments that should be provided at the same time, but as a MS Word file. Hard copies can be submitted, in which case fifteen (15) complete copies of each nomination must be submitted, and a one-page summary of accomplishments included with each nomination. This summary will be published in the RTWG Proceedings if the award is granted.**

a. Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

b. A member of an organization, described in 4.a, may nominate or co-nominate two persons.

c. Nominations are to be sent to the Awards Committee for appropriate consideration.

d. The deadline for receipt of nominations shall be three months preceding the biennial meeting. The executive committee reserves the right to entertain Distinguished Service Award packets at the opening executive committee meeting.

e. Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

D. Off-Year Executive Committee Business Meeting

The Executive Committee of the 2004 RTWG Meeting voted to have an Off-Year Executive Committee Business Meeting to add continuity, indoctrinate new Executive Committee members, and discuss pertinent topics more timely. The time and place of the Off-Year meeting is flexible and the possibility of conducting the meeting through distance education is a viable alternative to meeting at a designated location. The best time for the meeting is from February to August in the off-year, and it can be held in conjunction with such meetings as the Breeders' Conference or the organizational meeting for the next RTWG. The meeting can also be held independently at a central location or at the next RTWG meeting site to allow the Executive Committee to become familiar with the hotel and available facilities. A quorum (i.e., eight members are present, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. It is the responsibility of the RTWG Chair and the Secretary/Program Chair to call this meeting and set the agenda in concert with the other members of the Executive Committee.

Drafted by Richard J. Norman and approved by the 31st RTWG Executive Committee on March 1, 2006; revised by Garry McCauley and approved by the 32nd RTWG Executive Committee on February 21, 2008; revised by Cass Mutters and approved by the 33rd RTWG Executive Committee on February 25, 2010; revised by Tim Walker and approved by the 34th RTWG Executive Committee on March 1, 2012.

39TH RTWG ATTENDANCE LIST

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