Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Eighth Rice Technical Working Group

Orange Beach, AL: February 24 – 27, 2020

Edited by: Michael Salassi, Jason Bond, and Bruce Linquist

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

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station

TABLE OF CONTENTS

Page

Page

PROCEEDINGS ... THIRTY-EIGHTH
RICE TECHNICAL WORKING GROUP

RICE TECHNICAL WORKING GROUP

Organization and Purpose

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

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

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

Several months prior to the biennial meeting, panel chairs solicit and receive titles and interpretative summaries of papers to be presented. They work with the secretary-program chair in developing the program, including joint sessions as desired. RTWG program development includes scheduling of papers and securing persons to preside at each panel session. Each panel chair is in charge of (1) election of a successor and (2) updating of the panel recommendations.

Committees, which are appointed by the incoming chair, include: Nominations and Location and Time of Next Meeting, Members of the Nominations and the Location and Time of Next Meeting Committees are usually selected to represent the different geographical areas.

The RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and Extension being carried on by the states, federal government, and cooperating agencies. It develops proposals for future work, which are suggested to the participating agencies for implementation.

Location and Time of the 2020 Meeting

The 38th RTWG meeting was hosted by Mississippi and held at the Perdido Beach Resort in Orange Beach, AL, from February 24 – 27, 2020. The Executive Committee, which coordinated the plans for the meeting, included Bruce Linquist, Chair; Jason Bond, Secretary; and Lee Tarpley, Immediate Past Chair. Geographic Representatives were Jarrod Hardke (Arkansas), Whitney Brim-DeForest (California), Matthew VanWeelden (Florida), Manoch Kongchum (Louisiana), Bobby Golden (Mississippi), Gene Stevens (Missouri), Ted Wilson (Texas), and Mallory Everett (Industry). Administrative Advisors were Eric Young (Experiment Station), Rogers Leonard (Extension Service), and Anna McClung (USDA-ARS). Publication Coordinator was Michael Salassi (Louisiana). The Industry Representative was Mallory Everett (Valent USA). The Local Arrangements Coordinators for Mississippi were Bobby Golden (Chair), Kenner Patton (Vice Chair), Jason Bond and Lindsey Bell.

Location and Time of the 2022 Meeting

The 2022 RTWG Meeting Location Committee recommended that the 39th RTWG meeting be held by the host state Arkansas. The meeting will be held on February 20 – 24, 2022, at Hot Springs, Arkansas.

2020 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 not presented because no nominations were received. The team award was presented to the Advance Irrigation Management Practices team of Christine Bergman, Ming-Hsuan Chen, Jeremy Edwards, Robert Fjellstrom (deceased), Melissa Jia, Yulin Jia, Anna McClung, and William D. Park.

The Distinguished Service Award honors individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. This award usually requires a whole career to achieve, and thus, it can be argued that it is our toughest award to win. But, since more than one can be given at a RTWG meeting, it is our fairest award granted to all worthy of such distinction. This award was presented to Donald Groth, Kent McKenzie, Karen Moldenhauer, and Michael Orrin (Mo) Way.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 38th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2020 proceedings. The 2020 proceedings was edited by Michael Salassi, Bruce Linquist (Chair), and Jason Bond (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 39th RTWG (2022 meeting) proceedings are included in these proceedings.

Committees for 2022

Executive:

Chair:	Jason Bond	Mississippi
Secretary:	Jarrod Hardke	Arkansas

Geographical Representatives:

Trent Roberts	Arkansas
Ian Grettenberger	California
Matthew VanWeelden	Florida
Adam Famoso	Louisiana
Bobby Golden	Mississippi
Travis Jones	Missouri
Ted Wilson	Texas

Immediate Past Chair:

Bruce Linquist	California

Administrative Advisors:

Michael Salassi	Experiment Station
Steve Martin	Extension Service
Anna McClung	USDA-ARS

Publication Coordinator:

Michael Salassi	Louisiana

Web Page Coordinator:

Eric Webster	Louisiana

Industry Representative:

Mallory Everett	Valent USA

2022 Local Arrangements:

Nick Bateman (Chair)	Arkansas
Tommy Butts (Vice Chair)	Arkansas
Jarrod Hardke	Arkansas
Trenton Roberts	Arkansas

Nominations:

Eric Webster (Chair)	Louisiana
Nick Bateman	Arkansas
Thomas Tai	California
Matthew VanWeelden	Florida
Tom Allen	Mississippi
Travis Jones	Missouri
Fugen Dou	Texas
Mallory Everett	Industry-Valent USA

Rice Crop Germplasm:

Georgia Eizenga, Chair	USDA-ARS
Nick Bateman	Arkansas
Teresa deLeon	California
Adam Famoso	Louisiana
Ediliberto Redoña	Mississippi
Omar Samonte	Texas
Paul Sanchez	California
Xueyan Sha	Arkansas
Qiming Shao	Nutrien Ag Solutions
Shane Zhou	Texas

Ex Officio:

Harold Bockleman	USDA-ARS
Peter Bretting	USDA-ARS
Joseph Foster	USDA-APHIS
Trevis Huggins	USDA-ARS
Anna McClung	USDA-ARS
Jack Okamuro	USDA-ARS
National Germplasm Resources Laboratory:	
Gary Kinard	USDA-ARS

Rice Variety Acreage:

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

2022 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:	
Xueyan Sha	Arkansas
Economics and Marketing:	
K. Bradley Watkins	Arkansas
Plant Protection:	
Nick Bateman	Arkansas
Postharvest Quality, Utilization and Nutrition:	
Griffiths Utungula	Arkansas
Rice Culture:	
Trent Roberts	Arkansas
Rice Weed Control and Growth Regulation:	
Tom Barber	Arkansas
Student Contest Panel:	
Tommy Butts	Arkansas

RESOLUTIONS
38th RTWG – 2020

The 38th meeting of the RTWG, held in Orange Beach, Alabama, February 24 to 27, 2020, 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. The coordinated information exchange was beneficial to all participants and accomplished the goals of the RTWG. 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 38th meeting.

1. Bruce Linquist, RTWG Chair, and all other members of the Executive Committee who organized and conducted this successful meeting. We recognize Jason Bond 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 Perdido Beach Resort, Orange Beach, Alabama, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements Committee chaired by Bobby Golden and Kenner Patton, Mississippi, for the site selection and overseeing arrangements.

4. The faculty and staff of Mississippi State University's Delta Research and Extension Center in Stoneville for their time and assistance in conducting all aspects of pre-meeting and on-site logistics and other conference planning and operational details.

5. Karen Brasher and the staff of the Mississippi State University College of Agriculture, Forestry, and Veterinary Medicine Agriculture and Natural Resources Marketing office who contributed time and effort for developing and maintaining the conference website and coordinated conference registration.

6. The Panel Chairs, Ed Redoña, Steve Martin, Brian Mills, Jeff Gore, Tom Allen, Zhongli Pan, Bobby Golden, and Ben Lawrence, and moderators for planning, arranging, and supervising the technical sessions. The Symposia, Training Session, and Student Contest Chairs and Co-chairs, Jason Bond, Ben Lawrence, Bobby Golden, Justin McCoy and Wayne Ebelhar for planning, arranging and supervising these special sessions.

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

8. The Symposia, General Session, and Industry Luncheon speakers, Kenner Patton, Steve Martin, David Shaw, and Tim Walker, for sharing their knowledge and wisdom.

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

10. We gratefully recognize our many generous sponsors that made the 38th Rice Technical Working Group meeting successful.

2020 RTWG Conference Sponsorship

Opening Reception/Bonfire Sponsorship

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Distinguished Rice Research and/or Education Team Award

Christine Bergman, Ming-Hsuan Chen, Jeremy Edwards, Robert Fjellstrom, Melissa Jia, Yulin Jia, Anna McClung, and William D. Park

Research development and technology transfer efforts performed by this team have facilitated the deployment of genomic technologies for use in developing and characterizing improved varieties for the U.S. rice industry. The team developed six genetic markers for predicting rice end-use grain quality, two markers for important agronomic traits, and 13 fingerprinting markers for quality assurance, cultivar identification, and seed purification. In addition, five markers have been developed for tracking the presence of four major blast disease resistance genes, facilitating the characterization of the blast resistance spectra of over 40 U.S. cultivars.

Their efforts have specifically focused on serving the needs of the U.S. rice industry and to empower U.S. rice breeders with the same level of genomic technology tools being used in other rice producing countries. Thus, this team filled a critical research gap for the U.S. breeding community that would not have been realized otherwise.

The team has been active in technology transfer efforts by demonstrating the utility of the markers to breeders through genotyping of all the Uniform Regional Rice Nursery entries over the last 19 years. They have helped the breeding community adopt marker-assisted selection approaches by making informal presentations at 19 annual breeders' meetings, developing grant proposals with breeders to deploy the markers, and making some 45 formal scientific presentations on genomics, marker-assisted selection, and bioinformatics at Rice Technical Working Group meetings. Their research has evolved with changing genomic technologies and has resulted in new bioinformatic tools like Ricebase, which is the first database that connects genomic data from across diverse platforms enhancing the utility of public genomic databases to U.S. rice researchers.

The team has also contributed to the U.S. rice industry by deploying fingerprinting markers for performing genetic identity and purity analysis of seed resources for foundation seed and certification programs, seed companies, and the milling/processing industry.

This research effort has been a critical foundation for the marker technology now being used in all U.S. public rice breeding programs as well as in private U.S. seed companies. New breeding germplasm and varieties have been developed by the team which possess unique alleles or combinations of alleles in genetic backgrounds that are adapted to U.S. environments. These have been made available free of charge and with no intellectual property protection to facilitate broad use by breeders and geneticists. The unique perspective of this team has always been to modify, develop, and deploy genomic technology specifically to help the U.S. rice industry remain competitive in the world market.

Distinguished Service Award

Donald Groth

Dr. Don Groth has been active in rice research, Extension and the RTWG since he was hired as a Rice Pathologist by the LSU AgCenter in 1984. Don works at the H. Rouse Caffey Rice Research Station in Rayne, LA, where he conducts rice pathology research and Extension and is the Resident Coordinator, tasked with supervising 42 staff and seven faculty at this premiere research facility.

Don has been and continues to be very active in all phases of the RTWG. Here is a summary of Don's contributions towards, and honors received from, the RTWG:

1. Co-editor of the RTWG Proceedings for 10 years
2. Local Arrangements Committee member four times
3. Panel Chair three times
4. Nomination Committee member
5. Geographical Representative
6. Germplasm Committee member
7. Secretary 2004 RTWG
8. Chair 2006 RTWG
9. 2002 RTWG Distinguished Rice Research and Education Team Award for work on bacterial panicle blight
10. 2006 RTWG Distinguished Rice Research and Education Team Award for varietal development
11. 2008 RTWG Distinguished Rice Research and Education Individual Award for rice disease management

Don's research has impacted all rice disease management programs in the southern United States and has resulted in immense economic and environmental benefits to this region's rice industry. Don's accomplishments are far too numerous to mention in this brief career summation. However, suffice it to say, Don has played no small role in doubling Louisiana's rice yields over the past 30 years (from 4,500 lb/A in 1986 to 7,100 lb/A in 2018). Furthermore, this represents an increase of over 6 million hundred weights (cwt) of rice - worth a conservative $90 million annually to Louisiana farmers.

On a more personal level, we all know Don is a most decent, cooperative, friendly, honest, diligent, talented and dedicated scientist. Dr. Don Groth is most deserving of this prestigious honor which proves that "Sometimes the Good Guy Wins"!

The RTWG sincerely thanks Dr. Don Groth for all his outstanding work while recognizing his stellar career!

Distinguished Service Award

Kent McKenzie

Dr. Kent McKenzie has been working in rice for 45 yrs and has participated in RTWGs for over 40 years. Born and raised in California, he received PhD in Genetics from UC Davis. He started his career in Arkansas as a breeder then moved to Louisiana where he served as an Associate Professor and Plant Breeder for 7 years. In 1988, he was hired as a Plant Breeder at the California Rice Experiment Station and was promoted to Director in 2000 – a position he currently holds. He plans to retire at the end of this year. He has been an active participant in the California rice industry, as a member of various committees with the California Rice Commission and USA Rice Federation.

In his time as Director, he and his team have been involved in the release of over 20 varieties and a couple traits, with several more release proposals in the near future. In addition, through his leadership, he has helped address issues that have arisen in the California rice industry, including blast, Liberty Link, herbicide-resistant weeds, and weedy red rice. He has also developed the infrastructure at the station at a cost of over $2 mill, culminating most recently in the RES Genetics Lab. His dissertation research focused on grain quality and this has been a common theme through his career and includes the release of the variety "Cypress" in Louisiana and the improvement in grain quality and milling in short-, medium- and long-grain varieties in California which has helped California achieve worldwide market recognition for grain quality.

Most recently, he has led a team that has developed California's first herbicide tolerant rice. ROXY™ is a nonGM trait in rice that gives a high level of resistance to the PPO herbicide oxyfluorfen. It was discovered at Rice Experment Station in 2013 and should be available for commercial release in 2023.

His collaboration and support of University of California scientists has allowed for countless research gains in a variety of subjects, ranging from pesticide development to new fertility programs to varietal testing. He has also mentored and supported more than 40 graduate students through direct interaction with students, as well as through administration of the Marlin Brandon Fellowship, which provides funding to support graduate students.

Distinguished Service Award

Karen Moldenhauer

Karen Moldenhauer has been a Professor of Crops Soils and Environmental Science at the University of Arkansas since 1982 and is the holder of the Rice Industry Chair for Variety Development. She is located at the University of Arkansas System, Division of Agriculture, Rice Research and Extension Center in Stuttgart, AR. Dr. Moldenhauer accepted her position as a rice breeder with the University of Arkansas as an Assistant Professor in Agronomy right after college. Karen is married to Dr. Paul M. Moldenhauer and they have two children Jonathan and Henry.

Dr. Moldenhauer's primary research focuses on improving grain yield, cooking quality characteristics and disease resistance in rice. During her tenure as project leader for the rice breeding and cultivar development program at the University of Arkansas, 33 rice cultivars have been released to producers. These cultivars have had a substantial impact on rice production in Arkansas, helping the state average rice yields increase from 95 bushels/acre in 1982 to as high as 168 bushels/acre in 2013 and 2014. Her latest releases Diamond (2016), Jewel (2019) and CLL16 (2019) all have excellent yield potential, Diamond has been adopted by the producers of Arkansas and was grown on approximately 20% of the acreage in 2018. Her releases Drew, Kaybonnet, and Katy were the first commercially available cultivars with resistance to all of the common blast races in the southern U.S. growing region. They have provided a source of rice blast resistance to the rice breeding programs in Louisiana, Mississippi and Texas.

Dr. Moldenhauer has 14 utility patents and 12 PVP certificates granted. She has published 11 book chapters, 90 referred publications, 272 reviewed publications, and 139 abstracts. She is a Fellow of the Crop Science Society of America, the American Society of Agronomy and the American Association for the Advancement of Science.

It would be difficult to estimate the number of acres that Karen's varieties have been planted on over the course of her career and even more difficult to determine the impact of her selections as they have been used by other breeders. She has dedicated her professional life to the advancement of rice production for the betterment of rice farmers in the state of Arkansas. Karen has announced her retirement this coming June and will be sorely missed by the University and Arkansas rice farmers, as well as all her coworkers and colleagues in Stuttgart.

Distinguished Service Award

Michael Orrin "Mo" Way

Mo joined the Texas A&M AgriLife Research and Extension Center at Beaumont in 1982 when he was hired to develop Integrated Pest Management (IPM) programs for rice and soybeans. Mo is primarily a rice entomologist, but Mo has also been involved with tadpole shrimp, crayfish, blackbirds, mites, rodents, feral hogs, and channeled apple snails which have been or are rice production pests in either the South or California.

Mo began participating in RTWG meetings in 1976 as a graduate student/technician under Dr. Al Grigarick, a rice entomologist with UC Davis. He was Secretary in 1996, Chairman in 1998 and Local Arrangements Chair in 2016. He received the 1986 Distinguished Rice Research and Education Team Award for being part of the team that developed and released Lemont. He received the same award in 2014 for being on the team that developed IPM programs for the major insect pests of rice in the United States. Finally, in 2018, Mo received the Distinguished Rice Research and Education Award for developing and implementing IPM programs for the major and minor arthropod pests attacking Texas rice.

Mo has authored or co-authored over 85 peer-reviewed papers on rice, soybean, sugarcane and sorghum IPM. He has written eight book chapters, including three on rice IPM. Over his career, he garnered more than $3 million in grants. He has served as major or co-major advisor for two MS and three PhD students. He also served on many MS and PhD student committees, as well as served as a mentor for many undergraduate student interns during his career.

Mo has built a solid international reputation with visits to various rice-producing countries, including Mexico, Costa Rica, Cuba, Dominican Republic, Nicaragua, Colombia, Brazil, Malaysia, China and South Korea. In addition, he consulted for FAO (of the UN) in 1991 when he visited North Korea to advise the country on how to deal with a newly introduced pest of rice - the rice water weevil which is native to the southeastern United States.

Mo's proudest accomplishments involve serving the Texas rice industry by developing and implementing IPM programs for most of the pests attacking rice. Mo is also proud of playing an instrumental role in providing data and recommendations to TDA and USEPA for approval of Furadan, Fipronil seed treatment, various pyrethroids, Tenchu, Endigo ZC, Belay, Dimilin, and CruiserMaxx, NipsIt INSIDE, and Dermacor X-100 seed treatments.

Minutes of the 38th RTWG Meeting

Opening Executive Committee Meeting

In Attendance: Bruce Linquist, UC Davis, Chair; Ted Wilson, Texas A&M; Matt VanWeelden, University of Florida; Anna McClung, USDA-ARS; Lee Tarpley, Texas A&M, Past chair; Mallory Everett, Valent USA; Whitney Brim-Deforest, University of California; Manoch Kongchum, LSU AgCenter; Steve Martin, MSU; Eric Young, NCSU; Tameka Sanders, MSU; Jason Bond, MSU, Secretary; Jeff Gore, MSU; Jarrod Hardke, University of Arkansas Division Agriculture; Bobby Golden, MSU, Local Arrangements.

Tarpley called meeting to order at 7:24 am.

Linquist presented details about the last meeting in Long Beach.
285 participants; 2 symposia; 13 presentations
126 technical presentations; 22 in student competition
67 poster presentations; 15 in student competition

Linquist stated minutes from the last meeting are printed in the proceedings. Tarpley moved that minutes from previous meeting not be read. Gore seconded.

Bond discussed RTWG 2020 program and venue.

-Extension Training/Certified Crop Advisor Training on February 24.
-No formal symposium but several titles were submitted related to rice water management, and the decision was made to pool those talks in a session Monday afternoon instead of scattered throughout the program on Tuesday and Wednesday.
-Program includes 132 papers and 96 posters.
-The only program modification so far was withdrawal of 2 posters and 1 paper
-4 student contests:
-1 poster contest with 15 participants.
-Oral contest has 28 participants in three panels (Plant Protection, Rice Culture, Weed Control)
-43 total graduate students competing
-As of Friday, February 21, there were 251 people registered.

Linquist announced awards recipients.

There were four Distinguished Service Awards.
Don Groth
Kent McKenzie
Karen Moldenhauer
Michael Orrin (Mo) Way

Rice Research and Education Team Award
Christine Bergman
Ming-Hsuan Chen
Jeremy Edwards
Robert Fjellstrom (deceased)
Melissa Jia
Yulin Jia
Anna McClung
William D. Park

Few nominations for Research and Education Team Award were received. Participants should be encouraged to apply for these awards in the future.

There were no nominations for the individual Research and Education Award.

Linquist presented who is in the necrology report. Asked for any additions.

One person will be mentioned at the opening business meeting, Chau-Teng Tseng from California.

Hardke mentioned Gary Thompson, but it was decided to remove his name from the necrology report because rice was not his main area.

It was agreed upon that Linquist not ask for other names during the opening business meeting. If someone has a name, it could still be listed in the proceedings.

Tarpley provided SERA018 Project proposal update. RTWG is not a society but a multi-state research project, and it is the name of SERA 18 (Southern Extension Research Activity 18).

A new proposal must be submitted every five years with the last in 2018. The writing concluded in 2018, and the writing team consisted of Steve Linscombe (Chair), Chuck Wilson, Lee Tarpley.

New project has been approved and runs from October 1, 2018, to September 30, 2023.

Another proposal writing team should be appointed in 2022 or 2023.

Young is retiring at end of June and will be finding a replacement.

Annual report is due (minutes of the RTWG business meeting and individual panel business meetings and accomplishments). These should reflect the size and scope of conference and anything else done over past two years. Also, information on the number of participants and institutions represented may be listed as accomplishments.

Discussion on RTWG attendance and participation ensued. RTWG attendance is low.

Priorities within panels should be discussed at the panel business meetings.

Young asked if executive committee had considered getting leadership team together during off years to give a normal pattern of annual meeting to help with continuity of thought on priorities.

Linquist stated this was a good idea because it would help with planning for the next meeting and avoid some problems with nominations as seen this year.

Everett stated Valent hosts a rice meeting on the off-year that could be used as a meeting since most RTWG leadership attends that meeting.

Linquist initiated discussion on the organization of RTWG. There was confusion on roles of nominations committee, specifically who is supposed to nominate whom. The nominations committee is responsible for nominating the Geographical Representatives to the Executive Committee, and they nominate their own replacements.

Hardke suggested nominating the Secretary for the 2024 meeting this year. They do not have to be a member of the leadership team, but they should be identified.

Arkansas, Louisiana, and Missouri do not yet have a nomination for Geographical Representative or Nominations Committee.

Hardke nominated Trent Roberts as Geographical Representative and Nick Bateman for Nominations Committee representing Arkansas.

Manoch Kongchum nominated Adam Famoso for Geographical Representative and Eric Webster for Nominations Committee representing Louisiana.

Missouri was not represented at the meeting, but Bond stated Travis Jones was Geographic Representative. If confirmations are received, names will be announced at Opening Business Meeting. If not, then announcement will be made at Closing Business Meeting. Emails will be sent to Geographic Representatives and Nominations Committee with their responsibilities to give them an idea of what they are expected to do.

McClung reminded everyone that in order to sustain the RTWG legacy, there needs to be involvement from representatives from all the rice-producing states.

Mike Salassi is the Publications Coordinator, however; there needs to be a replacement for him. Linquist will ask Salassi who his replacement would be.

A lengthy discussion ensued on RTWG website. RTWG does not have an official website. There is only the website dedicated to an individual meeting.

A site should be developed to describe RTWG, archive all of the Proceedings, list host and dates of next meeting. Hardke proposed use of contractors (Squarespace) to setup independent site with support from University of Arkansas. Cost would be $300 to $500 per year. Website would be a way of promoting meetings and archiving information. McClung has the past proceedings in electronic version.

Other business. None discussed.

Hardke provided update on the 39th RTWG. Embassy Suites in West Little Rock is a 250-room hotel ballrooms and individual meeting rooms big enough for all RTWG activities. All the catering is done in house.

Hot Springs Convention Center was the site for RTWG in 2012. Embassy Suites is located beside but independent from the convention center. At the other end of the convention center is another hotel useful for overflow.

The date for RTWG 2022 will be February 20 to 24.

Currently, there is a $10,000 difference between the two proposed sites.

McClung mentioned that RTWG hotel cost is beyond per diem for ARS employees; therefore, they often do not stay in the conference hotels because they would have to pay out of pocket or share a room.

Linquist mentioned that in 2018 they negotiated reduced rates for 15-room block for ARS employees so that it met the $100 government per diem.

Meeting was adjourned at 8:40 a.m.

Opening Business Meeting

Chairman Jason Bond called the meeting to order at 8:00 a.m. on February 25, 2020, at the Perdido Beach Resort in Orange Beach, Alabama.
Bruce Linquist welcomed participants to the 38th RTWG and emphasized that as Chair of Executive Committee, his goal was to make RTWG the premiere rice science conference in the U.S., providing opportunities to

network, catch up on latest research, and training and mentoring the new generation of rice scientists.

Linquist asked Bond to read the minutes from RTWG 2018. Bobby Golden moved to dispense with the reading of the minutes. Wayne Ebelhar seconded.

Linquist read Necrology Report, which included Dr. Shu-Ten Tseng who passed away July 4, 2019. Dr. Tseng was a Rice Breeder at the California Rice Experiment Station.

Jarrod Hardke reported plans for the next RTWG. The 39th RTWG will be held February 20 to 24, 2022, at the Hot Springs Convention Center.

As acting Chair of the Nominations Committee, Hardke announced the following nominations for the 39th RTWG meeting:

Jason Bond, Chair
Jarrod Hardke, Secretary
Bruce Linquist, Past Chair

Geographical Representatives:
Ted Wilson, TX
Bobby Golden, MS
Ian Grettenberger, CA
Matthew VanWeelden, FL
Trent Roberts, AR
Adam Famoso, LA
Travis Jones, MO
Mallory Everett, Industry

Nominations Committee:
Fugen Dou, TX
Tom Allen, MS
Thomas Tai, CA
Matthew VanWeelden, FL
Nick Batman, AR
Eric Webster, LA
Travis Jones, MO
Mallory Everett, Industry

Ebelhar moved and Bond seconded to accept these nominations.

Bond provided program highlights for RTWG 2020.

Bond recognized meeting sponsors.

- He highlighted BASF's sponsorship of opening reception.
- RiceTec sponsored name badge lanyards.
- Horizon Ag provided prize money for student contests.
- Twenty-three organizations provided money or items for the registration bags to RTWG.

Bond mentioned that RTWG is not a society or organization but a multi-state research project.

- He acknowledged the Administrative Advisors are Dr. Steve Martin, Extension Advisor, and Dr. Eric Young, Experiment Station Advisor.

Bond recognized the RTWG Executive Committee, which is made up of Geographic Representatives from participating states, USDA-ARS, and industry.

For the 38th RTWG meeting, there are participants from 19 U.S. states and territories, and countries are also represented.

Bond highlighted recent changes to RTWG.

- Breeding, Genetics, and Cytogenetics Panel has been renamed to Breeding, Genetics, and Genomics for this meeting to better reflect activities in that panel.
- There is one symposium for RTWG 2020. Interest in water use and management in rice was high; therefore, Bobby Golden, Rice Culture Panel Chair, decided to pool those talks into a symposium held Monday.

Bond recognized Panel Chairs:

- Ben Lawrence, Certified Crop Advisor/Extension Training
- Bobby Golden and Justin McCoy, Water Syposium
- Wayne Ebelhar and Taghi Bararpour, Student Contest
- Ed Redona, Breeding, Genetics, and Genomics
- Brian Mills, Economics and Marketing
- Jeff Gore and Tom Allen, Plant Protection
- Zhongli Pan, Post-harvest Quality, Utilization, and Nutrition
- Ben Lawrence, Rice Weed Control and Growth Regulation
- The 38th RTWG program includes 131 papers and 95 posters.
- Student contests were continued as they were held at RTWG 2018.
- The student poster contest consists of one section of posters with 15 contestants.
- The oral contest has three sections: Plant Protection, Rice Culture, and Weed Control with 28 contestants.
- First, second, and third prizes will be awarded in all four student competitions.
- Bond recognized Kenner Patton, Lindsey Bell, Matt Edwards, and Tameka Sanders for their contributions to planning and organizing in 38th RTWG meeting.

Meeting was adjourned at 8:20 am.

Closing Executive Committee Meeting

In Attendance: Bruce Linquist, UC Davis, Chair; Anna McClung, USDA-ARS; Jason Bond, MSU, Secretary; Tameka Sanders, MSU; Manoch Kongchum, LSU AgCenter; Bobby Golden, MSU, Local Arrangements Chair; Steve Martin, MSU; Kenner Patton, MSU; Eric Young, NCSU; Jarrod Hardke, U of A Division of Agriculture; Matt VanWeelden, University of Florida; Mallory Everett, Valent USA; Ted Wilson, Texas A&M; and Lee Tarpley, Texas A&M, Past Chair

Linquist called meeting to order at 8:10 a.m.

Bond provided report on the program.

- He reported 280 participants at RTWG 2020.
- The program included 131 papers and 95 posters.
- At least one individual was not present for their presentation and two to three posters were not exhibited. The abstracts from these will be removed from the proceedings prior to publishing the proceedings.
- The student contests included 28 oral and 15 poster presentations.

Linquist stated that industry representation has decreased over the past few RTWG meetings.

- Everett stated this is mostly due to consolidation and budget cuts.
- Hardke added that there have been conflicts with multiple meetings at the same time that have resulted in low industry attendance.

Hardke confirmed the next RTWG meeting would be held February 20 to 24, 2022, at the Hot Springs Convention Center and Embassy Suites.

- Panel chairs will include:
  Xueyan Sha – Breeding, Genetics, and Genomics
  Trent Roberts – Rice Culture
  Nick Bateman – Plant Protection
  Tom Barber – Weed Control and Growth Regulation
  Griffiths Atungulu – Postharvest Quality, Utilization, and Nutrition
  Brad Watkins – Economics and Marketing
  Tommy Butts – Student Competition

- Hardke is working on securing government rates for USDA-ARS attendees.

Lengthy discussion concerning RTWG website ensued.

- McClung stated there is a permanent USDA website, which could possibly be utilized. It could be used as a permanent repository for proceedings and a page to advertise the next meeting and list points of contact.
- Golden mentioned a suggestion to him about making RTWG presentations available online for those interested in viewing after the meeting. Concerns were raised about whether this would result in decreased attendance and people waiting until the information was posted online instead of attending the meetings.
- Patton stated that the website would be a promotional opportunity to generate interest in RTWG and the biennial meeting. This would require a robust website with current content. The website should include the proceedings, business meeting information, videos of the speakers, and possibly featured presentations.
- Linquist expressed concerned about the website being difficult to maintain due to the RTWG meeting rotating from state to state and due to the lack of funds to keep it current.
- Hardke suggested using SquareSpace to house a permanent RTWG website and update this site continually with information and new payment links for upcoming meetings.
- Linquist proposed that Hardke develop a website that could be continued from one meeting to the next. Depending on acceptance, this could become the permanent website.
- Linquist asked for a motion to terminate RTWG's relationship with Aristotle. Wilson moved, Tarpley seconded.

RTWG awards were discussed at length.

- McClung proposed that a 300-word summary be included in the nominations for RTWG awards and that this language be added to the manual of operating procedures.
- Linquist asked for a motion to have the 300-word summary of accomplishments be read at the awards ceremony. Wilson motioned, Tarpley seconded.
- Tarpley moved that the 15 hard copies be removed. Golden seconded.
- Wilson suggested adding Staff Award to the RTWG awards. It was decided that the Service Award embodies all individuals. In the past it has been awarded to people who were not just faculty or project leaders.

Linquist mentioned participants asking him about being involved in RTWG.

- He suggested considering this interest in the future as volunteers for Geographical Representatives to the Executive Committee, Nominations Committee, and Panel Chairs are solicited.
- Linquist would like more women in RTWG leadership roles.

Linquist recommended RTWG recognize individuals in necrology report and read their contributions to the rice industry at the Opening Session at future meetings.

It was decided that the off-year meeting of the RTWG Executive Committee would be held during the Rice Outlook Conference in December of even-numbered years.

Meeting was adjourned at 9:48 a.m.

Closing Business Meeting

Bruce Linquist called the meeting to order at 10:00 am on February 27, 2020, at the Perdido Beach Resort in Orange Beach, AL.

Georgia Eizenga presented report from the Rice Acreage Committee.

- Rice Acreage Committee met Monday, February 24, 2020, at 3:30 pm.
- Attendees included representatives from each rice-producing states except Missouri and four non-committee members.
- Attendees reported on what varieties were grown in each state in 2018 and 2019, how the data were collected, new varieties in each state, and estimates of acreage for 2020.

Report from Rice Germplasm Committee was presented.

- Rice Germplasm Committee met Monday, February 24, 2020, at 10:00 am.
- Sixteen members and nine guests were present.
- Reports were given by each member.

Linquist presented report of Executive Committee.

- There were 280 participants at the 38th RTWG meeting.
- The committee liked the direction of the student competition as it brings good science to the meeting, as well as the interest of students.
- The Executive Committee discussed holding a meeting between biennial RTWG meetings.
  - This meeting would serve to help in continuity with leadership and to assist the incoming Secretary who will be organizing the next RTWG meeting.
  - Bond and Hardke will organize a meeting during the Rice Outlook Conference during even-numbered years.
- An RTWG website was proposed to increase participation and provide a place to archive proceeding and maintain interest in RTWG.
  - Hardke will take lead in developing a model of what a permanent website would be for the 39th RTWG and at that meeting we will decide whether to maintain that site in the future.
- The Executive Committee desires broader participation in RTWG.
- Mike Salassi is changing positions but will continue his role as RTWG Proceedings Editor.
- Language in the operating procedures will be refined related to awards, and Anna McClung will initiate this effort.
- Eric Young, director of SERA, is retiring, and Mike Salassi will replace him.

Linquist passed the gavel to Bond as incoming RTWG Chair.

Bond presented Linquist a plaque acknowledging his dedication as Chair of 38th RTWG meeting.

Bond announced that the 39th RTWG meeting will be held February 20 to 24, 2022, in Hot Springs, AR.

Meeting was adjourned at 10:15 am.

SPECIAL COMMITTEE REPORTS

Nominations Committee

The Nominations Committee proposed the following individuals for membership on the 2022 RTWG Executive Committee and Nominations Committee:

<u>Executive Committee:</u>

Jason Bond	Chair
Jarrod Hardke	Secretary
Bruce Linquist	Immediate Past Chair

<u>Geographical Representatives:</u>

Arkansas	Trent Roberts
California	Ian Grettenberger
Florida	Matthew VanWeelden
Louisiana	Adam Famoso
Mississippi	Bobby Golden
Missouri	Travis Jones
Texas	Ted Wilson
Industry	Mallory Everett

<u>Nominations Committee:</u>

Arkansas	Nick Bateman
California	Thomas Tai
Florida	Matthew VanWeelden
Louisiana	Eric Webster, Chair
Mississippi	Tom Allen
Missouri	Travis Jones
Texas	Fugen Dou
Industry	Mallory Everett

Rice Crop Germplasm Committee

The 40th Rice Crop Germplasm Committee meeting was held on Mon., February 24, 2020 in Orange Beach, Alabama. Members in attendance were Georgia Eizenga (Chair), Teresa De Leon, Anna McClung, Karen Moldenhauer, Jack Okamuro, Ed Redoña, Xueyan Sha, Paul Sanchez, Qiming Shao and Shane Zhou. Members joining via conference call were: Peter Bretting, Harold Bockelman, Gary Kinard and Martha Malapi-Wight. Members not present were Adam Famoso and Dante Tabien. Guests in attendance were Nick Bateman, Trevis Huggins, Nanyen Chou, Jagadusha Gouda, Melissa Jia, Yulin Jia, Joe Kepiro, Kent McKenzie, Santosh Sharma and Ted Wilson. The meeting was called to order. The minutes of the virtual 39th Rice Crop Germplasm Committee held on February 20, 2019 were approved by a motion from Xueyan Sha, seconded by Karen Moldenhauer, and supported by the other committee members.

Peter Bretting USDA/ARS Office of National Programs, reported on the status of the National Plant Germplasm System (NPGS) which highlighted the increase in accessions, distribution of accessions, NPGS budget and relatively flat budget when adjusted for inflation from 2010 to 2019. Key challenges are managing and expanding the NPGS to meet the increased demand for germplasm and associated information, developing/applying cryopreservation or in vitro preservation for clonal stocks, managing accessions with genetically engineered traits, and acquiring additional germplasm especially crop wild relatives. Lastly, with at least 1/3 plant genetic resource (PGR) managers eligible to retire in the next five years, a USDA/NIFA grant was used to discuss development of a training program on PGR management which will be delivered primarily through distance learning which included a survey published in Crop Science (2019) 59:2308-16 and a NIFA Higher Education Challenge grant was submitted to further develop the training materials. In the past year there were budget increases for coffee, citrus and industrial hemp.

Gary Kinard, USDA/ARS National Germplasm Resources Lab, reported currently there are four vacant positions in the lab, including a Botanist position, all of which they hope to fill in 2020. GRIN taxonomy continues to be improved and expanded to provide thorough coverage of wild relatives of all major and minor crops. The GRIN platform was migrated from in-house servers to the Microsoft Azure cloud in September 2019 and the group anticipates releasing a new version of the GRIN-Global public website in spring 2020. Proposals for the Plant Exploration and Exchange Program for FY2019 are due July 24, 2020 to Karen Williams.

Martha Malapi-Wight, USDA/APHIS Plant Germplasm Quarantine Program (PGQP) reported she has accepted a promotion within APHIS and the Director, Joseph Foster will manage the program until further notice. The Poaceae team continued validating the use of high-throughput sequencing (HTS) with the goal of introducing this technology as a routine diagnostic tool in PGQP. In 2019, the PGQP received 82 accessions, of which 74 flowered and produced seed. Of these, 38 were randomly selected for sequencing (HTS) and bioinformatic analysis revealed eight had viral strains closely related to the O. sativa or O. rufipogon endornavirus. A literature survey indicated that there are no reports demonstrating endornaviruses induce disease, but it needs to be determined if these viruses are commonly found in the USA. The group is waiting for further guidance from the USDA-APHIS Plants for Planting Policy group as to the next step with these materials.

Harold Bockelman, Curator of the Small Grains Collection, reported 2,230 accessions (seed packets) have been distributed in 135 separate requests since January 2019. Currently there are 19,134 accessions in the Oryza collection with 18,922 being O. sativa accessions. Harold shared the "Crop Vulnerability Update for Rice" which was reviewed by the committee and edits were suggested for the slide. This report is used to set priorities for the NPGS and determine where the U.S. crop vulnerabilities are.

Trevis Huggins, USDA/ARS Dale Bumpers National Rice Research Center (DBNRRC), was introduced as the newly hired curator for the rice germplasm collection, thus an ex-officio member of the Rice CGC, replacing Dr. Wengui Yan who previously held the position. Trevis reported on growth of Genetic Stocks-Oryza (GSOR) collection which is part of the NPGS and distributed from the DBNRRC. From Jan. 2019 through Feb. 2020 there had been 130 shipments of 4,741 entries to locations within the USA and 16 shipments of 94 entries to nine countries outside the USA. Trevis recommended adding six new trait descriptors for rice, apiculus color, awn color, daylength sensitivity, leaf blade pubescence, shattering, and long sterile lemma, to GRIN-Global. Trevis reviewed the issues most often reported by those requesting seed as misclassified accessions, flowering time (daylength sensitivity), line purity, seed viability and redundant accessions. Lastly, he reported that the protocol for rejuvenating the accessions in the collection has been amended to include genotyping with 24 markers, 14 of which are trait specific. The markers were used to determine the species (O. sativa or O. glaberrima), subspecies (indica or japonica) and subpopulations (aus, indica, aromatic, temperate japonica or tropical japonica) and the genotypic similarity of accessions which had the same cultivar name. Other future plans include developing a detailed operations and management guides, genotyping all donated materials prior to acceptance, only using the winter nursery for photoperiod sensitive accessions, and incorporating high throughput phenotyping methods.

Committee members, Karen Moldenhauer and Rodante Tabien will retire this year, thus, Nick Bateman (Extension entomologist, Arkansas) was recommended to complete Karen's term and Omar Samonte (hybrid breeder, Texas) was recommended to complete Dante's term. Also, the six-year terms for Xueyan Sha (Arkansas) and Teresa De Leon (California) will terminate in 2020. Both Sha and Teresa have agreed to serve another six-year term. A motion was made by Karen Moldenhauer to accept the aforementioned committee member changes and additional terms, the motion was seconded by Paul Sanchez and the motion was supported by all committee members.

A motion to amend the by-laws to allow the committee chair to serve an unlimited number of two-year terms was made by Karen Moldenhauer, the motion was seconded by Teresa De Leon and Paul Sanchez and the motion was supported by all committee members. Based on the committee recommendation on February 28, the current chair, Georgia Eizenga, circulated an email vote for the 2020-2022, chair. Georgia Eizenga was unanimously supported as the 2020-22 committee chair on March 11, 2020.

Karen Moldenhauer motioned to adjourn, Paul Sanchez seconded the motion, and the motion was supported by all members.

Rice Germplasm Committee members as of February 24, 2020 business meeting with year term ends in parentheses:

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Publication Coordinator/Panel Chair Committee

Publication Coordinator Michael Salassi communicated by email with the panel chairs before the 2020 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 2022 proceedings. Proceedings should be available in both hard copy and CD format within 12 months of the meetings.

Submitted by
Michael Salassi

Rice Variety Acreage Committee

The meeting of the Rice Technical Working Group (RTWG) Acreage Committee was called to order by Dustin Harrell at 3:30 p.m.

In attendance were committee members: Jarrod Hardke, University of Arkansas; Kent McKenzie of California Cooperative Rice Research Foundation; Dustin Harrell of Louisiana State University AgCenter; Bobby Golden of Mississippi State University; Ted Wilson of Texas A&M Agrilife; and Matthew Van Weelden of University of Flordia. Guests in attendance were Tim Walker, Dana Dickey, Xeuyan Sha, and Russell Rasmussen.

Harrell distributed and presented the minutes of the 2018 Acreage Committee meeting and asked for a motion to accept. Kent McKenzie moved and Ted Wilson seconded a motion to accept the minutes. The motion carried.

The California report was presented by Kent McKenzie. He reported that the California estimates are based on foundation seed sales. In 2018, approximately 506,000 acres were planted. Medium grain accounted for 436,000 acres, short grain 31,353 acres, and long grain 7,731 acres. M-206 and M-209 were the two most widely grown varieties. In 2019, approximately 492,000 acres were grown. Medium grain accounted for 425,394 acres, short grain 33,870 acres, and long grain 13,055 acres. M-206 and M-209 were the most widely grown varieties.

The Texas report was presented by Ted Wilson. Data was determined by a survey of 50-60 respondents and USDA-FSA certified acres. Texas planted rice acres for 2018 and 2019 were approximately 191,988 and 154,052 acres, respectively. Acres were predicted to increase in 2020 to around 180,000-192,000 acres. The top planted varieties were XL723 (23.9%), CLXL745 (13.6%) and

Presidio (10.1%). A new Foundation release will be Trinity. Trinity is a conventional long grain.

The Arkansas report was given by Jarrod Hardke. Rice acres for 2018 and 2019 were estimated at 1.4 and 1.1 million acres, respectively. Top planed varieties over the past few years included XP753, Gemini, Diamond, Jupiter, and CLXL745. Medium grains typically made up around 12.5% with Jupiter and Titan being the bulk of those acres in 2019. Approximately 50% of Arkansas acres are planted with hybrids and 37% to Clearfield. New Arkansas variety releases include CLL15 (Clearfield long grain), CLL16 (Clearfield long grain), Jewl (conventional long grain), Lynx (conventional medium grain), and CLM04 (Clearfield medium grain).

The Mississippi report was given by Bobby Golden. The rice acres were approximately 134,849 and 114,376 in 2018 and 2019, respectively. Rice acres for 2020 were projected around 170,000. Hybrids made up 51% with XL753 and CLXL745 making up the largest acres in 2018. Hybrids made up 55% of the acres 2019 with XL753 and CLXL745 having the highest acreage. Clearfield acreage made up 52% and 53% in 2018 and 2019, respectively.

The Florida report was given by Matthew Van Weelden. Crop consultants with the Florida Crystals provided the estimates. 2018 and 2019 acres were 23,748 and 23,673, respectively. Diamond (35%), Cheniere (16%), and Taggart (14%) were the most widely grown varieties in 2018. Diamond (39%), LaKast (22%), and Rex (19%) made up the bulk of the acres in 2019.

Dustin Harrell gave the report for Louisiana. Acres in Louisiana for 2018 and 2019 were approximately 434,000 and 409,000, respectively. Long grains made up about 89% while medium grains made up approximately 10% in 2018. The top grown varieties and hybrids in 2018 included CL153 (19%), CL111 (14%), and Cheniere (12%). In 2019, long grain made up 87% and medium grain 12% of the acres. The top grown varieties and hybrids in 2019 included CL153 (14.8%), CL111 (12.5%), and Cheniere (12.3%). Hybrids made up 22.4% and 25.8% of the acreage in 2018 and 2019, respectively. Clearfield acres made up approximately 59% and 52% of the acres in 2018 and 2019, respectively. Provisia was planted on 2.3% of the acres in 2018 and 5.3% of the cares in 2019.

There being no further business, a motion was moved by Kent McKenzie and seconded by Jarrod Hardke. The motion passed and the meeting was adjourned.

Submitted by
Dustin Harrell

Industry Committee

The Rice Technical Working Group Industry Committee held a successful luncheon at the 38th RTWG meeting in Orange Beach, Alabama, on Tuesday, February 25, 2020. The purpose of the Industry Committee luncheon is to enhance the meeting experience in several ways. First, it serves as a means of strengthening the cohesiveness of the committee itself, allowing the committee members to become better acquainted with each other. Since the luncheon is open to all attendees of the Rice Technical Working Group meeting, it naturally encourages an interaction between industry and public sector researchers. Finally, it serves as another meeting opportunity where an invited speaker may share with the RTWG membership their thoughts and information on timely topics.

The 2020 Industry luncheon met all of these goals. The luncheon was attended by approximately 280 guests who heard Dr. Tim Walker, General Manager of Horizon Ag, LLC. Tim spoke about his perspective on challenges and opportunities in the USA rice industry. Imports, exports, acreage, and consumer preference have all changed in the last ten years. Dr. Walker discussed those trends and how we can learn to adjust to better the rice market in the future.

The Industry Committee would like to thank Dr. Bobby Golden and Dr. Jason Bond for their assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 39th RTWG meetings hosted by Arkansas in 2022.

Submitted by
Mallory Everett

2018 Arkansas Harvested[1] Rice Acreage Summary.

COUNTY/ PARISH	2017 Acreage	2018 Acreage	MEDIUM GRAIN				LONG GRAIN							
			CL272	Jupiter	Titan	Others[2]	CL151	CL153	Diamond	RT 7311 CL	RT CLXL745	RT Gemini 214 CL	RT XP753	Others[2]
Arkansas	66,009	79,435	0	2,942	1,878	0	935	3,572	14,074	4,374	14,257	10,731	21,160	5,513
Ashley	4,092	6,616	0	0	0	0	0	0	1,402	0	4,589	135	422	68
Chicot	20,441	23,642	0	439	0	0	0	29	5,685	4,687	2,088	1,783	5,537	3,393
Clark	2,181	3,368	0	0	0	0	0	0	842	0	0	0	2,526	0
Clay	63,950	81,418	3,223	2,832	2,627	0	3,844	12,220	12,705	3,667	16,899	4,877	6,239	12,285
Craighead	56,568	74,033	2,980	5,750	4,166	0	4,995	17,108	10,624	0	8,139	1,009	7,603	11,659
Crittenden	41,202	46,808	0	4,513	1,512	0	0	0	1,533	393	8,512	3,571	25,538	1,235
Cross	61,578	85,735	0	4,719	8,468	0	2,273	21,099	12,750	2,706	6,309	6,664	10,835	9,912
Desha	9,162	17,067	0	332	0	0	0	45	4,490	1,611	2,137	2,446	5,754	252
Drew	8,138	11,890	0	0	0	0	0	0	0	5,945	0	0	5,945	0
Greene	67,214	77,653	0	2,064	0	757	8,091	0	9,457	2,149	13,602	16,363	22,132	3,038
Independence	7,274	12,660	0	2,035	2,035	0	0	4,295	859	0	0	1,718	1,718	0
Jackson	77,306	109,340	6,000	13,239	12,597	0	1,457	8,845	13,228	8,720	5,277	12,140	21,803	6,035
Jefferson	55,105	65,725	0	465	0	0	0	6,692	10,291	0	0	5,977	41,501	799
Lafayette	4,798	4,864	0	0	0	0	0	0	1,945	0	486	0	2,432	0
Lawrence	88,320	108,018	5,135	3,157	11,393	1,095	5,422	11,257	46,234	916	7,299	5,085	3,741	7,284
Lee	7,314	18,539	0	985	657	0	0	0	10,186	0	676	1,907	3,717	410
Lincoln	15,068	23,510	0	0	0	0	0	0	4,749	795	6,226	2,197	4,964	4,581
Lonoke	80,333	84,246	0	625	818	426	465	1,124	7,725	7,359	9,055	15,025	36,270	5,354
Mississippi	49,073	62,284	0	895	0	1,010	0	2,780	19,605	767	7,309	3,852	21,434	4,632
Monroe	37,228	53,666	0	3,957	1,907	0	0	6,537	12,206	2,905	2,681	7,808	8,248	7,418
Phillips	13,473	27,703	0	0	2,758	0	0	797	12,074	0	1,953	1,395	7,535	1,190
Poinsett	91,810	117,557	3,163	25,026	1,299	0	2,685	12,520	31,180	3,294	15,906	8,344	9,052	5,089
Pope	2,525	3,102	0	0	0	0	0	0	0	0	0	465	1,551	1,086
Prairie	54,410	62,398	0	4,159	1,759	51	195	1,999	4,597	5,428	16,844	13,916	9,519	3,930
Pulaski	4,899	5,416	0	0	0	0	0	0	596	325	650	1,191	2,491	162
Randolph	28,066	40,743	0	6,313	5,943	0	1,278	7,853	7,789	91	461	1,922	5,113	3,980
St. Francis	25,981	34,527	0	1,377	2,951	0	0	33	4,819	393	6,930	8,492	675	8,857
White	6,013	10,763	0	0	0	0	0	0	0	386	772	0	7,756	1,849
Woodruff	46,473	59,356	0	0	7,178	0	0	1,183	21,753	5,312	1,234	13,285	8,026	1,386
Others[3]	5,981	11,320	0	0	0	0	196	0	2,047	101	1,147	697	4,735	2,397
Unaccounted[4]	2,018	3,599												3,599
2018 Total		1,427,000	20,501	85,826	69,947	3,339	31,834	119,988	285,444	62,326	161,438	152,995	315,971	117,391
2018 Percent		100.00%	1.44%	6.01%	4.90%	0.23%	2.23%	8.41%	20.0%	4.37%	11.31%	10.72%	22.14%	8.23%
2017 Total	1,104,000		6,807	98,333	33,615	6,225	75,283	98,473	94,480	11,415	205,015	7,749	181,879	284,725
2017 Percent	100.00%		0.62%	8.91%	3.04%	0.56%	6.82%	8.92%	8.56%	1.03%	18.57%	0.70%	16.47%	25.79%

[1] - Harvested acreage. Source: USDA-NASS, 2019.

[2] - Other varieties: RT XP760, RT CLXL729, CL172, CL111, Roy J, PVL01, LaKast, RT CLXP756, CL163, Wells, RT XL723, AB647, Caffey, Jazzman-2, RT XP754, Rex, Taggart, Jazzman, Francis, Cheniere, Della-2, and Cocodrie.

[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 preliminary estimates obtained from each county FSA.

2019 Arkansas Harvested[1] Rice Acreage Summary

COUNTY/ PARISH	2018 Acreage	2019 Acreage	MEDIUM GRAIN			LONG GRAIN								
			Jupiter	Titan	Others[2]	CL151	CL153	Diamond	RT7311 CL	RT CLXL745	RT Gemini 214 CL	RT XP753	RT XP760	Others[b]
Arkansas	79,435	74,687	2,604	1,027	269	2,061	2,439	6,924	2,513	9,201	14,295	21,796	3,709	7,849
Ashley	6,616	5,409	0	0	0	0	0	0	0	4,720	690	0	0	0
Chicot	23,642	17,880	843	0	0	341	2,003	0	0	0	768	3,204	0	10,721
Clark	3,368	1,860	0	0	0	0	0	752	0	0	0	1,108	0	0
Clay	81,418	64,931	5,022	672	0	4,081	5,377	4,034	2,812	1,032	5,977	12,812	2,543	20,569
Craighead	74,033	53,183	12,417	2,029	0	3,821	7,959	4,086	2,275	3,705	6,577	10,037	57	219
Crittenden	46,808	43,743	1,928	6,354	341	0	0	4,044	0	2,109	2,047	22,924	3,470	526
Cross	85,735	71,600	8,574	6,834	649	1,943	6,852	8,778	2,155	6,879	7,821	15,003	3,233	2,879
Desha	17,067	20,399	2,185	2,185	0	0	333	2,705	0	926	3	8,088	505	3,469
Drew	11,890	9,137	0	0	0	0	0	0	900	4,291	0	716	2,985	245
Greene	77,653	58,606	0	3,101	0	0	0	0	3,685	6,938	27,255	17,628	0	0
Independence	12,660	5,311	938	938	0	0	1,718	344	0	0	687	687	0	0
Jackson	109,340	66,127	17,334	11,196	0	319	796	6,828	4,188	3,039	6,578	8,516	0	7,332
Jefferson	65,725	51,730	272	272	0	0	5,346	6,482	0	0	0	39,225	0	134
Lafayette	4,864	3,456	0	0	0	0	0	1,382	0	0	346	1,728	0	0
Lawrence	108,018	76,188	3,984	17,251	0	0	0	11,105	0	9,228	9,015	18,254	1,236	6,115
Lee	18,539	16,670	1,897	759	0	0	0	5,307	690	0	2,823	2,007	1,305	1,882
Lincoln	23,510	17,466	322	0	0	0	0	0	4,412	0	12,732	0	0	0
Lonoke	84,246	65,728	1,859	0	0	0	0	664	3,864	6,276	18,129	24,883	4,933	5,120
Mississippi	62,284	56,313	453	568	1,278	0	2,707	14,239	5,615	15,671	201	12,534	100	2,948
Monroe	53,666	39,999	3,498	4,397	0	2,413	1,756	6,751	0	3,194	10,191	6,583	259	956
Phillips	27,703	26,920	0	2,456	0	0	0	4,530	0	906	0	0	17,215	1,812
Poinsett	117,557	94,753	27,590	1,307	3,460	2,542	1,491	17,161	1,848	9,839	11,154	8,469	4,398	5,495
Pope	3,102	1,898	0	0	0	380	0	285	0	0	285	569	0	380
Prairie	62,398	53,623	4,091	905	384	229	990	2,308	4,119	8,139	14,602	14,599	2,140	1,116
Pulaski	5,416	2,894	0	0	85	0	0	0	0	2,809	0	0	0	0
Randolph	40,743	27,582	3,935	5,677	198	0	0	3,079	0	2,446	2,164	10,082	0	0
St. Francis	34,527	34,508	895	3,784	0	602	0	3,803	3,214	2,257	3,789	11,900	1,375	2,890
White	10,763	7,871	1,070	459	0	0	0	737	470	374	1,383	2,776	603	0
Woodruff	59,356	49,495	5,182	1,321	0	4,550	2,697	6,145	2,101	4,702	8,246	10,429	1,717	2,405
Others[3]	11,320	2,855	0	0	0	151	0	448	0	109	547	1,489	0	109
Unaccounted[4]	3,599	3,179												3,599
2019 Total		1,126,000	106,892	73,490	6,665	23,434	42,464	122,922	44,863	108,791	168,302	288,046	51,783	88,350
2019 Percent		100.00	9.49	6.53	0.59	2.08	3.77	10.92	3.98	9.66	14.95	25.58	4.60	7.85
2018 Total	1,427,000		85,826	69,947	23,840	31,834	119,988	285,444	62,326	161,438	152,995	315,971	18,287	99,104
2018 Percent	100		6.01	4.90	1.67	2.23	8.41	20.00	4.37	11.31	10.72	22.14	1.28	6.94

[1] Harvested acreage. Source: USDA-NASS, 2020.
[2] Other varieties: RT XL723, PVL01, LaKast, RT CLXP756, Roy J, CL111, RT CLXL729, CL172, CL272, RT XP754, CL163, RT7801, Caffey, CLL15, Jazzman-2, Cheniere, Wells, AB647, and Jazzman.
[3] Other counties: Conway, Faulkner, Franklin, Hot Springs, Little River, Logan, Miller, and Yell.
[4] Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and estimates obtained from each county FSA.

California Rice Acreage Summary, 2018 and 2019.

Variety	2018			2019		
	Seed Acres[1]	Percentage	Estimated Acres[2]	Seed Acres[1]	Percentage	Estimated Acres[2]
M-104	103	0.50%	2372	0	0.00%	0
M-105	2236	11.40%	54,118	2385	11.00%	52,142
M-205	2061	10.00%	47,740	1665	7.70%	36,413
M-206	8424	41.00%	195,156	10,066	46.60%	220,101
M-208	96	0.40%	1820	0	0.00%	0
M-209	4467	21.80%	103,490	3742	17.30%	81,816
M-210	5	0.10%	300	270	1.30%	5906
M-211[3]	--			7	0.00%	7
M-401	1219	5.90%	28,236	1186	5.50%	25,932
M-402	144	0.70%	3324	141	0.70%	3083
Medium Grain	18,775	91.80%	436,558	19,461	90.10%	425,394
S-102	189	0.90%	4370	262	1.20%	5720
S-202	2	0.00%	2	2	0.00%	37
Calhikari-201	85	0.40%	1974	87	0.40%	1894
Calhikari-202	137	0.70%	3185	142	0.70%	3116
Calmochi-101	884	4.30%	20,468	977	4.50%	21,359
Calmochi-203	57	0.30%	1316	77	0.40%	1679
Calamylow-201	10	0.00%	38	3	0.00%	66
Short Grain	1364	6.60%	31,353	1549	7.20%	33,870
L-205	--	0.00%	0	1	0.00%	30
L-206	67	0.30%	1584	88	0.00%	1917
L-207	9	0.00%	212	85	0.40%	1868
L-208[3]	NR			1	0.00%	1
A-201	205	1.00%	4754	195	0.90%	4264
A-202	49	0.20%	1123	144	0.70%	3156
Calmati-202	--	0.00%	20	1	0.00%	31
Calaroma-201	5	0.00%	38	82	0.40%	1788
Long Grain	335	1.50%	7731	589	2.80%	13,055
NASS CA Acres			506,000			492,000

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

[2] Acreage estimates are the previous year's seed production percentage of CCRRF varieties (~95% of CCIA certified or QA rice seed production) times the NASS acreage for the following year.

The remaining percentages are assumed to be planted to proprietary, Japanese short grains, or older CCRRF varieties not in seed production.

[3] New variety first release of foundation seed in 2019.

Florida Rice Acreage Report, 2018 and 2019.

Variety	2018		2019	
	Acreage	Percentage	Acreage	Percentage
XL723	37	<1	0	0
XP753	36	<1	295	1
XP754	0	0	69	<1
XP760	35	<1	305	1
Cheniere	3,848	16	2,848	12
Diamond	8,238	35	9,313	39
LaKast	2,660	11	5,101	22
Mermentau	0	0	74	<1
Mixed	382	2	0	0
Rex	2,568	11	4,438	19
Taggart	3,277	14	0	0
Thad	1,121	5	0	0
Long Grain	**22,202**	**93**	**22,443**	**95**
Jupiter	1,546	7	1,018	4
Titan	0	0	212	1
Medium Grain	**1,546**	**7**	**1,230**	**5**
Total	**23,748**	**100**	**23,673**	**100**

2018 LOUISIANA RICE ACREAGE SUMMARY
All Classes

Parish	2017 Total	2018 Total	Long Grain	Medium Grain	Special Purpose	Percent of State Total (by Parish)
Acadia	80,324	83,831	78,572	4,932	327	19.3
Allen	14,452	15,672	13,450	2,222	0	3.6
Avoyelles	12,203	14,283	14,283	0	0	3.3
Beauregard	912	825	825	0	0	0.2
Bossier	121	121	121	0	0	0.0
Calcasieu	11,136	11,844	11,657	187	0	2.7
Caldwell	650	769	769	0	0	0.2
Cameron	10,312	10,402	9,669	458	275	2.4
Catahoula	2,921	3,839	3,839	0	0	0.9
Concordia	8,253	6,115	6,115	0	0	1.4
East Carroll	1,489	2,025	1,250	455	320	0.5
Evangeline	41,829	45,185	40,861	4,324	0	10.4
Franklin	4,017	4,705	2,805	1,900	0	1.1
Iberia	295	360	331	29	0	0.1
Iberville	135	254	254	0	0	0.1
Jefferson Davis	76,377	82,671	71,050	11,321	300	19.0
Lafayette	908	1,103	812	291	0	0.3
Madison	5,957	7,975	5,111	2,864	0	1.8
Morehouse	20,624	29,062	20,957	8,105	0	6.7
Natchitoches	2,113	3,408	2,721	687	0	0.8
Ouachita	6,861	7,780	3,414	4,366	0	1.8
Pointe Coupee	250	900	900	0	0	0.2
Rapides	8,040	10,654	10,654	0	0	2.5
Red River	406	406	406	0	0	0.1
Richland	5,152	6,932	6,012	124	905	1.6
St. Landry	21,329	26,076	25,600	476	0	6.0
St. Martin	2,518	4,294	4,294	0	0	1.0
Tensas	4,935	2,665	2,550	0	115	0.6
Vermilion	45,380	49,182	48,601	581	0	11.3
West Baton Rouge	565	565	565	0	0	0.1
West Carroll	608	220	40	180	0	0.1
Total Acreage	391,071	434,123	388,488	43,502	2,242	100
Percent of Total	100	100	89.49	10.02	0.52	100

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Long Grain

Parish	2018 Total	Long Grain	Variety															Hybrid							
			Catahoula	Cheniere	CL111	CL151	CL152	CL153	CL163	CL172	Cocodrie	LaKast	Mermentau	PVL01	Roy J	Thad	Wells	CLXL729	CLXL745	Gemini214 CL	RT7311 CL	XL723	XP753	XP760	Hybrid NS[1]
Acadia	83,831	78,572	0	12,982	13,350	4,726	0	16,692	0	3,150	0	85	12,560	3,925	0	0	0	2,363	4,726	0	0	75	3,938	0	0
Allen	15,672	13,450	0	850	2,140	0	0	2,480	0	0	0	0	2,145	650	0	0	0	1,280	1,570	735	350	0	1,250	0	0
Avoyelles	14,283	14,283	735	3,036	1,750	0	0	4,892	0	542	0	0	428	714	0	0	0	0	758	0	0	0	1,428	0	0
Beauregard	825	825	0	0	0	0	0	121	0	0	0	0	0	0	0	0	0	0	400	0	304	0	0	0	0
Bossier	121	121	0	0	0	0	0	121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	11,844	11,657	0	220	4,210	1,597	0	3,060	0	514	78	110	664	0	0	0	0	0	864	90	250	0	0	0	0
Caldwell	769	769	0	769	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	10,402	9,669	0	433	1,740	0	0	967	0	387	0	0	0	0	0	0	0	290	2,417	2,178	1,257	0	0	0	0
Catahoula	3,839	3,839	0	1,939	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	0	0	0	1,300	0	0
Concordia	6,115	6,115	0	200	0	0	0	860	0	0	0	0	330	0	0	0	0	0	1,975	0	0	0	450	0	2,300
East Carroll	2,025	1,250	0	0	0	0	0	400	0	200	0	0	0	0	0	0	0	0	250	200	200	0	0	0	0
Evangeline	45,185	40,861	0	3,200	8,646	0	1,120	7,200	0	0	0	0	7,650	1,350	0	0	0	2,900	3,850	1,975	600	0	2,370	0	0
Franklin	4,705	2,805	0	0	0	0	0	0	120	0	0	0	0	0	0	0	0	0	1,500	1,185	0	0	0	0	0
Iberia	360	331	0	93	0	0	0	165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0
Iberville	254	254	0	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	82,671	71,050	0	7,000	15,800	6,000	0	12,000	0	5,500	0	175	11,475	0	0	0	0	3,500	4,000	1,100	1,500	0	3,000	0	0
Lafayette	1,103	812	0	0	376	0	0	341	0	0	0	0	0	45	0	0	0	0	50	0	0	0	0	0	0
Madison	7,975	5,111	0	0	0	0	0	242	1,603	0	0	0	0	0	952	0	0	0	610	0	0	0	1,668	36	0
Morehouse	29,062	20,957	0	0	0	0	0	250	4,350	0	0	0	0	0	250	0	0	0	11,011	4,556	0	0	0	540	0
Natchitoches	3,408	2,721	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,361	0	0	0	1,360	0	0
Ouachita	7,780	3,414	0	223	0	0	0	90	1,292	0	0	0	0	0	71	0	580	0	947	96	0	115	0	0	0
Pointe Coupee	900	900	0	135	100	0	0	432	0	0	0	0	0	0	0	0	0	0	233	0	0	0	0	0	0
Rapides	10,654	10,654	533	2,664	1,172	0	0	3,516	0	320	0	0	318	533	0	0	0	0	533	0	0	0	1,065	0	0
Red River	406	406	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	203	0	0	0	203	0	0
Richland	6,932	6,012	0	0	0	0	0	420	450	0	0	0	0	50	0	109	0	0	2,521	2,356	0	0	68	0	38
St. Landry	26,076	25,600	0	4,162	2,042	462	0	15,752	0	0	0	0	2,560	622	0	0	0	0	0	0	0	0	0	0	0
St. Martin	4,294	4,294	0	150	0	0	0	929	0	0	0	0	0	150	0	0	0	0	614	0	362	0	2,089	0	0
Tensas	2,665	2,550	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	960	840	0	0	510	0	0
Vermilion	49,182	48,601	0	12,664	9,776	1,458	0	13,333	0	972	0	0	7,387	1,944	0	0	0	0	0	0	315	489	263	0	0
West Baton Rouge	565	565	0	565	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	220	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0
Total Acreage	**434,123**	**388,488**	**1,268**	**51,539**	**61,102**	**14,243**	**1,120**	**84,503**	**7,815**	**11,585**	**78**	**370**	**45,517**	**9,983**	**1,273**	**109**	**580**	**10,333**	**41,953**	**15,311**	**5,138**	**679**	**21,075**	**576**	**2,338**
Percent (of Long Grain)		**100**	**0.33**	**13.27**	**15.73**	**3.67**	**0.29**	**21.75**	**2.01**	**2.98**	**0.02**	**0.10**	**11.72**	**2.57**	**0.33**	**0.03**	**0.15**	**2.66**	**10.80**	**3.94**	**1.32**	**0.17**	**5.42**	**0.15**	**0.60**
Percent (of all acres)		**89.49**	**0.29**	**11.87**	**14.07**	**3.28**	**0.26**	**19.47**	**1.80**	**2.67**	**0.02**	**0.09**	**10.48**	**2.30**	**0.29**	**0.03**	**0.13**	**2.38**	**9.66**	**3.53**	**1.18**	**0.16**	**4.85**	**0.13**	**0.54**
Total Acreage			**291,084**															**97,404**							
Percent (of Long Grain)			**74.93**															**25.07**							
Percent (of all acres)			**67.05**															**22.44**							

[1] Hybrid NS includes hybrid seed rice production not specified and RT7801.

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Medium Grain

Parish	2018 Total	Medium Grain	Variety			
			Caffey	CL272	Jupiter	Titan
Acadia	83,831	4,932	80	1,097	2,580	1,175
Allen	15,672	2,222	0	0	2,222	0
Avoyelles	14,283	0	0	0	0	0
Beauregard	825	0	0	0	0	0
Bossier	121	0	0	0	0	0
Calcasieu	11,844	187	0	0	187	0
Caldwell	769	0	0	0	0	0
Cameron	10,402	458	0	0	458	0
Catahoula	3,839	0	0	0	0	0
Concordia	6,115	0	0	0	0	0
East Carroll	2,025	455	0	0	455	0
Evangeline	45,185	4,324	0	125	4,114	85
Franklin	4,705	1,900	0	0	1,900	0
Iberia	360	29	0	29	0	0
Iberville	254	0	0	0	0	0
Jefferson Davis	82,671	11,321	0	2,321	5,000	4,000
Lafayette	1,103	291	0	46	245	0
Madison	7,975	2,864	0	0	2,864	0
Morehouse	29,062	8,105	7,755	0	350	0
Natchitoches	3,408	687	0	0	687	0
Ouachita	7,780	4,366	657	0	3,709	0
Pointe Coupee	900	0	0	0	0	0
Rapides	10,654	0	0	0	0	0
Red River	406	0	0	0	0	0
Richland	6,932	124	0	0	124	0
St. Landry	26,076	476	0	0	48	428
St. Martin	4,294	0	0	0	0	0
Tensas	2,665	0	0	0	0	0
Vermilion	49,182	581	0	83	203	295
West Baton Rouge	565	0	0	0	0	0
West Carroll	220	180	0	0	180	0
Total Acreage	**434,123**	**43,502**	**8,492**	**3,701**	**25,326**	**5,983**
Percent (of medium grain)		**100**	**19.52**	**8.51**	**58.22**	**13.75**
Percent (of all acres)		**10.02**	**1.96**	**0.85**	**5.83**	**1.38**

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Special Purpose

Parish	2018 Total	Special Purpose	Variety					
			Blanca Isabel	CLJ01	Hidalgo	Jazzman-2	Sabine	Toro-2
Acadia	83,831	327	52	150	0	125	0	0
Allen	15,672	0	0	0	0	0	0	0
Avoyelles	14,283	0	0	0	0	0	0	0
Beauregard	825	0	0	0	0	0	0	0
Bossier	121	0	0	0	0	0	0	0
Calcasieu	11,844	0	0	0	0	0	0	0
Caldwell	769	0	0	0	0	0	0	0
Cameron	10,402	275	0	0	0	175	0	100
Catahoula	3,839	0	0	0	0	0	0	0
Concordia	6,115	0	0	0	0	0	0	0
East Carroll	2,025	320	0	0	320	0	0	0
Evangeline	45,185	0	0	0	0	0	0	0
Franklin	4,705	0	0	0	0	0	0	0
Iberia	360	0	0	0	0	0	0	0
Iberville	254	0	0	0	0	0	0	0
Jefferson Davis	82,671	300	0	0	0	300	0	0
Lafayette	1,103	0	0	0	0	0	0	0
Madison	7,975	0	0	0	0	0	0	0
Morehouse	29,062	0	0	0	0	0	0	0
Natchitoches	3,408	0	0	0	0	0	0	0
Ouachita	7,780	0	0	0	0	0	0	0
Pointe Coupee	900	0	0	0	0	0	0	0
Rapides	10,654	0	0	0	0	0	0	0
Red River	406	0	0	0	0	0	0	0
Richland	6,932	796	0	0	188	0	608	0
St. Landry	26,076	0	0	0	0	0	0	0
St. Martin	4,294	0	0	0	0	0	0	0
Tensas	2,665	115	0	0	0	0	115	0
Vermilion	49,182	0	0	0	0	0	0	0
West Baton Rouge	565	0	0	0	0	0	0	0
West Carroll	220	0	0	0	0	0	0	0
Total Acreage	**434,123**	**2,133**	**52**	**150**	**508**	**600**	**723**	**100**
Percent (of Special Purpose)		**100**	**2.44**	**7.03**	**23.82**	**28.13**	**33.90**	**4.69**
Percent (of all acres)		**0.49**	**0.01**	**0.03**	**0.12**	**0.14**	**0.17**	**0.02**

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Clearfield

Parish	2018 Total	Clearfield Total	Variety							Hybrid			
			CL111	CL151	CL152	CL153	CL163	CL172	CL272	CLXL729	CLXL745	Gemini214 CL	RT7311 CL
Acadia	83,831	46,104	13,350	4,726	0	16,692	0	3,150	1,097	2,363	4,726	0	0
Allen	15,672	8,555	2,140	0	0	2,480	0	0	0	1,280	1,570	735	350
Avoyelles	14,283	7,942	1,750	0	0	4,892	0	542	0	0	758	0	0
Beauregard	825	825	0	0	0	121	0	0	0	0	400	0	304
Bossier	121	121	0	0	0	121	0	0	0	0	0	0	0
Calcasieu	11,844	10,585	4,210	1,597	0	3,060	0	514	0	0	864	90	250
Caldwell	769	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	10,402	9,236	1,740	0	0	967	0	387	0	290	2,417	2,178	1,257
Catahoula	3,839	600	0	0	0	0	0	0	0	0	600	0	0
Concordia	6,115	2,835	0	0	0	860	0	0	0	0	1,975	0	0
East Carroll	2,025	1,250	0	0	0	400	0	200	0	0	250	200	200
Evangeline	45,185	26,416	8,646	0	1,120	7,200	0	0	125	2,900	3,850	1,975	600
Franklin	4,705	2,805	0	0	0	0	120	0	0	0	1,500	1,185	0
Iberia	360	194	0	0	0	165	0	0	29	0	0	0	0
Iberville	254	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	82,671	51,721	15,800	6,000	0	12,000	0	5,500	2,321	3,500	4,000	1,100	1,500
Lafayette	1,103	813	376	0	0	341	0	0	46	0	50	0	0
Madison	7,975	2,455	0	0	0	242	1,603	0	0	0	610	0	0
Morehouse	29,062	20,167	0	0	0	250	4,350	0	0	0	11,011	4,556	0
Natchitoches	3,408	1,361	0	0	0	0	0	0	0	0	1,361	0	0
Ouachita	7,780	2,425	0	0	0	90	1,292	0	0	0	947	96	0
Pointe Coupee	900	765	100	0	0	432	0	0	0	0	233	0	0
Rapides	10,654	5,541	1,172	0	0	3,516	0	320	0	0	533	0	0
Red River	406	203	0	0	0	0	0	0	0	0	203	0	0
Richland	6,932	5,747	0	0	0	420	450	0	0	0	2,521	2,356	0
St. Landry	26,076	18,256	2,042	462	0	15,752	0	0	0	0	0	0	0
St. Martin	4,294	1,905	0	0	0	929	0	0	0	0	614	0	362
Tensas	2,665	2,040	0	0	0	240	0	0	0	0	960	840	0
Vermilion	49,182	25,937	9,776	1,458	0	13,333	0	972	83	0	0	0	315
West Baton Rouge	565	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	220	0	0	0	0	0	0	0	0	0	0	0	0
Total Acreage	**434,123**	**256,804**	**61,102**	**14,243**	**1,120**	**84,503**	**7,815**	**11,585**	**3,701**	**10,333**	**41,953**	**15,311**	**5,138**
Percent (of Clearfield)		**100**	**23.79**	**5.55**	**0.44**	**32.91**	**3.04**	**4.51**	**1.44**	**4.02**	**16.34**	**5.96**	**2.00**
Percent (of all acres)		**59.15**	**14.07**	**3.28**	**0.26**	**19.47**	**1.80**	**2.67**	**0.85**	**2.38**	**9.66**	**3.53**	**1.18**
Total Acreage			**184,069**							**72,736**			
Percent (of Clearfield)			**71.68**							**28.32**			
Percent (of all acres)			**42.40**							**16.75**			

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Hybrid

Parish	2018 Total	Hybrid Total	Clearfield				Non-Clearfield			Hybrid NS[1]
			CLXL729	CLXL745	Gemini214 CL	RT7311 CL	XL723	XP753	XP760	(not-specified)
Acadia	83,831	11,102	2,363	4,726	0	0	75	3,938	0	0
Allen	15,672	5,185	1,280	1,570	735	350	0	1,250	0	0
Avoyelles	14,283	2,186	0	758	0	0	0	1,428	0	0
Beauregard	825	704	0	400	0	304	0	0	0	0
Bossier	121	0	0	0	0	0	0	0	0	0
Calcasieu	11,844	1,204	0	864	90	250	0	0	0	0
Caldwell	769	0	0	0	0	0	0	0	0	0
Cameron	10,402	6,143	290	2,417	2,178	1,257	0	0	0	0
Catahoula	3,839	1,900	0	600	0	0	0	1,300	0	0
Concordia	6,115	4,725	0	1,975	0	0	0	450	0	2,300
East Carroll	2,025	650	0	250	200	200	0	0	0	0
Evangeline	45,185	11,695	2,900	3,850	1,975	600	0	2,370	0	0
Franklin	4,705	2,685	0	1,500	1,185	0	0	0	0	0
Iberia	360	73	0	0	0	0	0	73	0	0
Iberville	254	0	0	0	0	0	0	0	0	0
Jefferson Davis	82,671	13,100	3,500	4,000	1,100	1,500	0	3,000	0	0
Lafayette	1,103	50	0	50	0	0	0	0	0	0
Madison	7,975	2,314	0	610	0	0	0	1,668	36	0
Morehouse	29,062	16,107	0	11,011	4,556	0	0	0	540	0
Natchitoches	3,408	2,721	0	1,361	0	0	0	1,360	0	0
Ouachita	7,780	1,158	0	947	96	0	115	0	0	0
Pointe Coupee	900	233	0	233	0	0	0	0	0	0
Rapides	10,654	1,598	0	533	0	0	0	1,065	0	0
Red River	406	406	0	203	0	0	0	203	0	0
Richland	6,932	4,983	0	2,521	2,356	0	0	68	0	38
St. Landry	26,076	0	0	0	0	0	0	0	0	0
St. Martin	4,294	3,065	0	614	0	362	0	2,089	0	0
Tensas	2,665	2,310	0	960	840	0	0	510	0	0
Vermilion	49,182	1,067	0	0	0	315	489	263	0	0
West Baton Rouge	565	0	0	0	0	0	0	0	0	0
West Carroll	220	40	0	0	0	0	0	40	0	0
Total Acreage	**434,123**	**97,404**	**10,333**	**41,953**	**15,311**	**5,138**	**679**	**21,075**	**576**	**2,338**
Percent (of Hybrid)		**100**	**10.61**	**43.07**	**15.72**	**5.27**	**0.70**	**21.64**	**0.59**	**2.40**
Percent (of all acres)		**22.44**	**2.38**	**9.66**	**3.53**	**1.18**	**0.16**	**4.85**	**0.13**	**0.54**
Total Acreage			**72,736**				**22,330**			**2,338**
Percent (of Hybrid)			**74.67**				**22.93**			**2.40**
Percent (of all acres)			**16.75**				**5.14**			**0.54**

[1] Hybrid NS includes hybrid seed rice production not specified and RT7801.

2018 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
RATOON CROP AND CONSERVATION TILLAGE

	2018 Total Acres	Ratoon Crop	No Till			Reduced Tillage Production (Stale Seedbed)						Total Acres using Con. Tillage
			Drill Planted	Dry Broadcast	Water Planted	Drill Planted		Dry Broadcast		Water Planted		
						Fall	Spring	Fall	Spring	Fall	Spring	
Acadia	83,831	54,405	3,100	1,000	0	12,000	5,500	0	2,000	1,000	4,000	28,600
Allen	15,672	3,447	1,150	0	0	1,700	3,900	0	0	0	0	6,750
Avoyelles	14,283	2,142	714	714	714	2,142	714	285	285	1,428	714	7,710
Beauregard	825	645	450	0	0	130	0	0	0	0	0	580
Bossier	121	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	11,844	8,883	0	0	0	3,250	850	0	0	2,100	0	6,200
Caldwell	769	0	385	0	0	0	0	0	0	0	384	769
Cameron	10,402	7,802	800	0	0	1,600	0	0	0	0	0	2,400
Catahoula	3,839	0	1,900	0	0	1,941	0	0	0	0	0	3,841
Concordia	6,115	0	3,000	0	0	3,115	0	0	0	0	0	6,115
East Carroll	2,025	0	0	0	0	2,025	0	0	0	0	0	2,025
Evangeline	45,185	10,500	8,300	0	0	7,200	2,400	0	0	0	0	17,900
Franklin	4,705	0	1,560	0	0	3,105	0	0	0	0	0	4,665
Iberia	360	120	0	0	0	70	25	40	0	0	0	135
Iberville	254	0	0	0	0	0	0	0	0	125	0	125
Jefferson Davis	82,671	57,869	1,200	0	1,500	22,000	2,300	1,200	1,200	5,000	2,000	36,400
Lafayette	1,103	528	0	0	0	200	50	50	50	100	50	500
Madison	7,975	0	0	0	0	5,375	0	0	0	0	0	5,375
Morehouse	29,062	0	0	0	0	14,268	3,132	0	0	0	0	17,400
Natchitoches	3,408	0	0	0	0	3,408	0	0	0	0	0	3,408
Ouachita	7,780	0	1,900	0	0	0	2,500	0	0	0	0	4,400
Pointe Coupee	900	0	0	0	0	0	0	0	0	0	0	0
Rapides	10,654	1,598	533	533	533	1,598	533	213	213	1,065	533	5,754
Red River	406	0	0	0	0	406	0	0	0	0	0	406
Richland	6,932	0	2,310	0	0	2,310	2,312	0	0	0	0	6,932
St. Landry	26,076	1,280	0	0	11,264	14,336	0	0	0	0	0	25,600
St. Martin	4,294	1,932	0	0	230	605	0	100	0	0	0	935
Tensas	2,665	0	1,250	0	0	1,300	0	0	0	0	0	2,550
Vermilion	49,182	23,660	8,472	847	1,412	18,890	1,950	650	693	890	14,109	47,913
West Baton Rouge	565	0	0	0	0	0	100	0	0	230	0	330
West Carroll	220	0	0	0	0	0	220	0	0	0	0	220
Total Acreage	**434,123**	**174,811**	**37,024**	**3,094**	**15,653**	**122,974**	**26,486**	**2,538**	**4,441**	**11,938**	**21,790**	**245,938**
				55,771		**149,460**		**6,979**		**33,728**		

2018 Rice Variety by Acreage Survey

Parish	2018 Total Rice Acreage	Planting Method							Non-Traditional Water Management	
		Water Seeded Acres			Total Water Seeded	Dry Seeded Acres		Total Dry Seeded	Alternate wetting and drying (AWD)	Furrow Irrigated
		Pin-point	Continous	Delayed		Drilled	Dry Broadcast			
Acadia	83,831	2,000	3,850	6,200	12,050	56,661	15,120	71,781	0	0
Allen	15,672	1,800	0	3,600	5,400	9,622	650	10,272	0	0
Avoyelles	14,283	1,428	0	7,570	8,998	4,857	428	5,285	0	288
Beauregard	825	0	0	0	0	825	0	825	0	0
Bossier	121	0	0	0	0	121	0	121	0	0
Calcasieu	11,844	0	0	4,145	4,145	7,699	0	7,699	0	0
Caldwell	769	384	0	0	384	385	0	385	0	0
Cameron	10,402	2,802	2,200	0	5,002	5,400	0	5,400	0	0
Catahoula	3,839	0	0	0	0	3,841	0	3,841	0	1,450
Concordia	6,115	0	0	0	0	6,115	0	6,115	0	20
East Carroll	2,025	0	0	0	0	2,025	0	2,025	0	0
Evangeline	45,185	2,100	0	7,200	9,300	33,795	2,500	36,295	0	0
Franklin	4,705	0	0	0	0	4,705	0	4,705	0	0
Iberia	360	0	0	110	110	210	40	250	0	0
Iberville	254	254	0	0	254	0	0	0	0	0
Jefferson Davis	82,671	18,000	1,000	8,281	27,281	36,890	18,500	55,390	0	0
Lafayette	1,103	100	0	50	150	800	153	953	0	0
Madison	7,975	0	0	0	0	7,975	0	7,975	195	500
Morehouse	29,062	0	0	0	0	27,062	2,000	29,062	1,100	1,400
Natchitoches	3,408	0	0	0	0	3,408	0	3,408	0	0
Ouachita	7,780	0	0	0	0	7,780	0	7,780	0	0
Pointe Coupee	900	0	900	0	900	0	0	0	0	0
Rapides	10,654	1,136	0	5,079	6,215	3,480	959	4,439	0	0
Red River	406	0	0	0	0	406	0	406	0	0
Richland	6,932	0	0	0	0	6,932	0	6,932	0	428
St. Landry	26,076	0	0	11,264	11,264	14,812	0	14,812	0	0
St. Martin	4,294	135	0	375	510	2,984	800	3,784	0	0
Tensas	2,665	0	0	0	0	2,665	0	2,665	0	870
Vermilion	49,182	17,164	0	0	17,164	29,828	2,190	32,018	0	0
West Baton Rouge	565	465	0	0	465	100	0	100	0	0
West Carroll	220	0	0	0	0	220	0	220	0	0
Total Acreage	**434,123**	**47,768**	**7,950**	**53,874**	**109,592**	**281,603**	**43,340**	**324,943**	**1,295**	**4,956**
Percent of Total	**100**	**11.00**	**1.83**	**12.41**	**25.24**	**64.87**	**9.98**	**74.85**	**0.30**	**1.14**

2019 LOUISIANA RICE ACREAGE SUMMARY
All Classes

Parish	2018 Total	2019 Total	Long Grain	Medium Grain	Percent of State Total (by Parish)
Acadia	83,831	84,007	78,463	5,544	20.5
Allen	15,672	13,431	11,377	2,054	3.3
Avoyelles	14,283	13,778	13,778	0	3.4
Beauregard	825	743	743	0	0.2
Caddo	0	118	118	0	0.0
Calcasieu	11,844	8,238	8,106	132	2.0
Caldwell	769	366	366	0	0.1
Cameron	10,402	9,180	9,106	74	2.2
Catahoula	3,839	2,484	2,484	0	0.6
Concordia	6,115	4,995	4,995	0	1.2
East Carroll	2,025	1,064	1,064	0	0.3
Evangeline	45,185	44,894	37,998	6,896	11.0
Franklin	4,705	10,428	9,132	1,296	2.5
Iberia	360	500	500	0	0.1
Jefferson Davis	82,671	77,799	66,841	10,958	19.0
Lafayette	1,103	1,160	863	297	0.3
Madison	7,975	4,424	2,662	1,762	1.1
Morehouse	29,062	33,981	21,697	12,284	8.3
Natchitoches	3,408	768	768	0	0.2
Ouachita	7,780	4,680	1,228	3,452	1.1
Pointe Coupee	900	1,148	1,148	0	0.3
Rapides	10,654	9,880	7,867	2,013	2.4
Richland	6,932	3,060	3,014	46	0.7
St. Landry	26,076	23,354	20,991	2,363	5.7
St. Martin	4,294	3,528	3,528	0	0.9
Tensas	2,665	2,132	2,132	0	0.5
Vermilion	49,182	48,483	47,076	1,407	11.8
West Baton Rouge	565	737	737	0	0.2
West Carroll	220	217	217	0	0.1
Total Acreage	434,123	409,577	358,999	50,578	100
Percent of Total	100	100	87.65	12.35	100

* In 2018, Bossier had 121 acres, Iberville had 254 acres, and Red River had 406 acres. These parishes had 0 acres in 2019.

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Long Grain

Parish	2019 Total	Long Grain	Variety															Hybrid							
			Catahoula	Cheinere	Cocodrie	Diamond	LaKast	Mermentau	Presidio	CL111	CL151	CL153	CL163	CL172	CLL15	PVL01	PVL02	CLXL729	CLXL745	CL Gemini 214	CL RT 7311	RT 7301	XP753	XP760	Hybrid Seed Prod.
Acadia	84,007	78,463	0	11,050	0	65	85	7,595	225	8,214	3,378	17,115	0	2,103	0	4,598	196	985	5,512	3,885	3,110	1,225	6,285	1,787	0
Allen	13,431	11,377	0	1,247	0	0	0	1,950	0	1,200	0	1,700	0	0	0	750	0	0	1,750	1,050	350	0	1,380	0	0
Avoyelles	13,778	13,778	0	3,536	158	0	0	1,260	0	1,323	0	2,646	0	50	0	1,655	0	0	630	0	0	0	2,520	0	0
Beauregard	743	743	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	185	270	0	0	288	0	0
Caddo	118	118	0	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	8,238	8,106	0	230	43	0	0	282	0	3,233	1,450	1,040	0	0	0	0	0	243	750	315	240	0	0	280	0
Caldwell	366	366	0	366	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	9,180	9,106	0	380	0	0	0	460	0	1,625	0	832	0	228	0	0	0	246	1,796	1,259	1,154	0	956	0	0
Catahoula	2,484	2,484	0	1,444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	510	0	0	0	530	0	0
Concordia	4,995	4,995	0	500	0	0	0	0	0	0	0	700	0	0	0	0	0	0	600	0	0	0	3,175	20	0
East Carroll	1,064	1,064	0	0	0	0	0	0	0	0	0	0	397	0	0	0	0	0	0	0	0	0	117	0	0
Evangeline	44,894	37,998	0	5,200	0	0	0	6,250	0	3,900	1,650	4,150	0	0	0	1,975	0	4,800	3,450	2,223	0	0	4,400	0	0
Franklin	10,428	9,132	0	0	0	0	0	0	0	0	0	340	85	0	0	0	0	0	3,722	1,195	0	600	140	0	3,050
Iberia	500	500	0	98	0	0	0	0	0	202	106	94	0	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	77,799	66,841	0	8,150	160	0	0	8,760	0	12,210	4,750	13,980	0	3,850	80	6,780	0	1,950	2,580	875	780	66	1,600	0	0
Lafayette	1,160	863	0	0	0	0	0	0	0	451	0	168	0	0	0	0	0	0	0	0	0	0	0	0	0
Madison	4,424	2,662	0	0	0	0	0	0	0	0	0	0	1,066	0	0	0	0	0	1,596	0	0	0	0	0	0
Morehouse	33,981	21,697	0	0	0	0	0	0	0	300	0	160	3,300	500	0	0	0	0	7,937	5,040	0	0	1,060	3,400	0
Natchitoches	768	768	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	0	0	0	384	0	0
Ouachita	4,680	1,228	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	428	0	0	0	0	0	0
Pointe Coupee	1,148	1,148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	574	287	0	0	287	0	0
Rapides	9,880	7,867	0	2,014	90	0	0	720	0	756	0	1,512	0	29	0	946	0	0	360	0	0	0	1,440	0	0
Richland	3,060	3,014	0	0	0	0	0	0	0	0	0	445	462	0	0	0	0	0	392	489	0	0	0	250	0
St. Landry	23,354	20,991	0	3,958	0	0	0	3,106	0	5,200	1,112	4,365	0	524	0	2,309	0	0	0	0	0	0	0	0	0
St. Martin	3,528	3,528	18	875	0	0	0	0	0	0	0	566	0	0	0	0	0	0	0	0	250	0	1,819	0	0
Tensas	2,132	2,132	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	970	150	100	0	100	0	452
Vermilion	48,483	47,076	0	10,575	0	0	0	7,150	0	12,527	272	10,899	0	429	0	2,439	0	0	1,900	0	0	0	885	0	0
West Baton Rouge	737	737	0	737	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	217	217	0	0	0	0	0	0	0	0	177	0	0	0	0	0	0	0	40	0	0	0	0	0	0
Total Acreage	**409,577**	**358,999**	**18**	**50,478**	**451**	**65**	**85**	**37,533**	**225**	**51,141**	**12,895**	**60,762**	**6,110**	**7,713**	**80**	**21,452**	**196**	**8,224**	**36,066**	**17,038**	**5,984**	**1,891**	**27,366**	**5,737**	**3,502**
Percent (of Long Grain)		**100**	**0.01**	**14.06**	**0.13**	**0.02**	**0.02**	**10.45**	**0.06**	**14.25**	**3.59**	**16.93**	**1.70**	**2.15**	**0.02**	**5.98**	**0.05**	**2.29**	**10.05**	**4.75**	**1.67**	**0.53**	**7.62**	**1.60**	**0.98**
Percent (of all acres)		**87.65**	**0.00**	**12.32**	**0.11**	**0.02**	**0.02**	**9.16**	**0.05**	**12.49**	**3.15**	**14.84**	**1.49**	**1.88**	**0.02**	**5.24**	**0.05**	**2.01**	**8.81**	**4.16**	**1.46**	**0.46**	**6.68**	**1.40**	**0.86**
Total Acreage			**249204**															**105808**							
Percent (of Long Grain)			**69.42**															**29.47**							
Percent (of all acres)			**60.84**															**25.83**							

[1] Hybrid NS includes hybrid seed rice production not specified and RT7801.

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Medium Grain

Parish	2019 Total	Medium Grain	Variety		
			Jupiter	Titan	CL272
Acadia	84,007	5,544	1,874	3,495	175
Allen	13,431	2,054	1,304	750	0
Avoyelles	13,778	0	0	0	0
Beauregard	743	0	0	0	0
Caddo	118	0	0	0	0
Calcasieu	8,238	132	132	0	0
Caldwell	366	0	0	0	0
Cameron	9,180	74	74	0	0
Catahoula	2,484	0	0	0	0
Concordia	4,995	0	0	0	0
East Carroll	1,064	0	0	0	0
Evangeline	44,894	6,896	5,546	1,350	0
Franklin	10,428	1,296	1,296	0	0
Iberia	500	0	0	0	0
Jefferson Davis	77,799	10,958	7,342	3,287	329
Lafayette	1,160	297	222	75	0
Madison	4,424	1,762	1,762	0	0
Morehouse	33,981	12,284	12,284	0	0
Natchitoches	768	0	0	0	0
Ouachita	4,680	3,452	3,452	0	0
Pointe Coupee	1,148	0	0	0	0
Rapides	9,880	2,013	2,013	0	0
Richland	3,060	46	46	0	0
St. Landry	23,354	2,363	1,620	731	12
St. Martin	3,528	0	0	0	0
Tensas	2,132	0	0	0	0
Vermilion	48,483	1,407	635	772	0
West Baton Rouge	737	0	0	0	0
West Carroll	217	0	0	0	0
Total Acreage	**409,577**	**50,578**	**39,602**	**10,460**	**516**
Percent (of Medium Grain)		**100**	**78.30**	**20.68**	**1.02**
Percent (of all acres)		**12.35**	**9.67**	**2.55**	**0.13**

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Special Purpose

Parish	2019 Total	Special Purpose	Variety			
			Thad	Blanca Isabel	Jazzman-2	CLJ01 (Jazzman)
Acadia	84,007	1,050	0	50	125	875
Allen	13,431	0	0	0	0	0
Avoyelles	13,778	0	0	0	0	0
Beauregard	743	0	0	0	0	0
Caddo	118	0	0	0	0	0
Calcasieu	8,238	0	0	0	0	0
Caldwell	366	0	0	0	0	0
Cameron	9,180	170	0	0	170	0
Catahoula	2,484	0	0	0	0	0
Concordia	4,995	0	0	0	0	0
East Carroll	1,064	550	550	0	0	0
Evangeline	44,894	0	0	0	0	0
Franklin	10,428	0	0	0	0	0
Iberia	500	0	0	0	0	0
Jefferson Davis	77,799	270	0	0	0	270
Lafayette	1,160	244	0	48	0	196
Madison	4,424	0	0	0	0	0
Morehouse	33,981	0	0	0	0	0
Natchitoches	768	0	0	0	0	0
Ouachita	4,680	0	0	0	0	0
Pointe Coupee	1,148	0	0	0	0	0
Rapides	9,880	0	0	0	0	0
Richland	3,060	976	976	0	0	0
St. Landry	23,354	417	0	0	0	417
St. Martin	3,528	0	0	0	0	0
Tensas	2,132	310	310	0	0	0
Vermilion	48,483	0	0	0	0	0
West Baton Rouge	737	0	0	0	0	0
West Carroll	217	0	0	0	0	0
Total Acreage	**409,577**	**3,987**	**1,836**	**98**	**295**	**1,758**
Percent (of Special Purpose)		**100**	**46.05**	**2.46**	**7.40**	**44.09**
Percent (of all acres)		**0.97**	**0.45**	**0.02**	**0.07**	**0.43**

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY
Clearfield

Parish	2019 Total	Clearfield Total	Variety								Hybrid			
			CLJ01	CL111	CL151	CL153	CL163	CL172	CLL15	CL272	CLXL729	CLXL745	CL Gemini 214	CL RT 7311
Acadia	84,007	45,352	875	8,214	3,378	17,115	0	2,103	0	175	985	5,512	3,885	3,110
Allen	13,431	6,050	0	1,200	0	1,700	0	0	0	0	0	1,750	1,050	350
Avoyelles	13,778	4,649	0	1,323	0	2,646	0	50	0	0	0	630	0	0
Beauregard	743	455	0	0	0	0	0	0	0	0	0	185	270	0
Caddo	118	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	8,238	7,271	0	3,233	1,450	1,040	0	0	0	0	243	750	315	240
Caldwell	366	0	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	9,180	7,140	0	1,625	0	832	0	228	0	0	246	1,796	1,259	1,154
Catahoula	2,484	510	0	0	0	0	0	0	0	0	0	510	0	0
Concordia	4,995	1,300	0	0	0	700	0	0	0	0	0	600	0	0
East Carroll	1,064	397	0	0	0	0	397	0	0	0	0	0	0	0
Evangeline	44,894	20,173	0	3,900	1,650	4,150	0	0	0	0	4,800	3,450	2,223	0
Franklin	10,428	5,342	0	0	0	340	85	0	0	0	0	3,722	1,195	0
Iberia	500	402	0	202	106	94	0	0	0	0	0	0	0	0
Jefferson Davis	77,799	41,654	270	12,210	4,750	13,980	0	3,850	80	329	1,950	2,580	875	780
Lafayette	1,160	815	196	451	0	168	0	0	0	0	0	0	0	0
Madison	4,424	2,662	0	0	0	0	1,066	0	0	0	0	1,596	0	0
Morehouse	33,981	17,237	0	300	0	160	3,300	500	0	0	0	7,937	5,040	0
Natchitoches	768	384	0	0	0	0	0	0	0	0	0	384	0	0
Ouachita	4,680	1,228	0	0	0	0	800	0	0	0	0	428	0	0
Pointe Coupee	1,148	861	0	0	0	0	0	0	0	0	0	574	287	0
Rapides	9,880	2,657	0	756	0	1,512	0	29	0	0	0	360	0	0
Richland	3,060	1,788	0	0	0	445	462	0	0	0	0	392	489	0
St. Landry	23,354	11,630	417	5,200	1,112	4,365	0	524	0	12	0	0	0	0
St. Martin	3,528	816	0	0	0	566	0	0	0	0	0	0	0	250
Tensas	2,132	1,270	0	0	0	50	0	0	0	0	0	970	150	100
Vermilion	48,483	26,027	0	12,527	272	10,899	0	429	0	0	0	1,900	0	0
West Baton Rouge	737	0	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	217	217	0	0	177	0	0	0	0	0	0	40	0	0
Total Acreage	**409,577**	**208,287**	**1,758**	**51,141**	**12,895**	**60,762**	**6,110**	**7,713**	**80**	**516**	**8,224**	**36,066**	**17,038**	**5,984**
Percent (of Clearfield)		**100.00**	**0.84**	**24.55**	**6.19**	**29.17**	**2.93**	**3.70**	**0.04**	**0.25**	**3.95**	**17.32**	**8.18**	**2.87**
Percent (of all acres)		**50.85**	**0.43**	**12.49**	**3.15**	**14.84**	**1.49**	**1.88**	**0.02**	**0.13**	**2.01**	**8.81**	**4.16**	**1.46**
Total Acreage			**140975**								**67312**			
Percent (of Clearfield)			**67.68**								**32.32**			
Percent (of all acres)			**34.42**								**16.43**			

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Hybrid

Parish	2019 Total	Hybrid Total	Clearfield				Non-Clearfield			Hybrid Seed Production (not-specified)
			CLXL729	CLXL745	CL Gemini 214	CL RT 7311	RT 7301	XP753	XP760	
Acadia	84,007	22,789	985	5,512	3,885	3,110	1,225	6,285	1,787	0
Allen	13,431	4,530	0	1,750	1,050	350	0	1,380	0	0
Avoyelles	13,778	3,150	0	630	0	0	0	2,520	0	0
Beauregard	743	743	0	185	270	0	0	288	0	0
Caddo	118	0	0	0	0	0	0	0	0	0
Calcasieu	8,238	1,828	243	750	315	240	0	0	280	0
Caldwell	366	0	0	0	0	0	0	0	0	0
Cameron	9,180	5,411	246	1,796	1,259	1,154	0	956	0	0
Catahoula	2,484	1,040	0	510	0	0	0	530	0	0
Concordia	4,995	3,795	0	600	0	0	0	3,175	20	0
East Carroll	1,064	117	0	0	0	0	0	117	0	0
Evangeline	44,894	14,873	4,800	3,450	2,223	0	0	4,400	0	0
Franklin	10,428	8,707	0	3,722	1,195	0	600	140	0	3,050
Iberia	500	0	0	0	0	0	0	0	0	0
Jefferson Davis	77,799	7,851	1,950	2,580	875	780	66	1,600	0	0
Lafayette	1,160	0	0	0	0	0	0	0	0	0
Madison	4,424	1,596	0	1,596	0	0	0	0	0	0
Morehouse	33,981	17,437	0	7,937	5,040	0	0	1,060	3,400	0
Natchitoches	768	768	0	384	0	0	0	384	0	0
Ouachita	4,680	428	0	428	0	0	0	0	0	0
Pointe Coupee	1,148	1,148	0	574	287	0	0	287	0	0
Rapides	9,880	1,800	0	360	0	0	0	1,440	0	0
Richland	3,060	1,131	0	392	489	0	0	0	250	0
St. Landry	23,354	0	0	0	0	0	0	0	0	0
St. Martin	3,528	2,069	0	0	0	250	0	1,819	0	0
Tensas	2,132	1,772	0	970	150	100	0	100	0	452
Vermilion	48,483	2,785	0	1,900	0	0	0	885	0	0
West Baton Rouge	737	0	0	0	0	0	0	0	0	0
West Carroll	217	40	0	40	0	0	0	0	0	0
Total Acreage	**409,577**	**105,808**	**8,224**	**36,066**	**17,038**	**5,984**	**1,891**	**27,366**	**5,737**	**3,502**
Percent (of Hybrid)		**100**	**7.77**	**34.09**	**16.10**	**5.66**	**1.79**	**25.86**	**5.42**	**3.31**
Percent (of all acres)		**25.83**	**2.01**	**8.81**	**4.16**	**1.46**	**0.46**	**6.68**	**1.40**	**0.86**
Total Acreage				**67,312**				**34,994**		**3502**
Percent (of Hybrid)				**63.62**				**33.07**		**3.31**
Percent (of all acres)				**16.43**				**8.54**		**0.86**

[1] Hybrid NS includes hybrid seed rice production not specified .

2019 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Planting and Tillage Practices

	2019 Total	Conventional Tillage					Fall Stale Seedbed					Spring Stale Seedbed					No-Till Seedbed				
		Dry Seeded		Water Seeded			Dry Seeded		Water Seeded			Dry Seeded		Water Seeded			Dry Seeded		Water Seeded		
		Drilled	Broadcast	Pin-point	Continuous	Delayed	Drilled	Broadcast	Pin-point	Continuous	Delayed	Drilled	Broadcast	Pin-point	Continuous	Delayed	Drilled	Broadcast	Pin-point	Continuous	Delayed
Acadia	84,007	11,000	7,432	5,200	0	3,500	15,500	4,500	3,300	0	3,300	19,775	7,500	0	0	0	3,000	0	0	0	0
Allen	13,431	6,181	1,250	950	0	1,150	1,850	0	0	0	0	1,000	0	0	0	0	1,050	0	0	0	0
Avoyelles	13,778	2,835	748	95	0	539	4,600	820	275	0	539	1,971	748	48	0	0	560	0	0	0	0
Beauregard	743	200	0	0	0	0	243	0	0	0	0	0	0	0	0	0	300	0	0	0	0
Caddo	118	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	8,238	4,155	1,235	1,000	0	408	1,200	0	240	0	0	0	0	0	0	0	0	0	0	0	0
Caldwell	366	0	0	366	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cameron	9,180	6,374	0	2,277	0	0	74	0	0	0	0	0	0	0	0	0	455	0	0	0	0
Catahoula	2,484	0	0	0	0	0	2,484	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Concordia	4,995	0	0	0	0	0	4,995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Carroll	1,064	0	0	0	0	0	0	0	0	0	0	1,064	0	0	0	0	0	0	0	0	0
Evangeline	44,894	13,594	3,000	2,200	0	7,300	8,000	0	0	0	0	2,200	0	0	0	0	8,600	0	0	0	0
Franklin	10,428	10,428	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iberia	500	0	0	0	0	0	0	0	0	0	0	106	0	0	0	0	221	0	0	0	173
Jefferson Davis	77,799	27,390	13,735	16,020	0	7,452	8,500	1,200	2,200	0	300	0	0	0	0	0	650	0	352	0	0
Lafayette	1,160	235		0	0	0	0	0	0	0	0	809	117	0	0	0	0	0	0	0	0
Madison	4,424	0	0	0	0		3,338	0	0	0		1,086	0	0	0	0	0	0	0	0	0
Morehouse	33,981	20,389	0	0	0	0	12,231	0	0	0	0	1,361	0	0	0	0	0	0	0	0	0
Natchitoches	768	0	0	0	0	0	768	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ouachita	4,680	4,680	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pointe Coupee	1,148	287	0	0	861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rapides	9,880	1,970	550	40	0	330	3,730	640	150	0	290	1,400	430	40	0	0	310	0	0	0	0
Richland	3,060	1,994	0	0	0	0	420	0	0	0	0	0	0	0	0	0	0	0	645	0	0
St. Landry	23,354	5,839	0	0	17,516	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Martin	3,528	1,183	0	0	0	0	0	0	0	0	0	385	0	75	130	0	1,755	0	0	0	0
Tensas	2,132	0	0	0	0	0	2,132	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vermilion	48,483	17,069	1,252	15,161	0	322	6,642	0	484	0	0	5,919	0	812	0	0	822	0	0	0	0
West Baton Rouge	737	737	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	217	217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Acreage	**409,577**	**136,875**	**29,202**	**43,309**	**18,377**	**21,001**	**76,707**	**7,160**	**6,649**	**0**	**4,429**	**37,076**	**8,795**	**975**	**130**	**0**	**17,723**	**0**	**997**	**0**	**173**
Percent (of all acres)		**33.42**	**7.13**	**10.57**	**4.49**	**5.13**	**18.73**	**1.75**	**1.62**	**0.00**	**1.08**	**9.05**	**2.15**	**0.24**	**0.03**	**0.00**	**4.33**	**0.00**	**0.24**	**0.00**	**0.04**
Total Acreage		**248,764**					**94,945**					**46,976**					**18,893**				
Percent (of all acres)		**60.74**					**23.18**					**11.47**					**4.61**				

2019 LOUISIANA RICE VRIETY BY PARISH SURVEY

Ratoon Production & Water Management

Parish	2019 Total Rice	Ratoon Acres	Water Management			
			Traditional Flood (cascade flooding)	Traditional flood with side inlet (poly pipe)	Alternate Wetting and Drying (AWD)	Furrow Irrigated (row rice)
Acadia	84,007	47,880	84,007	0	0	0
Allen	13,431	2,500	13,431	0	0	0
Avoyelles	13,778	0	13,778	0	0	0
Beauregard	743	500	743	0	0	0
Caddo	118	0	0	0	0	118
Calcasieu	8,238	5,358	8,238	0	0	0
Caldwell	366	0	366	0	0	0
Cameron	9,180	5,918	9,180	0	0	0
Catahoula	2,484	0	2,484	0	0	0
Concordia	4,995	0	3,995	0	0	1,000
East Carroll	1,064	0	992	0	0	72
Evangeline	44,894	9,500	44,894	0	0	0
Franklin	10,428	0	6,253	2,675	0	1,500
Iberia	500	201	500	0	0	0
Jefferson Davis	77,799	50,569	77,799	0	0	0
Lafayette	1,160	638	1,161	0	0	0
Madison	4,424	0	3,982	442	0	0
Morehouse	33,981	0	24,431	0	0	9,550
Natchitoches	768	0	768	0	0	0
Ouachita	4,680	0	3,276	1,404	0	0
Pointe Coupee	1,148	0	1,058	0	0	90
Rapides	9,880	0	9,980	0	0	0
Richland	3,060	0	1,909	550	0	600
St. Landry	23,354	1,168	21,320	0	0	2,035
St. Martin	3,528	1,234	3,528	0	0	0
Tensas	2,132	0	1,682	0	0	450
Vermilion	48,483	28,120	48,483	0	0	0
West Baton Rouge	737	0	737	0	0	0
West Carroll	217	0	217	0	0	0
Total Acreage	**409,577**	**153,586**	**389,192**	**5,071**	**0**	**15,415**
Percent of Total	**100**	**37**	**95.02**	**1.24**	**0.00**	**3.76**

Mississippi - 2018 and 2019 Rice Summary Table.

Certified Acreage All Rice

	Acreage	
Variety	2018	2019
Bolivar	34,650	31,796
Coahoma	9,970	5,768
DeSoto	1,605	586
Grenada	0	55
Holmes	1,036	126
Humphreys	4,264	4,089
Issaquena	435	0
Leflore	5,035	3,150
Panola	7,343	7,410
Quitman	10,311	10,247
Sharkey	647	0
Sunflower	12,458	9,854
Tallahatchie	6,803	7,890
Tate	797	934
Tunica	31,404	24,088
Washington	8,091	8,319
Yazoo	0	64
Grand Total	134,849.1500	114,376.3770

	Acreage		
Variety	2018	2019	Proj 2020
CL111	8000	4500	200
CL153	18000	12000	14500
CL163	1400	2100	400
CL15	0		20000
CLXL745	18000	17000	3600
CLXL729	3000	2500	0
CLXL4534	13000	14000	3500
Gemini	8000	9000	24000
FP7521	0	0	18000
FP7321	0	0	3200
PVL01	0	500	1500
PVL02	0	0	500
XL753	26000	19000	25000
RT7301	0	0	10000
XL723	600	1200	0
REX	12500	11000	14000
Lakast	2200	1200	500
Diamond	10000	7500	16000
Other	14000	13000	15000
TOTAL CL	69400	61100	87400
TOTAL HYBRID	68600	62700	87300
Grand Total	134700	114500	169900
	0.515219005	0.533624454	0.514420247
	0.509279881	0.547598253	0.513831666

2018 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

COUNTY	2017 ACREAGE	2018 ACREAGE	Acreage Change	% MC Ratooned	LONG GRAIN XL723	XL753	CLXL745	PRESIDIO	CL153	TEXMATI	CL151	CHENIERE	CL111	XL760	DIXIEBELLE	MERMENTAU	RT7311	DIAMOND	MEDIUM JUPITER	TITAN	OTHER
East Zone																					
Brazoria	15402	17082	10.90%	48	342		683	3075		512		171			512						11787
Chambers	23376	23893	2.20%	40		7707		5395		3854									6937		
Galveston	389	881	126.50%	82						379											502
Hardin	460	545	18.50%																		
Jefferson	20217	23083	14.20%	50			12015		2634				1805						6629		
Liberty	7055	9209	30.50%	76		2637	2663		1132		1139							240	599	799	
Orange																					
East Total	66899	74693	11.70%	50	345	10420	15474	8532	3794	4780	1147	172	1818		516			242	14269	805	12379
Northwest Zone																					
Austin	2089	2078	-0.50%	88		1231			847												
Colorado	32482	36367	12.00%	75	19250	8276	1561	3083	1348	225		782		1013		115					714
Fort Bend	4487	4517	0.70%	80	206	1897	979	770	154						462		48				
Harris	251																				
Lavaca	2673	2996	12.10%	60	2996																
Robertson																					
Waller	4311	3994	-7.40%	100	607	2426	497		102								362				
Wharton	35892	41093	14.50%	84	9651	6094	2795	4582	7989		7485	1639		533		325					
Lamar																					
NorthWest Total	82185	91045	10.80%	80	32710	19924	5832	8435	10440	225	7485	2421		1546	462	440	410				714
Southwest Zone																					
Calhoun		291																			
Jackson	8481	9991	17.80%	65	3850	597	165	1739	1030			1018							1592		
Matagorda	10032	13320	32.80%	63	4938			728	864	4938		1852									
Victoria	1451	1613	11.20%	100				1613													
Cameron																					
SouthWest Total	19964	25215	26.30%	66	8891	604	167	4128	1916	4996		2904							1611		
Northeast Zone																					
Bowie	810	1035	27.80%																		
Hopkins																					
Red River																					
Northeast Total	810	1035	27.80%																		
State Total	169858	191988	13.00%	67	42173	31116	21589	21209	16237	10055	8679	5527	1828	1554	983	442	412	243	15966	809	13164

Percent Variety Acres By County

COUNTY	2017 ACREAGE	2018 ACREAGE	Acreage Change	% MC Ratooned	LONG GRAIN														MEDIUM		OTHER
					XL723	XL753	CLXL745	PRESIDIO	CL153	TEXMATI	CL151	CHENIERE	CL111	XL760	DIXIEBELLE	MERMENTAU	RT7311	Diamond	JUPITER	Titan	
East Zone																					
Brazoria	15402	17082	10.90%	48	2		4	18		3		1			3						69
Chambers	23376	23893	2.20%	40		32.3		22.6		16.1									29		
Galveston	389	881	126.50%	82						43											57
Hardin	460	545	18.50%																		
Jefferson	20217	23083	14.20%	50			52.1		11.4				7.8						28.7		
Liberty	7055	9209	30.50%	76		28.6	28.9		12.3		12.4							2.6	6.5	8.7	
Orange																					
East Total	66899	74693	11.70%	50	0.5	14	20.7	11.4	5.1	6.4	1.5	0.2	2.4		0.7			0.3	19.1	1.1	16.6
Northwest Zone																					
Austin	2089	2078	-0.50%	88		59.2			40.8												
Colorado	32482	36367	12.00%	75	52.9	22.8	4.3	8.5	3.7	0.6		2.2		2.8		0.3					2
Fort Bend	4487	4517	0.70%	80	4.6	42	21.7	17.1	3.4						10.2		1.1				
Harris	251																				
Lavaca	2673	2996	12.10%	60	100																
Robertson																					
Waller	4311	3994	-7.40%	100	15.2	60.7	12.4		2.6								9.1				
Wharton	35892	41093	14.50%	84	23.5	14.8	6.8	11.2	19.4		18.2	4		1.3		0.8					
Lamar																					
NorthWest Total	82185	91045	10.80%	80	35.9	21.9	6.4	9.3	11.5	0.2	8.2	2.7		1.7	0.5	0.5	0.5				0.8
Southwest Zone																					
Calhoun		291																			
Jackson	8481	9991	17.80%	65	38.5	6	1.7	17.4	10.3			10.2							15.9		
Matagorda	10032	13320	32.80%	63	37.1			5.5	6.5	37.1		13.9									
Victoria	1451	1613	11.20%	100				100													
Cameron																					
SouthWest Total	19964	25215	26.30%	66	35.3	2.4	0.7	16.4	7.6	19.8		11.5							6.4		
Northeast Zone																					
Bowie	810	1035	27.80%																		
Hopkins																					
Red River																					
Northeast Total	810	1035	27.80%																		
State Total	169858	191988	13.00%	67	22.1	16.3	11.3	11.1	8.5	5.3	4.5	2.9	1	0.8	0.5	0.2	0.2	0.1	8.4	0.4	6.9

2019 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

COUNTY	2018 ACREAGE	2019 ACREAGE	Acreage Change	% MC Ratooned	LONG GRAIN: XL723	CLXL745	PRESIDIO	CL153	DIXIEBELLE	CHENIERE	XL753	CL151	XL754	Presidio Indigo	XL760	Gemini	Cheniere Indigo	CL151 Indigo	CL153 Indigo	Diamond	MEDIUM: JUPITER	OTHER
East Zone																						
Brazoria	17082	16588	-2.90%	48	448		2571	415		282												12872
Chambers	23893	19924	-16.60%	8		7711				5858	2451										3905	
Galveston	881	343	-61.10%	82			224															119
Hardin	545	642	17.80%																			
Jefferson	23083	15880	-31.20%	37		4034		1667													10179	
Liberty	9209	4457	-51.60%	78		3012					1021									214	210	
Orange																						
East Total	74693	57834	-22.60%	33	453	14923	2826	2105		6209	3510									216	14454	13137
Northwest Zone																						
Austin	2078	1985	-4.50%	0			1985															
Colorado	36367	30839	-15.20%	72	20394	1848	2188	3820	31	924	647			585		401						
Fort Bend	4517	3118	-31.00%	80	240	804	1500		374		200											
Harris	0																					
Lavaca	2996	2971	-0.80%	74	2258								713									
Robertson																						
Waller	3994	4198	5.10%	94	1129	1688		122			1259											
Wharton	41093	32770	-20.30%	78	8029	1311	3670	6357	1868	2130	2654	2556	1835	295	164	262	655	524	459			
Lamar																						
NorthWest Total	91045	75881	-16.70%	74	32058	5651	9341	10299	2272	3054	4759	2555	2547	881	164	663	655	524	459			
Southwest Zone																						
Calhoun	291																					
Jackson	9991	8676	-13.20%	52	3731		1796			338				816	573						1423	
Matagorda	13320	9127	-31.50%	0					9127													
Victoria	1613	1386	-14.10%	100			1386															
Cameron																						
SouthWest Total	25215	19189	-23.90%	31	3731		3182		9127	338				816	573						1423	
Northeast Zone																						
Bowie	1035	1148	10.90%																			
Hopkins																						
Red River																						
Northeast Total	1035	1148	10.90%																			
State Total	191988	154052	-19.80%	53	36514	20728	15464	12497	11485	9673	8331	2574	2566	1710	743	668	660	528	462	218	15996	13236

Percent Variety Acres By County

COUNTY	2018 ACREAGE	2019 ACREAGE	Acreage Change	% MC Ratooned	LONG GRAIN																MEDIUM	OTHER
					XL723	CLXL745	PRESIDIO	CL153	DIXIEBELLE	CHENIERE	XL753	CL151	XL754	Presidio Indigo	XL760	Gemini	Cheniere Indigo	CL151 Indigo	CL153 Indigo	Diamond	JUPITER	
East Zone																						
Brazoria	17082	16588	-2.90%	48	2.7		15.5	2.5		1.7												77.6
Chambers	23893	19924	-16.60%	8		38.7				29.4	12.3										19.6	
Galveston	881	343	-61.10%	82			65.3															34.7
Hardin	545	642	17.80%																			
Jefferson	23083	15880	-31.20%	37		25.4		10.5													64.1	
Liberty	9209	4457	-51.60%	78		67.6					22.9									4.8	4.7	
Orange																						
East Total	74693	57834	-22.60%	33	0.8	25.8	4.9	3.6		10.7	6.1									0.4	25	22.7
Northwest Zone																						
Austin	2078	1985	-4.50%	0			100															
Colorado	36367	30839	-15.20%	72	66.1	6	7.1	12.4	0.1	3	2.1			1.9		1.3						
Fort Bend	4517	3118	-31.00%	80	7.7	25.8	48.1		12		6.4											
Harris	0																					
Lavaca	2996	2971	-0.80%	74	76								24									
Robertson																						
Waller	3994	4198	5.10%	94	26.9	40.2		2.9			30											
Wharton	41093	32770	-20.30%	78	24.5	4	11.2	19.4	5.7	6.5	8.1	7.8	5.6	0.9	0.5	0.8	2	1.6	1.4			
Lamar																						
NorthWest Total	91045	75881	-16.70%	74	42.2	7.4	12.3	13.6	3	4	6.3	3.4	3.4	1.2	0.2	0.9	0.9	0.7	0.6			
Southwest Zone																						
Calhoun	291																					
Jackson	9991	8676	-13.20%	52	43		20.7			3.9				9.4	6.6						16.4	
Matagorda	13320	9127	-31.50%	0					100													
Victoria	1613	1386	-14.10%	100			100															
Cameron																						
SouthWest Total	25215	19189	-23.90%	31	19.4		16.6		47.6	1.8				4.3	3						7.4	
Northeast Zone																						
Bowie	1035	1148	10.90%																			
Hopkins																						
Red River																						
Northeast Total	1035	1148	10.90%																			
State Total	191988	154052	-19.80%	53	23.9	13.6	10.1	8.2	7.5	6.3	5.4	1.7	1.7	1.1	0.5	0.4	0.4	0.3	0.3	0.1	10.5	8.7

RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

E. REDONA, Chair; T. HUGGINS, T. TAI, J. VAUGHN, X. SHA, Y. JIA, C. HERNANDEZ, J. ROHILA, J. EDWARDS, E. SEPTININGSIH, C. ADDISON, G. EIZENGA, D. SANCHEZ, L. SINGH, S. SHARMA, B. ANJIRA, S. SAMONTE, L. GASPAR, D. REBONG, D. NORTH, P. MOSQUERA, I. WENEFRIDA, A. MCCLUNG, S. PINSON, J. ALPUERTO, K. REDDY, M. ESGUERRA, H. GU, and P. SUBUDHI, Participants.

High Priority Issues:

1. Need for more research emphasis on existing and novel genes underlying biotic and abiotic stresses that limit current and future U.S. rice production scenarios (e.g. climate change-related) and their interactions (e.g. physiological), including for addressing rice crop vulnerability.

2. Need to increase utilization of next-generation breeding technologies (e.g. genomic selection; CRISPR/CAS), genetic resources (U.S. mini core collection/new donors), data/information infrastructure (e.g. Gramene/Breedbase), and high throughput phenotyping (e.g. machine learning/ genomic predictions/AI) in U.S. rice breeding programs.

3. Need for training the next generation of U.S. rice scientists/experts on rice breeding, genetics and genomics and promoting scientific collaborations (e.g. workshops).

4. Need for further studying identifying and addressing thru breeding as needed the traits desired by target domestic and export markets for U.S. rice.

Recommendations:

5. The panel recommends that research on novel genes underlying biotic and abiotic stresses that currently limit/could limit future rice production scenarios, including their interactions and how they can be deployed to mitigate crop vulnerability of U.S. rice, be given emphasis by U.S. rice breeders, geneticists, and genomics scientists

6. The panel recommends that U.S. rice breeders, geneticists and genomics experts be provided greater access and the required resources in order for them to increase the utilization of next-generation breeding technologies, novel genetic resources, data/information infrastructure, and high throughput phenotyping in U.S. rice breeding programs

7. The panel recommends that more degree, non-degree, and on-the-job training opportunities, including at the technician/research support level, be created and provided for training the next generation of U.S. rice scientists/experts on rice breeding, genetics and genomics, promoting activities that would foster scientific collaborations (e.g. workshops).

8. The panel recommends that research to identify quality traits desired by target domestic and foreign markets for U.S. rice, including developing effective breeding-related strategies to increase U.S. rice competitiveness, be given emphasis in U.S. rice breeding programs

ECONOMICS AND MARKETING

B. MILLS, Chair; B. WATKINS, J. MCCANN, M. WEITZ, N. CHILDS, B. PETERSON-WILHELM, L. TARPLEY, T. GAUTAM, and A. DURAND-MORAT, Participants.

Supply/Production Research

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

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

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

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

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

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/ polices could change the economic landscape of rice production.

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

PLANT PROTECTION

T.W. ALLEN, Chair; N. BATEMAN, Chair-Elect (2020); J. GORE. BATEMAN, N., THRASH, B., GAIRE, S., ZHOU, X.-G., JIA, Y., WAMISHE, Y., GROTH, D., and WAY, M., Participants.

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 molecular mechanisms involved in the host-pathogen relationship, determining specifics regarding pathogenesis within each pathogen system, host resistance to rice pathogens, and ultimately the management of important yield-limiting rice diseases. Consequently, an effective and integrated disease management program relying on resistance, cultural practices, and chemical control based on cooperative research with scientists in agronomy, entomology, weed science, and molecular biology should be the main goal of the group. If advances are made in the understanding and application in biological 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); 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,* and possibly *Bipolaris*, *Fusarium*, 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 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*.

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, and biotechnology-based tools including CRISPR-CAS9 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 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, 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, 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 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; however, the delphacid or its injury has not been detected again since then.

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

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

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

2. Monitor rice for possible introduction of exotic pests. 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

Z. PAN, L. TARPLEY, L. ESPINO, M.H. CHEN, M. WEITZ, C. BERGMAN, R. WOOD, and T. GAUTUM, Participants.

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

Recommended Research Priorities:

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

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

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

Specific Recommendations:

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

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

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.

RICE CULTURE

B. GOLDEN, Chair; T.T. ROBERTS, Chair-Elect (2020); B. LINQUIST, L. TARPLEY, D. HARRELL, D. FRIZZELL, N. SLATON, J. HARDKE, and J. MCCOY; 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.

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 macro-environment of the rice canopy and its influence on growth of the rice crop.

Water
Accurately determine the complete water balance on rice as a function of soil textural groups, regions, time within the irrigation season, rice growth stage, and meteorological parameters.

Determine the impact of sub-optimal water availability at various physiological stages on dry matter accumulation, maturation, grain yield, and grain quality.

Determine optimum water management guidelines for flush-flood, pin-point flood, continuous-flood, and alternative irrigation.

Evaluate the effect of water conservation practices, such as underground pipe and/or flexible polyethylene pipe, land forming, multiple inlets, reduced levee intervals, and lateral maintenance on water use.

Continue to evaluate water quality in terms of salinity and alkalinity and its effect on rice productivity. Evaluate water use as related to water loss and evapotranspiration.

Quality
Determine the effect of various management systems on changes in the quality of water used in rice production. Monitoring should include all water quality parameters, such as nutrient inputs, suspended and/or dissolved solids, organic matter, etc.

Determine the fate of agricultural inputs in the soil, water, and plant continuum as related to varying rice cropping systems. This information should be applied to minimize losses from the field and reduce any attendant environmental degradation associated with such losses and in the development of Nutrient Management Plans.

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

Engineering Systems
Study energy inputs in rice production and harvesting.

Expand investigations to improve equipment for proper and efficacious applications of seed and fertilizers.

Analyze and improve harvesting practices to assure maximum recovery of top quality grain through timeliness of harvest and harvester adjustments by cultivar and climatic zone.

Determine ways to use the 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

B. LAWRENCE, Chair, C. SANDOSKI, E. WEBSTER, A. KENDIG, M. EDWARDS, J. BOND, R. KELLY, A. MANGIALARDI, and T. BARARPOUR, Participants.

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

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

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.

Growth Regulation

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

Study basic biological and physiological processes regulated by applied chemicals.

Facilitate label clearance for growth regulators.

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

Understand interactions between plant growth regulators and environmental factors.

Research Priorities

Identification and monitoring of *Echinochloa* species spread in California and midsouthern states.

Weed management under new water management strategies.

Chemical and non-chemical management of herbicide-resistant weeds.

Weed biology and competition studies.

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

Extension priorities

Online training for Extension and interactive tools.

Abstracts of Papers from the Water Symposium
Symposium Moderator: Drew Gholson

Advancements in Furrow Irrigated Rice

Henry, C.G. Mane, R., Simpson, G., Rix, J., and Pickelmann, D.M.

Furrow irrigated rice has many limitations, but improving its water use efficiency is the key for it to be a viable production practice. Little is known about the water use and yield differences between furrow irrigated rice and flooded rice.

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 system can measure water applied and tail water rates and ratios. The field is equipped with a low-cost novel type of tail water collection system. Previously we have demonstrated an over 90% irrigation efficiency or about a 30% increase in irrigation efficiency using this system over conventional furrow irrigation method currently available to producers. In 2016, the field was planted to Ricetec XL745CL, in 2017, Ricetec 7311 in 2018, and in 2019 to Ricetec Gemini. Plots are 30 ft in width and 1300 ft long, all treatments are replicated three times in a strip plot design.

Water use was 28 cm-ha/ha (11 ac-in/ac) and rainfall was 23 cm (9 in) in 2017. Water use in 2018 was 43 cm-ha/ha (16.9 in/ac-in) and total rainfall was 36 cm (14.3 in). Water use in 2019 was 29 cm-ha/ha (11.7ac-in/ac) and rainfall was 43 cm (16.8 inches).

Nitrogen forms for furrow rice production were evaluated, to test the feasibility of fertigating furrow irrigated rice. All treatments applied 150 units of nitrogen. The treatments included all urea up front, then split 100 units then 50 2-3 weeks later. The same was done with UAN, and two treatments of Environmentally Safe Nitrogen (ESN) were included where 75 units were applied followed by 75 units of urea and reverse. Finally, additional treatments for urea and UAN were included in years 2 and 3 to evaluate additional 25 units of nitrogen only on the top half of the field. No-till versus tillage was also evaluated as part of this study for 2018 and 2019.

On-farm comparisons between Multiple Inlet Rice Irrigation and furrow irrigated fields were completed between 2016 and 2018 on-farm we are paired comparison water use and yield between furrow and flood systems. Several on-farm cooperators have been comparing furrow, MIRI and AWD production systems.

On farm comparisons of 17 paired fields did not show a significant difference in yield (p=0.106) using Mann Whitney Rank Sum Test. Yields ranged for furrow irrigated rice between 209 and 131 BPA and averaged 179 BPA. In MIRI rice, yields raged from 155 to 223 and averaged 192 BPA. Water use ranged between 11.2 ac-in/ac and 44 ac-in/ac and averaged 21.6 ac-in.ac. In MIRI rice fields the average water use was 24.4 ac-in.ac and ranged between 53 and 14 ac-in/ac. However, this p-value is approaching an Alpha of 0.1. Many of the farmers in the dataset were new to furrow irrigated rice, which may explain a potential yield drag of 13 BPA. However, there was a significant difference in water use (p=0.0458) between furrow irrigated rice and MIRI, in that furrow rice fields used 12% less water than MIRI.

In 2016 and 2018, no nitrogen treatments were observed. Slight differences were found in 2017, however, these were due to UAN application issues due to very dry soil. We have concluded there are not differences in nitrogen forms or the splits we applied. Fertigation of furrow irrigated rice seems feasible as long as it can be uniformly applied during the first irrigation. Additional nitrogen on only the top half of the field may be beneficial, but we could not detect treatment differences.

In 2018, a significant difference in yield was observed between no till and tillage treatments. In 2019, no significant difference in yields were found (p=0.52).

Evaluation of Nitrogen Management in Furrow Irrigated Rice

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

Furrow irrigated rice (*Oryza sativa* L.) production (FIR) in the mid-south has increased in popularity over the last 3-years. In Louisiana alone, FIR hectares have increased from 567 in 2017, to 2007 hectares in 2018, and to 6243 ha in 2019. Hectares of FIR in Arkansas were estimated to exceed 43,740 in 2019. Interest in FIR and the potential for it to be an insurable practice in 2020 will further increase hectares in the coming year.

Nitrogen (N) management in drill-seeded, delayed flood rice production in Louisiana typically utilizes a 2-way split application, where two-thirds of the seasonal N need is applied pre-flood and the remainder of the seasonal N need is applied at mid-season. In this system, the application of the pre-flood urea fertilizer on dry ground and the timely establishment of the permanent flood stabilizes the ammonium-N, which maximizes the nitrogen use efficiency (NUE). The application of N fertilizers when utilizing furrow irrigation is not as efficient due to the repetitive wetting and drying of the soil. Significant losses of N can come from both ammonia volatilization and nitrification-denitrification. The objectives of the current studies were three-fold: 1) to compare N fertilizer rates in a when grown under FIR or traditional flooding; 2) evaluate single and split N fertilizer application timings; and 3) evaluate the effectiveness of urea treated with n-butyl thoiphosphoric trimide (NBPT) and urea treated with NBPT plus dicyandiamide (DCD) in FIR.

Fertilizer N rate trials utilized two management practices (traditional flooding and FIR) and six N rates (0, 101, 134, 168, 202, and 235m kg ha^{-1}). Fertilizer time of application trials utilized a single pre-flood, 2-way split, 3-way split, and a 4-way split applications at N rates of 155 and 206 kg N ha^{-1}. The N fertilizer source trial compared urea treated with NBPT (Agrotain Advanced) and NBPT+DCD urea (SuperU), three N rates (0, 109, and 155 kg N ha^{-1}) and three application methods (single application, 2-way split, and 3-way split). Trials were conducted in 2018 and 2019 at the H.R.C. Rice Research Station in Crowley, LA on a Crowley silt loam soil and at the Northeast Research Station in St. Joseph, LA on a Sharkey clay in 2019.

In 2018 on the silt loam soil, the optimal N rate was determined for CLXL745 at an N rate of 168 kg ha^{-1} when grown using FIR as compared to 101 kg ha^{-1} when grown in a delayed flood system. The optimal N rate for CL153 was 168 kg ha^{-1} when grown under FIR and traditional flooding. The optimal application timing for CLXL745 was achieved when using the 3-way split application at the rate of 155 kg N ha^{-1}. The optimal N application method for CL153 when growing under FIR was also the 3-way split when using the 155 kg N ha^{-1} rate.

In 2019 on the silt loam soil, the optimal N rate was determined for CLXL745 and CL153 at an N rate of 101 kg ha^{-1} when grown using FIR and traditional flooding. The optimal N rate for CLXL745 was achieved when using the 2-way split application at both the 155 and 206 kg ha^{-1} rates. The optimal N application method for CL153 when growing under FIR was the 4-way split when using the 155 kg ha^{-1} N rate and the 3-way split when using 206 kg ha^{-1}. The N source trial results indicated that the single, 2-way split, and 3-way split applications were not significantly different from each other; however, slight increase in yield was observed as the number of N applications increased. The NBPT-urea (urease inhibitor only) and the SuperU (urease inhibitor and nitrification inhibitor) fertilizer sources were not significantly different from each other; although, the SuperU had higher numerical yield averages.

Rates, timing, and the use of enhanced efficiency fertilizers varied across soils and years due to variations in environmental conditions at and after fertilization each year. Further research with N rates, timing, and enhanced efficiency fertilizers is needed before FIR best management practices a can be made.

Comparisons of Field-scale Irrigation Use Efficiencies for Alternative Rice Irrigation Practices

Massey, J., Reba, M., Adviento-Borbe, A., Sullivan, R., and Moore, R.

Producing rice in the 21st century is a complicated endeavor. It is impacted by numerous forces beyond the immediate control of producers, including weather, trade policies, advances in technology, and changing consumer-preferences. Yet, producers continue to refine their production practices to improve their economic and environmental sustainability. Results from a two-year field comparison of conventional (cascade) flooding, multiple-inlet rice irrigation, alternate wetting-drying flood management, and furrow-irrigated rice will be presented. Economics and other practical observations will be discussed.

Contribution of Winter Cover Crop on Ammonia and Greenhouse Gas Emissions in Furrow Irrigated Rice Systems

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

Flooded rice cultivation is one of the major sources of greenhouse gas emissions from agriculture primarily due to high methane (CH_4) emissions. Reduction in water use is one of the efficient ways of reducing CH_4 emissions from rice. Row rice/furrow irrigated rice, an alternative method to grow rice with less water, is increasingly adapted in the Mid-South, USA. A field experiment was established in 2019 rice growing season with three different water management practices; multiple inlet rice irrigation (MIRI), row rice (RR) and row rice with cereal rye as preceding winter cover crops (RRCC). RR and RRCC fields were further divided into top and bottom paddies for quantification of grain yields and gas flux measurements. Gas fluxes of CH_4 and nitrous oxide (N_2O) were measured using a static chamber technique and analyzed with gas chromatography in weekly intervals. Further, ammonia (NH_3) emissions were also monitored in weekly to biweekly intervals with photoacoustic gas spectroscopy.

The harvested grain yield from row rice was significantly lower in RR and RRCC than MIRI with the greatest yield reduction from top paddies of the field. NH_3 emissions were only detected for a few days after the fertilizer application. NH_3 emissions were higher from RR and RRCC as compared to MIRI with the highest value measured from bottom paddies of RRCC. Both RR and RRCC systems drastically reduced CH_4 emissions as compared to MIRI, however, it significantly increased N_2O emissions. CH_4 emissions were significantly higher from bottom paddies that received prolonged flooding for RR and RRCC. Combining both the top and bottom paddies emissions from RR and RRCC, highest daily CH_4 emissions were observed from MIRI followed by RR and RRCC. Total seasonal CH_4 emissions decreased in the order of 44 >12 >3 kg CH_4-C ha^{-1} from MIRI, RR and RRCC, respectively. In the case of N_2O, highest N_2O emission was recorded from RR and lowest from MIRI. In terms of global warming potential, the decrease in CH_4 emissions from RR and RRCC treatments was offset by the increase in N_2O emissions. Our results show that total greenhouse gas emissions in furrow irrigated rice are highly impacted by irrigation management.

Comparison of Field-scale Methane Reductions with Alternate Irrigation Techniques in U.S. Mid-south Rice Production

Reba, M.L., Fong, B.N., Reavis, C.W., Runkle, B.R., Suovčarev, K., Adviento-Borbe, A., and Massey, J.H.

Rice paddy cultivation generates higher CH_4 emissions due to flooded field conditions and plant structure compared to other crops. CH_4 fluxes were measured using eddy covariance (EC) in paired production sized-fields in NE Arkansas during the 2017 and 2018 production season (May-August). Greenhouse gas (GHG) measurements were made using both eddy covariance (EC). EC is the most direct method of measuring field-integrated turbulent fluxes. The EC method takes a field-integrated measure of the exchange of an entity of interest (e.g. CO_2, H_2O, CH_4) between the landscape and the atmosphere.

The irrigation techniques tested were multiple inlet irrigation (MIRI) with continuous flooding, multiple inlet irrigation with alternate wetting and drying (AWD), and furrow irrigation (ROW). Irrigation using cascade (CASC) flooding introduces irrigation water at the top paddy and allows it to fill before cascading into the next paddy and so forth. MIRI used polytubing (Delta Plastics, Little Rock, AR) perpendicular to levees and irrigation water was introduced into each paddy simultaneously. Continuous flooding maintains a constant flood on the crop from the V4-

V5 growth stage (4-5 leaf stage) until the R7 growth stage. AWD allows the applied irrigation water to subside until the field gets to a “wet mud” state at which time the field is re-flooded. In furrow irrigated rice, water flows down furrows planted in rice, and the field drains are blocked to allow water to pond in the bottom portion of the field. In furrow irrigated rice, there are three typical regions within the EC footprint that have varying methane emissions: 1) a portion that is nearly always flooded at the bottom of the field, 2) partially flooded in the middle, and 3) moist but not saturated at the top of the field.

Study fields were square, approximately 15-ha in size and graded to have 0.1% field slope. Each levee-rice treatment field was divided by six straight levees into seven 2.3-ha paddies. Furrow-irrigated rice was grown on raised beds that were approximately 10-cm (height) by 96-cm (width). Field outlets consisted of slotted-board risers that allow control of flood depths in each field. Irrigation water was supplied by groundwater derived from the Mississippi River Valley Alluvial Aquifer (MRVAA) using diesel or electric pumps with average irrigation delivery capacities of approximately 8 m^3 sec^{-1} ha^{-1}. Poly-tubing (38-cm wide x 10-mil (thickness)) was used to deliver irrigation water to the MIRI, AWD, and ROW-irrigated treatments. Irrigation was applied to every furrow for the furrow-irrigated treatment. *Pipe Planner* computerized-hole-selection software (Delta Plastics, Little Rock, AR) was used to achieve an even application of irrigation water down the furrows.

In a companion study at the study site, the AWD practice reduced water use, on average, by 15%, while furrow irrigation reduced water use by 23% compared to CASC fields. Growing season CH_4 emissions were reduced by 33% and 5% with AWD compared to MIRI in 2017 and 2018, respectively. During the most active part of the season, 27 June – 3 August 2018, the reduction in CH_4 compared to MIRI was 23% for AWD and 32% for ROW. The reduction in CH_4 was lower compared to similar studies and likely due to the degree of drying in the AWD treatment and to the crop rotation. Rice was rotated with soybean every 1-3 years, while other sites grow rice continuously, increasing soil carbon substrate. Alternatively, gross primary productivity (GPP) and plant development may concurrently impact CH_4 emissions. Overall, alternate irrigation techniques of AWD and furrow irrigated rice were shown to reduce methane emissions and groundwater use in U.S. mid-south rice.

Greenhouse Gas Emissions of Selected Southern U.S. Varieties under Alternate Wetting and Drying Irrigation Systems

Adviento-Borbe, A., Karki, S., Levenbach, B., Massey, J.H., Reba, M.L., and Ottis, B.

One of the multiple benefits of Alternate wetting and drying (AWD) practice is reduction of methane emissions while sustaining high grain yield. While several of U.S. rice varieties have shown potentials to mitigate CH_4 emissions under continuously flooded systems, AWD irrigation practice may decrease even more the emissions of CH_4 during dry events. We compare CH_4 and N_2O emissions, global warming potential ($GWP = CH_4 + N_2O$), and grain yield of four rice cultivars (three hybrids: CL XL 745, XP753, XP760 and one pureline: CL151) managed using AWD and continuous flood in a direct-seeded system. Grain yields ranged from 8.7 to 11.1 Mg ha^{-1} pooled across flooding and cultivar treatments. Daily CH_4 and N_2O emissions ranged from 0 to 6.15 kg CH_4-C ha^{-1} d^{-1} and -16 to 28 g N_2O-N $ha^{-1}d^{-1}$. Seasonal CH_4 emissions were not different between flooding practices or cultivar treatments. Differences in CH_4 emissions were observed between flooding practices on years when a complete dry down occurred in the AWD treatment. Total CH_4 emissions between hybrid and non-hybrid cultivars differed on average by a factor of 3.8. Differences in N_2O emissions were negligible among rice cultivars and within 10% of one another for global warming potential (GWP). Reduction of yield-scaled GWP of CLXL745 was more apparent under AWD than in continuously flooded. These findings highlight the potential for breeding high-yielding rice hybrids coupled with intermittent flooding for lower GWP. However, to achieve both reductions in water usage and GHG emissions, proper implementation of AWD practices is necessary.

Good to be Green: Enhancing Rice Production and Ecosystem Services with Algae

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

Crop rotation is important for soil health. Within a rice-on-rice rotation, there is an opportunity to improve soil health and other ecosystem services without interrupting the continuous rice rotation. The addition of a winter/spring cover crop provides various ecosystem services such as prevention of soil erosion, reduction of fertilizer use, and retention of soil moisture. Filamentous green algae (FGA) can provide some of these benefits when added to the rotation of zero grade fields. Developing a FGA as a cover crop for rice in the Mississippi River Valley has two major challenges; (1) the timing of field management and (2) consistent distribution of algae. The cultivation of FGA has been successful on a small scale and to a lesser extent on a large scale for biofuels, however large scale FGA cultivation is genera specific and information on inoculating agricultural fields with FGA is limited. The goals of our project were to 1) determine field conditions necessary to support off-season FGA growth in quantities for field application and management in rice agriculture and 2) determine the impact of FGA and irrigation water management on agronomic and field parameters of rice agriculture.

We evaluated two 16.2-hectare (40-acre) flooded rice fields in England, AR, historically known to contain large amounts of FGA to evaluate ideal algae management. These fields have been in a continuous rice rotation and were controlled for FGA management. FGA grows quickly in stagnant water when water temperatures are mild (55-70°F). In the mid-south, FGA has the greatest growth during late autumn and early spring prior to rice planting. Water can be removed from the system in order to plant rice without killing all of the FGA. The upper layers of the mat desiccate, creating a crust that shades and reduces water loss to the rest of the colony and soil substrate, but still can be drill seeded. When rice was seeded into the algal mat before complete water removal, it became sandwiched between the algal layers. The rice germinated through the algal mat and the underside of the mat remained green throughout the growing season. Water levels need to remain low until adequate rice rooting and prevention of uneven germination. We noted that rice germination was delayed compared to drill seeded fields, but physical plant differences were not seen at later plant stages.

We compared the two 16.2-hectare (40-acre) rice production fields that historically had FGA with two traditionally managed fields for agronomic and ecosystem services impacts. We found no agronomic difference between management techniques. However, we found differences in soil microbe populations, which are an aspect of soil health. Greater within-field microbial diversity tends to correlate to better soil health outcomes and is a component of new federal soil health standards. We analyzed surface soil samples for 16S and V3-4 plastidal rRNA to determine both eukaryote and bacteria taxonomy. FGA fields contained 1.5-fold greater diversity and total number of microbes compared to traditional fields at various time points in the FGA growth cycle. These FGA field characteristics may be exploited to withstand drought in an agricultural setting allowing rice producers to increase soil health and to extend timing between irrigation events, potentially without a yield penalty.

Comparison of Water-saving Irrigation Practices in Rice Production in Arkansas using Two Farm Sustainability Tools

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Globally, the scarcity of water and other environmental concerns necessitate looking for alternative practices to increase environmental sustainability in agricultural systems. In the U.S., Arkansas is the largest rice producer accounting for 50% of the country production. Rice uses 35% of Arkansas's irrigation water, which contributes to the decline of the state's groundwater resources. In addition, worldwide, rice is responsible for 11% of the anthropogenic methane emissions because of the flooded conditions common during its cultivation.

In this context, different practices are proposed to increase water use efficiency, decrease greenhouse gas (GHG) emissions associated with flooded periods, and decrease the use of energy to pump water. Five water-saving practices are evaluated in this work: alternate wetting and drying (AWD) (fields are intermittently flooded allowing the soil to dry down before re-flooding), row cropping (change from traditional flooding to a traditional row crop irrigation), precision land levelling or zero grade (fields are leveled all directions), multiple inlet rice irrigation (MIRI) with polypipe (where each paddy is flooded simultaneously instead of receiving the flow of water from upper paddies), and the use of new high-yielding hybrids (which increases the water use efficiency through the increase in yield).

These water-saving practices have shown a great potential to increase water use efficiency and decrease GHG emissions; however, life cycle perspective assessments are required to evaluate these farmer practices by including downstream and upstream flows. Life Cycle Assessment can be complex and time consuming and not always available for agricultural agents. To simplify that process, a number of decision-support tools have been developed over the last years. These tools are designed to have a user-friendly interface and are based on IPCC emission factors and both process-based and empirical models. In this study, two of these tools have been used to assess these irrigation practices in ten rice fields in Central-Eastern Arkansas during two consecutive growing seasons (2018-2019). The first tool, Cool Farm Tool (CFT), provides an estimate of CO_{2eq} emissions per unit of area or grain yield and includes a water assessment. The second tool, Field Print Platform (FPP), reports values in eight sustainability metrics, including GHG, energy use and irrigation water use, and it also provides the comparison with state and country benchmarks.

Several main findings were demonstrated. First, the values of yield obtained were independent on the irrigation applied for amounts higher than 500 mm, i.e. yield were not increased with increasing amounts of irrigation applied. Second, two water ratios provided by the sustainability tools were compared between practices. The Irrigation Water Use, provided by FPP, is calculated as the irrigation applied divided by the yield, and the Irrigation Efficiency, provided by CFT, is calculated as the irrigation applied divided by the crop demand. The practices that showed the lower, more efficient values were zero grade and zero grade practicing AWD.

Both tools showed differences in the GHG estimates because of differences in the internal calculations. However, both tools agreed that AWD and furrow irrigation were the practices with lower GHG emissions. These practices reduced methane emissions as the soil was allowed to dry down during the season. In fact, the methane emissions were one of the main contributors of the total GHG emissions and represented 80-90% of the total value in some cases. Thus, efforts should be made towards practices that reduce this GHG component. The water and residue management were shown to be two practices with great impact on the GHG emissions: i.e., AWD and burning the straw were practices that induced lower GHG emissions.

The comparison of metrics between water-saving practices and across farms is difficult because each farm has unique agronomic practices. The best way to evaluate practices is to do simulations for the same farm under different management or climate scenarios. Both tools allow the farmers to easily make these evaluations, which allows them to find the economically and environmentally balanced management practices.

Abstracts of Papers from the Student Oral Contest Panel – Plant Protection
Moderator: Jeff Gore

Evaluation of Strategy and Efficacy of Insecticide Options for Control of Rice Billbug *Sphenophorus pertinax* in Furrow Irrigated Rice Production Systems in Arkansas

Floyd, C.A., Lorenz, G.M., Bateman, N.R., Thrash, B.C., Hardke, J.T., Joshi, N.K., Taillon, N.M., Felts, S.G., Plummer, W.A., Plummer, W.J., McPherson, J.K., and Rice, C.

Arkansas rice producers have begun to revisit furrow irrigated production systems as a cost saving tillage and rotation practice. The elimination of a flood across the field has made rice more susceptible to some pests, specifically rice billbug (*Sphenophorus pertinax*). Historically, this insect has been considered a minor pest in the traditional flood irrigated production system. Billbugs feed on the roots and tillers of the rice plants, causing seed heads to abort, resulting in direct yield loss. Arkansas furrow irrigated acreage continues to increase from year to year. In order for this system to stay successful, a cost-effective management strategy for billbug will be required.

Experiments were conducted in 2018 and 2019 at the same furrow irrigated location to evaluate the effectiveness of insecticide seed treatments on rice billbug. Neonicotinoid and diamide insecticide seed treatments, alone and in combination were included in the study. Plots were monitored throughout the year for damage consistent with a billbug infestation. After panicle emergence, the number of blank heads within a plot were recorded. Plots were harvested and yield data was collected using a plot combine. No treatment reduced the number of blank seed heads within a plot when compared to the untreated check. However, plots with a seed treatment containing a diamide, such as Dermacor or Fortenza, resulted in yields greater than the untreated check or the neonicotinoid seed treatments alone.

Field Evaluation of Barnyardgrass Accessions to Loyant and Other Rice Herbicides

Priess, G.L., Norsworthy, J.K., Piveta, L.B., Brabham, C.B., Barber, L.T., and Butts, T.

Commercialization and use of Loyant (florpyrauxifen-benzyl) in 2018 in Arkansas rice resulted in complaints regarding less than expected barnyardgrass control in some fields. Subsequently, barnyardgrass seed were collected from many of the fields where failure occurred. Off-spring from these field samples were screened during the winter of 2018/2019 for sensitivity to florpyrauxifen-benzyl as well as other commonly applied rice herbicide. A field experiment was initiated the follow spring to assess barnyardgrass sensitivity to florpyrauxifen-benzyl alone and following a quinclorac, propanil, and imazethapyr application. The experiment was conducted near Stuttgart AR, at the Rice Research and Extension Center, and was setup as a split-plot in a randomized complete block with the whole-plot factor being herbicide treatment and the subplot factor being the barnyardgrass accession. Barnyardgrass accession nested within herbicide treatment significantly explained variability of florpyrauxifen-benzyl efficacy on the weed ($P=0.0030$). In general, barnyardgrass control with florpyrauxifen-benzyl decreased when imazethapyr, propanil, quinclorac where applied prior to the florpyrauxifen-benzyl application. Of the accessions tested, a decrease in efficacy was observed in all accessions when compared to the susceptible standard. Averaged across accessions, florpyrauxifen-benzyl controlled barnyardgrass approximately 40%. However, it should be noted that these accessions were mainly from fields where the herbicide failed the previous year and a much high level of control would be expected in most barnyardgrass accessions across the state. In fields where barnyardgrass is resistant to imazethapyr, propanil, or quinclorac, applying any of these herbicides to a resistant biotype prior to applying florpyrauxifen-benzyl is likely to result in decreased control with the later herbicide.

Tolerance to Insect Pests among Commonly Grown Rice Cultivars in Louisiana

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

Rice water weevil and stem borers are important insect pests of rice in the United States. Current management relies heavily on chemical control. However, reduced reliance on insecticides can be facilitated by development of an integrated pest management program that includes rice cultivars with resistance to rice water weevil and stem borers. In particular, tolerance is a type of plant resistance that allows crop plants to maintain yield in spite of herbivore injury. A more susceptible rice genotype generally suffers a greater yield loss than tolerant genotype when exposed to similar levels of injury. This study was conducted at H. Rouse Caffey Rice Research Station in Crowley, LA, in 2017–2019 to evaluate the level of tolerance among eight commonly grown rice cultivars in Louisiana (CL111, CL151, Catahoula, Cheniere, Cocodrie, Jazzman, Jupiter, and Mermentau) to rice water weevil and stem borer infestations. Seeds were drill-seeded in plots that were laid out following a randomized block experimental design with four blocks and one replicate per block. Rice water weevil and stemborers were excluded by treating seeds with chlorantraniliprole. Densities of immature rice water weevil were evaluated at three and four weeks after permanent flood was established using a metal core sampler following an established method for weevil sampling. Damage caused by stemborer infestations was assessed by recording the total number of whiteheads in each plot at 100 percent heading. Yield losses were calculated by taking the percentage difference between yields from treated and untreated plots. Data were analyzed separately by year using linear mixed models in SAS. Chlorantraniliprole seed treatment reduced weevil densities across years and cultivars, and 'Jupiter' consistently supported the highest weevil densities. Similarly, seed treatment reduced whitehead densities, and 'Jazzman' consistently supported the lowest numbers of whiteheads compared to other cultivars. Yield losses among cultivars ranged from 25.8-39.2%, 4.1-22.5%, and 7.7-25.5% in 2017, 2018, and 2019, respectively. All cultivars suffered substantial pest losses in all years when unprotected with insecticides. This suggests that plant tolerance among commonly grown cultivars may be insufficient to reduce reliance on insecticides.

Comparison of Thiobencarb and Clomazone in Mississippi Rice Herbicide Programs

Bowman, H.D., Bond, J.A., Lawrence, B.H., Seale, J.W., and Sanders, T.L.

Herbicide-resistant barnyardgrass (*Echinochla crus-galli* L. Beauv.) can be especially difficult to control in rice (*Oryza sativa* L.). Uncontrolled barnyardgrass can reduce grain yield by competing for light, space, soil nutrients, and moisture. Clomazone is the foundation preemergence (PRE) herbicide for barnyardgrass control in midsouthern U.S. rice. Other residual grass herbicides common in this area include quinclorac, pendimethalin, and thiobencab; however, none of these provide the same level of grass control as clomazone. In Mississippi, barnyardgrass populations resistant to photosystem II (PS II) inhibitors, synthetic auxins, acetolactoate synthase (ALS) inhibitors, and acetyl CoA carboxylase (ACCase) inhibitors have been confirmed. Although no resistance to clomazone has been identified in Mississippi barnyardgrass populations, a precedent for this exists in neighboring states. This resistance necessitates that herbicide programs targeting barnyardgrass utilize all possible herbicide modes of action. Therefore, research was conducted to evaluate herbicide programs for barnyardgrass control including clomazone and/or thiobencarb.

Two field studies (Residual Comparison Study and POST Comparison Study) were conducted at the Delta Research and Extension Center in Stoneville, MS, to evaluate herbicide options for barnyardgrass control in rice. Soil texture was a Sharkey clay with a pH of 7.5 and 2.4% organic matter. In both studies, the experimental design was a randomized complete block design with four replications. In the Residual Comparison Study, treatments included clomazone at 560 g ai ha^{-1}, thiobencarb at 3,363 g ai ha^{-1}, and clomazone plus thiobencarb at 560 plus 3,363 g ai ha^{-1} applied as delayed-preemergence (DPRE) treatments 3 to 5 d after planting alone or as components of a sequential herbicide treatment with bispyribac-sodium at 30 g ai ha^{-1} applied to rice in the three- to four-leaf (MPOST) stage. Clomazone plus pendimethalin at 1,434 g ai ha^{-1} DPRE followed by cyhalofop plus penosxsulam at 392 g ai ha^{-1} MPOST and a nontreated control were included for comparison. In the POST Comparison Study, clomazone plus thiobencarb at 560 plus 3,363 g ai ha^{-1} DPRE were followed by no POST treatment, bispyribac-sodium at 30 g ai ha^{-1}, quinclorac at 420 g ai ha^{-1}, or bispyribac-sodium plus quinclorac at 30 plus 420 g ai ha-1 MPOST. Delayed-preemergence-applications were followed by quinclorac at 420 g ai ha^{-1}, bispyribac-sodium at 30 g ai ha^{-1} or imazosulfuron 336 g ai ha^{-1} mid-postemergence (MPOST), to three- to four-leaf rice. Visible weed control was assessed 14 days after DPRE (DA-DPRE) and 14 days after MPOST applications (DA-MPOST), to evaluate weed control. Visible crop injury ratings were also taken at 14 DA-DPRE and 14 DA-MPOST. Data were subjected to

Analysis of Variance (ANOVA) using SAS 9.4 and means were separated using fisher's protected LSD ($p \leq 0.05$). Both experiments included a non-treated control for comparison of weed control and crop injury, which was excluded from the statistical analysis.

Generally, 14 DA-PRE no difference in control of barnyardgrass (89%) was seen when clomazone and thiobencarb were applied together DPRE over that of clomazone alone (89%). However, clomazone provided higher control levels of barnyardgrass over that of thiobencarb (73%). No visible rice injury was observed from any herbicide application. The greatest control of barnyardgrass (94%) 14 DA-MPOST was seen when clomazone DPRE was followed by byspyribac-sodium MPOST. When only a PRE or MPOST application was made unacceptable levels of barnyardgrass control were achieved < 75%.

These results indicate that control options for herbicide resistant barnyardgrass in Mississippi rice cropping systems exist. I t is important to note that single herbicide applications will not provide adequate control of barnyardgrass. However, incorporation of a full herbicide program including both PRE and MPOST can provide a high level of control, while also not causing injury to rice.

Pathogenicity and Genetic Diversity of *Rhizoctonia solani* AG-11 Isolates Associated with Rice Seedling Disease in the Southern United States

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

Rhizoctonia solani AG-11 has been recently recognized as a dominant fungal pathogen causing seedling disease in the southern rice-growing region of United States. However, its pathogenicity and genetic diversity remain largely unknown. The objectives of this study were to determine the pathogenicity and genetic diversity of *R. solani* isolates associated with seedling disease in the southern United States. A total of 90 *R. solani* AG-11 isolates collected from Arkansas, Mississippi, Missouri and Texas were examined. An additional six isolates of *R. solani* AG-1-IA and AG-4 were also included for comparison. Pathogenicity tests were conducted in the growth chamber. The results show that all the AG-11 isolates were pathogenic to rice seedlings with varying levels of aggressiveness. Genetic diversity of 96 isolates were evaluated by sequencing their genomics using NovaSeq 6000 illumina technique. Genetic relationships of these isolates were determined using a genome-wide single-nucleotide polymorphism (SNP) based phylogeny. High levels of SNPs were identified among the *R. solani* AG-11, AG-4 and AG-1-IA genomes as compared to the reference *R. solani* AG-3 genome (GCA_000524645). This is the first study of the genetic diversity of *R. solani* AG-11 and the findings will help to develop effective management strategies for control of seeding disease in rice.

Evaluation of Preplant and Preemergence Application of ALS Herbicides in No-Till Rice

Zaccaro, M.L., Norsworthy, J.K., Sandoski, C., Houston, M.M.

More than half of the rice produced in Arkansas utilizes conventional tillage systems, while no-till systems are practiced in a few selected locations in the state. Yet, the no-till area has almost doubled since 2016. No-till farming practices may reduce production costs, and benefits soil health by reducing erosion and increasing soil organic matter content. Still, cultivation is an important tool for weed control due to the benefit in weed seed suppression and reduction of weeds early in the season. In a no-till or reduced tillage system, the use of residual herbicide in combination with a burndown treatment is important to reduce weed competition. In general, herbicides from the sulfonylurea chemical family, which belongs to the acetolactate synthase inhibitor (ALS) group, are known to persist longer in alkaline soils. Consequently, we hypothesized that ALS herbicides used pre-plant causes minimal crop injury and still provides good weed control. The purpose of this study was to evaluate the impact of application timing of Gambit and other residual herbicides on crop injury and weed control in rice.

In 2019, a field experiment was established at the Rice Research and Extension Center (RREC) near Stuttgart, Arkansas. The trial was set up as factorial arrangement of treatments in a randomized complete block design, with four replications. Factor A was timing of application (pre-plant or preemergence) and factor B were the herbicide treatments contained ALS herbicides. Herbicide treatments were halosulfuron (Permit) at 50 and 70 g ai/ha, a halosulfuron + prosulfuron premix (Gambit) at 83 and 110 g ai/ha, prosulfuron (Peak) at 30 and 40 g ai/ha, and imazosulfuron (League) at 336 g ai/ha. Research plots measuring 2 by 5-m were laid out, and pre-plant treatments were applied 14 days prior to planting. Conventional rice (Diamond) was planted on April 17, at the rate of 72 seeds/m row. Preemergence treatments were made 4 hours after planting. All treatments received 870 g ae/ha of glyphosate (Roundup) plus 336 g ai/ha of clomazone (Command) at application. A nontreated check was included in the experiment. Herbicide treatments were applied using a CO_2-pressurized backpack sprayer coupled with AIXR 110015 nozzles, calibrated to deliver 140 L/ha. Crop injury and weed control were evaluated from 2 to 6 weeks after planting (WAP). Maturity delay was estimated by comparing the date when 50% of panicles have exerted above the flag leaf collar. Data were analyzed using JMP Pro 14, where analysis of variance test was performed, and appropriate means were separated using LSMeans procedure with a significance level of 0.05.

In general, crop injury was mainly affected by application timing. At 2 WAP, injury was equivalent to 33% for treatments applied preemergence, and 8% for pre-plant applications. The rice had recovered by 6 WAP because injury across treatments was ≤ 4%. None of the treatments resulted in a significant delay of maturity. In addition, weed control results were influenced by application timing. At 2 WAP, barnyardgrass (*Echinochloa crus-galli*) control was not statistically different, and ranged from 50 to 60%. But at 6 WAP, treatments applied preemergence controlled 92% of barnyardgrass while 88% were controlled by treatments applied at pre-planting. Therefore, we failed to reject our hypothesis because pre-plant treatments were safer on rice in comparison to treatments applied at preemergence. The use of sulfonylurea herbicides can be recommended for no-till and reduced tillage systems in rice; however, the successful use of these chemistry requires use of multiple modes of action and integrated weed management strategies to reduce the development of ALS-resistant weeds.

Evaluation of Simulated Rainfall Intervals on Fungicide Efficacy in Rice

Eubank, T., Golden, B., Bond, J., Carey, F., Mansour, J., McCoy, J., Pieralisi, B., and Richmond, T.

Sheath Blight, caused by *Rhizoctonia Solani* AG1-1A Kühn, is the most economically damaging disease of rice (*Oryza sativa* L.) that can result in significant losses in grain yield and quality. Many of the major row crops in the midsouth U.S. such as: rice, corn (*Zea maydis*), soybean (*Glycine max*), and cotton (*Gossypium hirsutum*) serve as hosts for *R. solani*. Early symptoms of sheath blight include green and gray lesions on the sheath that can be circular, oval, or ellipsoid in shape. Signs of sheath blight include pea-sized sclerotia and white hyphae, which allows for disease dissemination to other areas in the field. In severe situations sheath blight will move up vertically along the stem and can infect the flag leaf and panicle in rice. If sheath blight spreads to the culms of the plant it can cause severe lodging and greater yield losses. If not properly managed, grain yields can be reduced by approximately 50% in a conducive environment. In order to prevent field endemics of sheath blight, certain practices can be implemented to manage the severity, incidence, or dissemination such as: using resistant varieties of rice, lower plant populations, lowering nitrogen rate, crop rotation, and chemical control. Chemical control or fungicide applications are one of the most effective control methods for managing sheath blight. Certain scenarios may arise where a producer has applied a fungicide and a rainfall event may occur shortly after application. Depending on the time interval between fungicide application and rainfall event, there can be detrimental impacts to fungicide efficacy. This is referred to as rainfastness. There are limited reports that evaluate rainfastness and the effects on fungicide efficacy. Therefore, the objective of this study was to determine the effect of simulated rainfall intervals on fungicide efficacy in relation to rainfastness and sheath blight control in rice.

Field studies were conducted at the Delta Research and Extension Center in 2018 and 2019 near Stoneville, MS. A sheath blight susceptible variety 'Rex' was planted June 5, 2018, and May 30, 2019, at a rate of 57.9 kg/ha. At the one- to two-tiller stage nitrogen fertilizer (Urea 46% N) was applied at a rate of 200.7 kg N/ha. Flood levels were maintained at 822 m^3 of water to promote disease severity. Inoculation of sheath blight took place at panicle initiation. All fungicide applications were applied with a CO_2 backpack sprayer equipped with XR11002 spray nozzles. The spray volume was calibrated to 140 L/ha for fungicide application. At panicle differentiation + 10 days all fungicides were applied. To evaluate disease severity, the Area Under the Disease Progress Curve (AUDPC) was implemented to measure disease progression over time. Severity ratings were conducted 0, 7, 14, 21, and 28 days after application. Rainfall was simulated implementing overhead irrigation set to deliver 19 mm of rain over a 15-minute interval. In 2019, all small-plots were harvested on October 10 implementing a small-plot combine and grain yields were standardized to 12% moisture.

Preliminary studies in 2018 evaluated fungicide efficacy of inpyrfluxam (146 mL/ha; FRAC 7) on sheath blight with respect to various rainfall intervals of no rain, 0- and 30-minutes, as well as 1- and 4-hours after application. The study suggested that with shorter rainfastness intervals there was an increase in AUDPC values and a decrease in yield. In 2018, AUDPC values revealed a 53.2% difference in fungicide efficacy from the no rain-interval to the 0-minute interval. Data in 2018 dictated a need for further research regarding rainfastness and various fungicide modes of action to better understand to what extent rainfall can influence fungicide efficacy. In 2019, fungicide efficacy of azoxystrobin (657 mL/ha; FRAC 11), flutolanil (2.3 L/ha; FRAC 3) and inpyrfluxam were evaluated with respect to various rainfall intervals. Multiple rainfall intervals were established at 1, 2, 3, and 4 hours after fungicide application based upon preliminary data observed in 2018. All fungicides decreased AUDPC values compared to the untreated check with the exception of the 3-hour interval where only flutolanil decreased AUDPC values. Yields of all three fungicides were not different than the untreated check across all four-time intervals. Yields at the first three time intervals were not different but when comparing the 1-hour time interval to the 4-hour time interval yields were different. In conclusion, as rainfastness increased, differences in AUDPC values decreased with respect to fungicide efficacy over time. Whereas, yield did not increase when comparing all three fungicides and the untreated check.

Rice Response to Postemergence Herbicides Following Exposure to Paraquat

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

Paraquat-based herbicide treatments are recommended for weed control in Mississippi, particularly in the Delta region where glyphosate-resistant weeds are prolific. In the Delta, rice is routinely drill-seeded at same time preplant and/or preemergence herbicide treatments to corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean [*Glycine max* (L.) Merr.] are applied. Therefore, off-target movement of paraquat-based herbicide treatments onto rice planted adjacent to these crops is likely to occur. In an off-target herbicide movement event, as much as 25% of the herbicide can move from a few meters up to several kilometers from the target, resulting in crop injury and yield loss of non-target crops. Therefore, research was conducted to evaluate rice response to postemergence (POST) herbicides after exposure to a sub-lethal concentration of paraquat and characterize rice response to exposure to a sub-lethal concentration of paraquat at different reproductive growth stages.

Two field studies (POST Herbicide Study and Reproductive Timing Study) were conducted in 2019 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate rice response to labeled herbicides after exposure to a sub-lethal concentration of paraquat and characterize rice response to exposure to a sub-lethal concentration of paraquat at different stages of reproductive growth. In the POST Herbicide Study, treatments were arranged as a two-factor factorial within a randomized complete block design and four replications. Factor A was herbicide treatment and consisted of no herbicide treatment, imazethapyr at 105 g ai ha^{-1}, quinclorac at 420 g ai ha^{-1}, propanil at 3,363 g ai ha^{-1}, bispyribac-sodium at 28 g ai ha^{-1}, cyhalofop at 31 g ai ha^{-1}, and florpyrauxifen-benzyl at 29 g ai ha^{-1} applied to rice in the three- to four-leaf (MPOST) growth stage. Factor B was paraquat exposure and consisted of paraquat applied at 0 and 84 g ai ha^{-1} to spiking to one-leaf rice (VEPOST). In the Reproductive Timing Study, the experimental design was a randomized complete block with four replications. Paraquat was applied at 28 g ha^{-1} to rice at panicle differentiation (PD), 2.5-cm internode elongation (IE), 7.5-cm IE, 12.5-cm IE, 5% heading, milk, soft dough, hard dough, and 25% moisture content. A nontreated control was included in the Reproductive Timing Study for comparison. In both studies, visible estimates of aboveground rice injury were recorded 3, 7, 14, and 28 d after treatment (DAT). Rice height was recorded 21 DAT (POST Herbicide Study), 14 DAT (Reproductive Timing Study), and at maturity (both studies). In the POST Herbicide Study, the number of days to 50% heading was recorded as an indication of rice maturity, days to canopy closure, and green normalized difference vegetative index (NDVI) were recorded. In the Reproductive Timing Study, rough rice yield was collected at maturity and sub-samples were collected to determine whole and total milled rice yield. All data were subjected to ANOVA with means separated with estimates of the least square means at P=0.05.

In the POST Herbicide Study, no differences in rice injury were detected 3, 7, 14, and 21 DAT among postemergence herbicide treatments ($\geq$50%) except injury from propanil (43%) was less than other treatments 21 DAT. In the Reproductive Timing Study, rice injury 3 and 7 DAT were greatest following paraquat exposure at PD, 2.5-cm IE, and 25% moisture content. Injury was $\geq$ 40% and $\geq$ 58% following exposure at PD and 2.5-cm IE 14 and 28 DAT, respectively. Rice height was reduced $\geq$ 23% following exposure at PD, 2.5-, and 7.5-cm IE compared with the nontreated control. Rough rice yield was reduced at all stages of reproductive growth compared with the nontreated control. The greatest yield reduction occurred following rice exposure to paraquat at 12.5-cm IE (1,345 kg ha^{-1}) compared with yield of the nontreated control (12,777 kg ha^{-1}).

Both studies indicate rice growth and development was compromised following rice exposure to sub-lethal concentrations of paraquat. Applications of paraquat-based herbicide treatments to fields in proximity to rice should be avoided if conditions are conducive for off-target movement. After rice has been exposed to paraquat, weed management is still necessary and choice of POST herbicide should be based on weed spectrum. Rice exposure to paraquat during the early reproductive stages, when the rice plant is rapidly growing and the number of grains is increasing, has a detrimental effect on rough rice yield and should be avoided.

Assessing the Feasibility of Using Remote Sensing to Predict Populations of *Lissorhoptrus oryzophilus* (Coleoptera: Curculionidae) in Louisiana Rice

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

Remote sensing and precision agricultural practices are often used to monitor crop yields in relation to soil fertility and water management. Remote sensing technologies, such as digital aerial imagery, are now also being used for pest management. However, the applicability and efficacy of using aerial imaging for the monitoring of pests is still in the early stages of research and development. Nevertheless, such remote sensing technologies could potentially reduce input costs through precision targeting of insecticides and other IPM strategies. Early research has shown that insect feeding, which reduces canopy cover and crop growth, can be readily detected using digital imagery with the help of unmanned aerial vehicles. Cameras with different spectral capabilities can capture bands of light reflected by insect damaged and healthy crop plants, and can be used to calculate various vegetation indices, such as normalized difference vegetation index (NDVI).

Lissorhoptrus oryzophilus, or the rice water weevil (RWW), is considered the most damaging pest of rice in the United States. As a root feeding insect, RWW directly impacts nutrient uptake, tillering and vegetative growth in rice. Therefore, it is possible that remote sensing, using NDVI and other indices, will be able to accurately locate and quantify RWW presence and damage within rice fields. The aim of this study was to assess the effectiveness of remote sensing, using aerial imagery, to predict the distribution of RWW in controlled small-plot experiments. A DJI Matrice drone, equipped with a Micasense Red-edge camera was used to capture images of rice plots that had varying levels of RWW infestations. The images were stitched using Drone Deploy and the vegetation indices were calculated using QGIS. Ground weevil data was taken, using soil core samples, to ensure the accuracy of the image analyses. The various index output values for each plot were then correlated with corresponding yield values to determine whether remote sensing could predict RWW related yield loss.

Although the data is still being analysed to determine which flight protocols best predict RWW numbers, initial results indicate that digital aerial imagery can be used to differentiate which experimental plots have high RWW infestations. The visible atmospherically resistant index (VARI) is also highly correlated with rice yields and may help us to better understand the impacts that RWW has on rice productivity. Potential applications of remote sensing for rice insect pest management includes the detection of damage from soil insects, such as RWW, which are difficult to sample in large commercial fields. The ability to rapidly assess damage from such pests could greatly improve scouting tactics and potentially lead to precision targeted control tactics.

Rice Plant Biomass Traits Influencing Rhizosphere Soil Microbial Community Composition

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Soil microbial communities can increase nutrient availability to plants and influence plant growth and overall health. Likewise, soil microorganisms in the plant rhizosphere rely on root exudates, such as carbon metabolites and nutrients, as growth substrates. Plant species directly influence soil microbial communities through root exudates which change as the plant matures. Even within plant species, the rhizosphere soil microbial community can be altered by plant genotype differences. Plant breeding efforts have the potential to make use of beneficial plant-soil microbiome interactions. Specifically, understanding how changes in growth patterns of plant traits, such as root and shoot biomass, during developmental transition (e.g. from vegetative to reproductive stages) may shed light on plant trait–driven shifts in microbial community structure. Furthermore, studying the dynamic relationship between plant host and soil microbial populations could inform future plant breeding efforts to optimize beneficial microbial populations that influence soil health and plant nutrition.

To examine a temporal profile of microbial composition that are associated with changes in plant biomass (i.e., root and shoot), nine recombinant inbred lines (RILs) from a Francis/Rondo (FR) mapping population segregating for shoot biomass (SB) and root biomass (RB) were selected along with two parent lines, Rondo, with high RB/SB, and Francis, with low RB/SB. Plant and soil samples were collected at two developmental stages, i.e. heading and grain fill, and were evaluated for RB and SB dry weights and rhizosphere microbial community profiles, respectively. These two developmental stages were selected for displaying contrasting RB and SB growth patterns across the 11 inbred lines as well as representing the changes that occur during reproduction. Shotgun metagenomic sequencing was used to examine the temporal relationship between rice cultivar-specific root and shoot biomass traits and the rhizosphere soil microbial community. Libraries were constructed with DNA extracted from rhizosphere soil samples for metagenomic sequencing on the NextSeq platform.

Microbial taxa that were associated with changes in biomass included species from the *Actinobacteria*, *Chloroflexi*, *Planctomycetes*, *Proteobacteria*, and *Verrucomicrobia* phyla. Within the *Proteobacteria*, several *Alphaproteobacteria* species were identified and correlated with shoot and root biomass. Within this phylum, a *Phenylobacterium* sp., aerobic or facultatively anaerobic non-spore forming bacteria, was negatively correlated with RB, SB, and grain fill. Perhaps unsurprisingly, a *Bradyrhizobium* sp., which is a known rice root endophyte capable of nitrogen-fixation, was identified as positively associated with root biomass, but, interestingly, also with shoot biomass and during grain fill. Several taxa showed a significant positive correlation with rice shoot biomass and this pattern was well-presented during grain fill. Especially interesting, *Anaeromyxobacter* spp. Are gram negative facultative anaerobes that are known to perform dissimilatory iron reduction and have been shown to use nitrate as an electron acceptor making it an important species for biogeochemical cycling of nutrients. A methanogen, *Methanocella avoryzae*, was also positively correlated with increased shoot biomass and during grain fill stage. Generally, many of the community functions and genes observed during the heading stage were representative of cell growth, while functions identified as correlated with grain fill were indicative of cell decay indicating that some microbial communities exist whose metabolic functions correspond positively to plant shoot and root biomass. Understanding how plant traits, such as root and shoot biomass, and plant developmental stage impact the structure and function of rhizosphere soil microbial communities is essential for selecting plant-beneficial microbes through trait-driven breeding.

Abstracts of Papers from the Student Oral Contest Panel – Rice Culture
Moderator: Bobby Golden

Evaluation of Alternative Fertilizer Sources in Delayed-Flood Rice

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In 2018, 1.9 million hectares (4.8 million acres) of principal crops, of which 56,656 hectares (140,000 acres) of rice (*Oryza Sativa L.*) were planted in the state of Mississippi. Rice is typically grown in a direct-seeded, delayed-flood production system throughout the mid-southern United States. Nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) are the four primary essential nutrients needed in order for rice to produce adequate yields. Nitrogen fertilizer and its application is the single greatest expense for rice producers. Urea fertilizer-N is the most commonly used nitrogen source in the mid-southern U.S. based on its relatively low price and high (46%) nitrogen content. Blended fertilizers are occasionally used such as urea ammonium nitrate (UAN), ammonium sulfate (AMS), and diammonium phosphate (DAP) are typically used as starter fertilizers. These products all contain elemental N, but at lower analyses than urea and are more expensive. Triple superphosphate and potash are the primary fertilizers used to supply phosphorus and potassium, respectively. However, new fertilizers products are attempting to enter the rice fertilizer market. These new products include environmentally smart nitrogen (ESN; Nutrien, Saskatoon, Canada), MicroEssentials®SZ® (MESZ; Mosaic, Tampa FL), and SYMTRX (Anuvia Plant Nutrients, Zellwood, FL). Fertilizer ESN is a polymer coated urea (PCU) that slowly releases the nitrogen over a period of time. SYMTRX is an organic slow release fertilizer that contains nitrogen, phosphorus, and sulfur. The goal of these products is to try to coincide nutrient release with plant uptake. MESZ is a proprietary fertilizer that combined nitrogen, phosphorus, sulfur, and zinc into a single granule. With all of these new fertilizer sources hitting the market, it is crucial to evaluate their effectiveness in production rice systems.

Research was established from 2015-2019 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, on to soil textures. The primary objective is to evaluate alternative fertilizer management strategies that may potentially be used to reduce cost associated with current rice fertilization strategies. Secondary objectives of this research were to evaluate alternative fertilizer nitrogen and sulfur sources in direct-seeded, delayed-flood rice production systems. Trials were arranged in a randomized complete block design. Data from all site-years for specific objectives were pooled together for analysis to evaluate differences among alternative fertilizer sources and management strategies. Objective 1 was established in 2015 and 2016 and contained four nitrogen sources: AMS (21-0-0-24S), PCU (44-0-0), DAP (18-46-0), and urea + NBPT (46-0-0). Nitrogen was managed eight different ways in this study with different blends of nitrogen sources being applied at different timings. Objective 2 was established in 2017, 2018, and 2019 with fertilizer sources consisting of two primary sulfur sources: SymTRX20S and ammonium sulfate. The two sulfur sources were applied in combination with DAP, urea, and triple superphosphate. All data was analyzed using PROC GLIMMIX in SAS v9.4 (SAS Institute, Cary, NC). Means were subjected to analysis of variance (ANOVA) and separated using Fischers Protected LSD (α=0.05).

Results for objective 1 indicate that PCU management strategies need to be altered to be effective in dry-seeded, delayed-flood production system. Rice yields produced with PCU management strategies ranged from 6 to 17% less than yields achieved with the standards of single optimum pre-flood and two-way split application strategies when urea was applied. The slow release nature of PCU did not perform as well as urea in the aquatic environment of rice production or proper timing of application for this product is yet to be determined. Offsite fertilizer granular movement may contribute to reduced grain yield by PCU; which was observed during irrigation.

Nitrogen fertilizer additions positively impacted rice grain yields; however, the urea-based strategies applied at 7 DBF outperformed the slow-release product PCU in grain yield except PCU applied at two leaf growth stage. Results for objective 2 indicate that SymTRX20S equally effective as AMS. Rice yield were statistically similar when AMS or SymTRX20S was applied. Treatments with AMS or SymTRX20S produced a 17% greater yield when applied on soils where sulfur was limiting. SymTRX20S and AMS also produced statistically similar yields compared to urea when applied 7 days before flood. SymTRX20S is a product that can possibly be used in mid-south rice production when additional sulfur is needed to produce maximal yield.

Nitrogen Management in Furrow-Irrigated Rice Production

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Furrow-irrigated rice (*Oryza sativa* L.) production (FIR) has increased nearly four-fold over the past two growing seasons in Arkansas, to approximately 60,000 hectares in 2019. Nitrogen (N) management recommendations must be tailored specifically for the FIR system as the potential for greater N loss exists, mainly via nitrification-denitrification cycles. A three-year study was initiated in 2018 to define N management schemes which have the potential to optimize FIR production on clay soils across the Mid-South. Urea with an added urease inhibitor (n-butyl thiophosphoric triamide, or NBPT) was applied in multiple rates and timing schemes, ranging from a single application up to a four-way split application of nitrogen. Application timings began at V4 to V5 (preflood), included the three subsequent weeks, and are denoted as (kg N ha^{-1} Week 1-Week 2-Week 3-Week 4). Trials were conducted at two sites in both 2018 and 2019 on a Sharkey clay soil texture in a split-plot design, with whole-plot factor being area of the field (upper versus lower end) and split-plot factor being N management scheme. Grain yield and milling yield were measured at harvest, while total N uptake was measured and analyzed at 50% heading. It was initially hypothesized that a four-way split application would result in the greatest yield and optimize N uptake. However, data from 2018 and 2019 suggest that a three-way split application including an additional 52 kg N ha^{-1} (84-0-84-52) consistently optimized rice grain yield, milling yield, and total N uptake. In the upper portion of the field, where an upland environment was present, the 84-0-84-52 application yielded at least 1,931 kg ha^{-1} greater than all treatments other than the high N check at one site, while all treatments other than the single preflood application yielded greatest at the second site in 2018. In 2019, the 84-0-84-52 application yielded at least 1,483 kg ha^{-1} greater than all treatments other than the high N check and single preflood application at one site, while several three- and four-way split applications as well as the high N check yielded greatest at the second site. Meanwhile, head rice yield averaged across top and bottom of the field showed similar trends. Managing nitrogen under this regime has the potential to optimize FIR production on clay soils for producers across the Mid-South.

Evaluation of the Linear Relationship between GreenSeeker and UAS-Derived Normalized Difference Vegetation Index (NDVI) to Rice Grain Yield

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Nitrogen (N) has a heavy impact on rice grain yield and quality. Nitrogen is supplied to rice through fertilizer applications that can either positively or negatively affect rice growth and development. In Louisiana, the preferred method of N fertilization is the 2-way split application. The first N fertilizer application is applied prior to flooding and the second N fertilizer application is applied at mid-season. Accurate mid-season N fertilizer rates can be difficult to determine because fertilizer rates at mid-season are typically determined by visual observation by a grower or consultant. Remote sensing technology has been used successfully to more accurately determine mid- season N rates. The predominant remote sensing tool used is the GreenSeeker handheld active sensor. The GreenSeeker collects vegetative indices that evaluates the reflectance value of the crop canopy. Vegetative indices collected are a widely used, consistent indicator of yield potential. Yield potential is one of the three factors used in an algorithm to estimate rice mid-season N rates of fertilization. A mid-season predictive algorithm has been developed by LSU, however, it hasn't been extensively adopted by growers or consultants because the GreenSeeker doesn't account for variation across a whole field. Technological advances have shown Unmanned Aerial System (UAS) have the potential to collect vegetative indices on a whole field basis which would account for variation throughout the field. However, the UAS is equipped with a passive light source sensor which can cause variability among the data collected. The variability that persists with UAS data collection comes from the variation in light intensity due to cloud cover, angle of light differences depending on sensing time, and bidirectional scattering. The two objectives of this study were to 1) Compare the GreenSeeker and UAS-derived vegetative indices and 2) Evaluate the linear relationship between GreenSeeker and UAS-derived vegetative indices to rice grain yield.

This research was conducted in 2017, 2018, and 2019 across five locations in Louisiana. Multiple rice cultivars were treated with eight pre-flood N rates, each replicated four times (0, 34, 67, 101, 134, 168, 202, and 235 kg ha^{-1}). Multiple rice hybrids were treated with six pre-flood N rates, each replicated four times (0, 67, 101, 134, 168, and 202 kg ha^{-1}). Remote sensor data was collected between panicle initiation and panicle differentiation. The two remote sensors used were the GreenSeeker (active sensor) and UAS mounted with the RedEdge-M multispectral camera (passive sensor) by Micasense. The UAS remote sensor was flown at 30 m altitude collecting multispectral images at a rate of 10 m/s with a 75% front and side overlap. The multispectral images were stitched together to form a reflectance map using PIX4D software. Farm Works Trimble Ag software was used to collect NDVI data from the reflectance maps created in PIX4D. A small plot combine equipped with a HarvestMaster H2 high capacity grain gage was used to determine the weight and moisture of the harvested rice plots.

GreenSeeker and UAS-derived NDVI had a high linear relationship at four of the five locations in 2017 and 2018. The R^2 values for Crowley, Palmetto, Monroe, and Saint Joseph ranged between 0.58 and 0.89. The Iowa location had a relatively lower R^2 value of 0.32 between GreenSeeker and UAS derived NDVI. The low relationship between the two remote sensors derived NDVI at Iowa could have been a result from the high incidence of sheath blight which developed after sensing. The GreenSeeker and UAS derived NDVI were both poor predictors of rice grain yield at four of the five locations. The relationship between GreenSeeker derived NDVI and rice grain yield for the five locations had an R^2 value range between 0.05 and 0.53. The relationship between UAS derived NDVI and rice grain yield for the five locations had an R^2 range between 0.15 and 0.52. Iowa and Palmetto both had the lowest linear relationships between GreenSeeker and UAS derived NDVI to rice grain yield. Those two locations both had a high incidence of sheath blight. A rice production system is highly restricted in producing preferable yield when a disease is present during the growth and development. Palmetto NDVI values were also collected closer to panicle differentiation than panicle initiation. It's been shown that the ability of vegetative indices to predict yield potential is decreased when vegetative indices are collected closer to panicle differentiation. This data also showed the UAS derived NDVI produced heavier saturation on the higher end of the NDVI scale between 0.7 and 0.9 NDVI values. The heavy saturation could have been a result from the UAS collecting NDVI measurements at a higher spatial resolution compared to ground-based remote sensors. Further research will need to be conducted to determine if a reliable relationship between GreenSeeker and UAS derived NDVI to yield can be formed in order to improve the determination of mid-season N fertilization requirements in rice.

Starter Nitrogen Sources and Preflood N Rate Effects on Rice Grown on Clayey Soils

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Seedling rice (*Oryza sativa* L.) grown on clayey-textured soils generally develops slowly and requires greater preflood-N rates to produce maximal yield as compared to loamy-textured soils. Farmers often apply 'starter' fertilizer N shortly after rice emergence to stimulate seedling growth. Our objective was to examine the effects of starter-N source and preflood-N rates on canopy closure, total N uptake, and grain yield of rice grown on clayey-textured soils. Research was conducted in fields with soil mapped as a Sharkey/Desha clay at the Rohwer Research Station (RRS) in Arkansas and a Commerce silty clay at the Delta Research and Extension Center (DREC) in Mississippi. Starter-N sources included no starter N (NONE), ammonium sulfate (AMS), diammonium phosphate (DAP), and urea (UREA) treated with N-(n-butyl) thiophosphoric triamide applied at 24 kg N ha^{-1} at the rice 2-leaf stage followed by five preflood-N rates ranging from 0 to 224 kg N ha^{-1} at the rice 5-leaf stage immediately before flooding. Two cultivars, one hybrid and one pure-line, were grown at each location. Canopy cover was measured on the Sharkey/Desha clay in Arkansas using the Canopeo program once a week for 5 weeks after starter-N application (WAS).

Starter N, regardless of the source, increased canopy coverage by 3 to 18% compared to rice that received no starter N for up to 5 weeks. Starting at 4 WAS, rice receiving preflood-N rates > 112 kg N ha^{-1} produced canopy cover that was 3 to 5% greater than rice fertilized with 56 kg N ha^{-1} and 45 to 63% greater than rice receiving no preflood N. A small rate of starter N increased early-season rice canopy coverage compared with rice that received no starter N. Aboveground total-N uptake by the pure-line variety at both locations was affected only by preflood-N rate and increased with each increase in preflood-N rate. Rice receiving no preflood N contained 32 to 53 kg N ha^{-1} at the R3 stage. The apparent fertilizer-N recovery efficiency of rice receiving no starter N and fertilized with 56 to 224 kg preflood-N ha^{-1} ranged from 64 (DREC) to 68% (RRS). At the RRS, the pure-line cultivar grain yield was affected only by preflood-N rate, averaged across starter-N sources, which increased significantly with each increase in preflood-N rate and reached maximal yield when fertilized with 224 kg preflood-N ha^{-1}. The grain yield of hybrid cultivar at RRS was affected by the significant starter N by preflood-N rate interaction, which generally showed that yield was maximized by application of 168 kg preflood-N ha^{-1} with starter N or 224 kg preflood-N ha^{-1} regardless of starter N. At DREC, the pure-line cultivar grain yield was affected by starter-N sources where AMS and UREA produced grain yields 285-314 kg ha^{-1} greater than NONE and DAP grain yields, which were similar. The pure-line cultivar at DREC grain yield was affected by preflood-N rate, averaged across starter N sources, which increased significantly with each increase in preflood-N rate until maximal yield was produced with 168 kg preflood-N ha^{-1}. A the DREC, no interaction occurred between starter-N sources and preflood-N rates.

The Effects of Late Season Nitrogen Application on Milling Quality in Hybrid Rice

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Rice (*Oryza sativa* L.) plays a major role in the agricultural and economic sectors of the Mid-south. Over the last two decades, the number of hybrid rice cultivars planted has increased to account for as much as 50% of the total rice area planted each year. Hybrid rice cultivars exhibit many different qualities compared to pureline cultivars such as increased disease and drought tolerance, a lower seeding rate, increased tiller number, increased grain yield, and higher susceptibility to lodging. These differences require alterations to our traditional nitrogen (N) fertilizer application rates and timings. Trials were established at two locations within the state of Arkansas, one on a clay soil and another on a silt loam soil to compare the effects of N application timing and rate on hybrid rice milling yield. The hybrid rice cultivars selected included RT XL 753 and RT Gemini 214 CL as they represent a significant portion of the hybrid rice planted. Nitrogen treatments included six preflood N rates ranging from 0-168 kg N ha^{-1} with an additional factor of 0 or 33 kg N^{-1} applied late-season during the R3 or 'boot exertion' growth stage. Results indicate significant differences in milling yield across locations and N fertilizer management treatments with the boot applications increasing grain yield and milling yield across all preflood N rates. Results from this trial indicate differences in the milling potential between the main stem and outside tillers when applying the boot application. These results bring us one step closer to better understanding where and how the N use between our pureline and hybrid cultivars differs. The work presented here will better define the metabolic and physiologic functions behind the need for late-season N applications to hybrid rice cultivars.

Development of Multi-Parent Rice Lines from Eight United States Elite Varieties

Cerioli,T., Gentimis, T., Linscombe S.D., and Famoso, A.N.

Rice yield and quality are highly influenced by the planting date. Each year the Breeding Project at the H. Rouse Caffey Rice Research Station conducts a date of planting experiment to determine the optimal planting date. This experiment focuses on the effect of different planting dates on 12 varieties, representing the most commonly grown varieties in Louisiana and new potential varieties. In this study we investigated the influence of planting date on key agronomic traits, grain yield, whole kernel milling yield and days to 50% heading from year 2011 to 2018. Initially, we compared the amount of variation determined by planting date, genotype and their interaction across different years. Planting date significantly influenced grain yield and heading date, explaining on average 55.6% of the total variation for yield and 85.5% for heading date. In contrast, grain milling yield variation was greater between years and genotypes, rather than across planting dates.

We compared the average relative values for every trait across different planting windows to determine the optimum planting time in South Louisiana. Yield showed highest values in planting window W2 and W3 (March 10 to March 31), while a decrease of yields was observed with delayed planting. Highest average values for whole kernel milling yield were recorded when rice was planted during early planting windows W1-W3 (from February 23 to March 31) or in late plantings W8 (June 9 to June 20). The reduction in milling yield during the middle planting windows corresponded to the highest temperatures during flowering.

We developed a model with average relative values of yield across days of the year for yield loss estimation purposes. Yield decreases when rice is planted after the optimal planting window with a cubic regression trend. Thus, the decrease in average relative values of yield increases with delayed plantings. On average, it takes 20 days after the optimal planting date to lose the first 5% of potential yield, 9 extra days to lose 10% and extra 7 days to lose the 15%. Overall, these results underline the importance of choosing the optimal planting date to optimize rice yields.

Impact of Rice Planting Arrangement on Stand Density and Grain Yield

Lytle, M.J., Hardke, J.T., Roberts, T.L., Frizzell, D.L., Castaneda-Gonzales, E.,
Frizzell, T.D., Chlapecka, J.L., Hale, K.F., and Clayton, T.L.

In Mid-South rice (*Oryza sativa L.*) production, drill-seeding is the most common planting practice. Novel rice plant spacing and arrangement may allow producers to reduce seeding rates and increase grain yield by creating improved plant spatial density and more rapid canopy closure. Two experiments evaluating the impact of row spacing and planting arrangement on rice stand density and grain yield were conducted in 2019 at the Rice Research and Extension Center (RREC) near Stuttgart, AR and at the Northeast Research and Extension Center (NEREC) near Keiser, AR. The row spacing study consisted of a pureline cultivar, Diamond, and a hybrid cultivar, XP753, planted at a range of seeding rates, which included 108, 215, 323, 431, and 538 seed m^{-2} for Diamond and 43, 75, 108, 140, and 172 seed m^{-2} for XP753 using drill row spacings of 8, 19, 25, and 38 cm. The experiment was set up as a two-factor factorial randomized complete block design, with the first factor being row spacing and the second factor being seeding rate. Grain yield data were collected at harvest. On 25 cm row spacings at the RREC, Diamond yielded at least 302 kg/ha more than all other spacings and XP753 yielded at least 1,110 kg/ha more than all other row spacings. When subjected to 25 cm row spacing at the NEREC, Diamond yielded at least 539 kg/ha more than 8 cm and 38 cm row spacings and XP753 yielded at least 683 kg/ha more than all other row spacings. An additional study focusing on planting arrangement evaluated the same two cultivars on 19 cm spacing. Seeding rates were identical to those described for the previous study; however, seed was planted in a single pass in one direction or divided over two passes with the second pass being perpendicular to the first. Each plot was photographed and canopy coverage was analyzed three times at approximately seven days apart using the Canopeo App and grain yield data were collected at harvest. The planting arrangement study was set up as a two-factor factorial randomized complete block design, with the first factor being planting arrangement and the second factor being seeding rate. Diamond had significantly greater yields when cross-planted versus straight-planted at the RREC (10,549 vs. 10,140 kg/ha) and at the NEREC (10,213 vs. 9,726 kg/ha). XP753 had significantly greater yields when cross-planted versus straight-planted at the RREC (11,484 vs. 11,120 kg/ha), but not at the NEREC (10,673 vs. 10,756 kg/ha). This research suggests that a crossed planting arrangement as well as a drill row spacing increase to 25 cm have the potential to increase yield.

Comparing the Effects of Multiple Planting Dates on Rice Grain Yield and Quality

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High night temperature (HNT) has been shown to negatively affect rice grain yield and quality making the issue of special concern to Arkansas rice producers. A field study was conducted at the Rice Research and Extension Center in Stuttgart, Arkansas, in 2018 and 2019. Seventy-two entries representing popular Arkansas and U.S. varieties were planted each year in three replications of randomized complete blocks on four dates separated by two or three weeks. Hourly air temperature was recorded from planting to harvest date, and the time taken for each plot to reach developmental stages R2 and R4 was recorded. Grain yield, milling yield and chalk data were collected. A pipeline for collecting and analyzing biological data is described, and multivariate analysis is performed to describe the responses of rice varieties to HNT during two developmental periods (panicle development and grain filling). Responses to planting date confirmed previous results showing higher yield with earlier planting and decreasing yield in later plantings. The data processing methods used are applicable to historical data sets such as the Arkansas Rice Performance Trial relying only on relevant and commonly available variables such as emergence date, air temperature, heading date, grain yield and milling yield. Our study improves understanding of the effects of environmental variables on grain yield and quality and is an important step toward the goal of developing new Arkansas rice varieties tolerant to HNT.

Abstracts of Papers from the Student Oral Contest Panel – Weed Control and Growth Regulation
Moderator: Ben Lawrence

The Effect of Reduced Rates of Florpyrauxifen-benzyl on Soybean Yield Components

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In the Southern United States, there are many areas where rice (*Oryza sativa* L.) and soybean [*Glycine max* (L.) Merr.] are grown near one another. Many of the herbicides used in rice or soybean are only labeled for one crop and can be injurious to other crops. Due to this, there are many instances where herbicide applications move off-target and deposit on susceptible vegetation.

Florpyrauxifen-benzyl is a new synthetic auxin that has activity on select broadleaf, grass, sedge, and aquatic weeds in rice. Soybean have shown to be extremely susceptible to off-target florpyrauxifen deposition, like other synthetic auxin herbicides. Therefore, a study was conducted to determine at what application timing and what rates this herbicide can damage soybean and the impact it has on soybean yield components.

Treatments were arranged in a 2-factor factorial, with factor A consisting of application timing at either the V4 to V5 or R1 to R2 growth stage and factor B consisting of a 5-rate titration from 1/4 to 1/1028 of a florpyrauxifen rate of 29.44 g ai ha^{-1}. A rate of dicamba shown to cause minimal injury and with little to no yield loss was also applied as a comparison. Herbicide applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} of spray solution. Injury ratings and plant height were recorded at 1, 7, 14, and 28 DAT.

Results indicated that all applied rates of florpyrauxifen resulted in total plant death at the 1/4 rate to a 12% yield reduction at the 1/1024 rate. Furthermore, there was no difference between application timings with regards to soybean yield. Yield components were also affected up to the 1/256 rate with decreases in total branch length, pod number and seed number occurring as well. This research suggests that florpyrauxifen applied near soybean has a high potential to cause significant damage and growers should consider environmental conditions and have equipment properly calibrated before making an application.

Rice Varietal Tolerance to Single and Sequential Loyant Applications

Farr, R.B., Norsworthy, J.K., Piveta, L.B., Lancaster, Z.D., and Patterson, J.A.

The commercial release of florpyrauxifen-benzyl, branded as Loyant, for use in rice production has been met with questions regarding the tolerance of rice cultivars to this herbicide. Field applications of florpyrauxifen-benzyl have been shown to be occasionally injurious to rice, but it has not been determined if injury leads to significant yield reduction in specific cultivars. The purpose of this study was to determine the impact of single and sequential applications of florpyrauxifen-benzyl on crop injury and grain yield. This study was conducted at the Rice Research and Extension Center near Stuttgart. The study was designed as a 5x3 factorial study with five different rice cultivars and three different application treatments. The five rice cultivars used were Gemini, Titan, Diamond, XL753, and XL745. The three application treatments were 30 g ha^{-1} of florpyrauxifen-benzyl at V5, 60 g ha^{-1} of florpyrauxifen-benzyl at V5, and 30 g ha^{-1} of florpyrauxifen-benzyl at V3 followed by 30 g ha^{-1} of florpyrauxifen-benzyl 14 days later. Visual estimates of injury on a 0-100 scale were taken at 7, 14, 21, and 28 days after final treatment, days to 50% heading was recorded, and yield was collected at maturity. Results from this study indicate that there is a significant difference in relative yield, maturity, and injury among herbicide treatments within some cultivars. Injury as high as 43% was observed on XL745 when sequential applications of florpyrauxifen-benzyl were applied. Gemini and XL753 had comparable levels of injury following sequential applications and injury to Diamond and Titan was less than that observed on the three hybrid cultivars. Rice grain yield was reduced 28% by sequential applications to XL753. Multiple applications of florpyrauxifen-benzyl in drill-seeded, flooded rice production systems are not recommended because of the occurrence of greater injury with sequential than with a single application.

Benzobicyclon for Weedy Rice Control in a Provisia System

Patterson, J.A., Norsworthy, J.K., Sandoski, C., France, O.W., Beesinger, J.W., and Piveta, L.B.

Weedy rice (*Oryza sativa*) is particularly difficult to control in Midsouth rice cropping systems due to its highly competitive and resilient nature, genetic similarity to cultivated rice, and resistance to herbicides. Hence, there is a need for new modes of action in rice production. Gowan Company is currently pursuing registration of benzobicyclon, a Group 27 herbicide, as a post-flood option in rice. It will be the first 4-hydroxyphenylpyruvate dioxygenase-inhibiting (HPPD) herbicide commercially available in Midsouth rice production. In 2019, field experiments were conducted at the Pine Tree Research Station near Colt, AR and the Rice Research and Extension Center near Stuttgart, AR. The experiments were implemented as randomized complete block designs with four replications. The objective of the experiments was to evaluate benzobicyclon-containing weedy rice control programs, most of which contain Provisia™ herbicide, in Midsouth rice compared to currently used programs. The herbicides used in the experiments included Prowl H_20 (pendimethalin), Bolero (thiobencarb), Warrant (acetochlor), Provisia (quizalofop), and Rogue (benzobicyclon). The herbicides were applied in various combinations and timings, except all Rogue applications were made post-flood. At PineTree, four weeks after the post-flood application, >98% weedy rice control was observed for all programs containing Provisia followed by a post-flood application of Rogue. At four weeks after the post-flood application, no more than 5% injury was observed from treatments containing Provisia followed by Rogue. At Stuttgart, four weeks after the post-flood application, >92% weedy rice control was observed for all treatments but were not significantly different. At four weeks after the post-flood application, ≤10% injury was observed from treatments containing Provisia followed by Rogue. These data suggest that the use of benzobicyclon in Provisia rice systems could be a viable weedy rice control option and may provide some protection against weedy rice evolving resistance to Provisia herbicide.

Palmer Amaranth Response to Loyant in Furrow-irrigated Rice

Beesinger, J., Norsworthy, J., Barber, L., Priess, G., Castner, M., and Piveta, L.

Furrow-irrigated rice acres have increased in Arkansas over the last 5 years, due to lower initial input cost. Aerobic conditions in furrow-irrigated rice is a suitable environment for Palmer amaranth germination and growth, as opposed to the anaerobic conditions of flooded rice. Therefore, new management strategies need to be developed to control Palmer amaranth in furrow-irrigated rice. A field study was designed to optimize Palmer amaranth control utilizing rates and timing of applications of Loyant (florpyrauxifen-benzyl). An experiment was conducted in the growing season of 2019 at the Lon Mann Cotton Research and Extension Center in Marianna, Arkansas. The experiment was designed as a two-factor factorial randomized complete block. An interaction between rate and timing was not observed (p-value=0.89). However, a significant main effect of rate and timing was observed (p-value=0.008, p-value=0.0001, respectively). Palmer amaranth control generally increased as rate of Loyant increased. Palmer amaranth control was optimized when Loyant was sprayed within 2 to 4 weeks after planting. Failure to apply Loyant before 4 weeks after planting resulted in a decrease in Palmer amaranth efficacy. Delaying removal of Palmer amaranth with Loyant also negatively impacted rice grain yield. The experiment shows Loyant as a part of a herbicide program will provide the Palmer amaranth control needed by farmers in their furrow-irrigated rice.

Overlaying Residual Herbicides in Louisiana Upland Rice Production

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Furrow-irrigated rice (*Oryza sativa* L.), has recently gained popularity in Mid-South rice production. In the Gulf Coast Prairie region of Louisiana, the soil is relatively shallow due to an impervious clay fragipan approximately 15 to 45 cm below the surface. This clay fragipan prevents the downward percolation of water making the region conducive for growing rice in a conventional flooding system. The thought of disturbing the clay fragipan makes growing furrow-irrigated rice an insubstantial production method in the Gulf Coast Prairie region; however, a similar production system that does not require raised beds can be referred to as upland rice production. Rice grown under upland conditions can provide lower yields compared with rice grown under flooded conditions. In addition to lower rice yields, weed infestations and spectrums can be altered due to the lack of cultural weed control from flooding.

A study was conducted in 2019 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate overlaying residual herbicides in upland rice production. Plot size was 3-m by 11.3-m with 16-19.5 cm drill-seeded rows of 'CLXL-729' at 39.2 kg ha^{-1}. The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted very early postemergence (VEPOST) applications of 1) no VEPOST application, 2) a prepackaged mixture of imazethapyr plus quinclorac at 560 g ai ha^{-1}, 3) imazethapyr at 70 g ai ha^{-1} mixed with clomazone at 211 g ai ha^{-1}, 4) imazethapyr at 70 g ha^{-1} mixed with pendimethalin at 1120 g ai ha^{-1}, 5) imazethapyr at 70 g ha^{-1} mixed with a prepackaged mixture of clomazone plus pendimethalin at 717 g ai ha^{-1}, or 6) imazethapyr at 70 g ha^{-1} mixed with a prepackaged mixture of halosulfuron plus prosulfuron at 83 g ai ha^{-1}. Factor B consisted of either no late postemergence (LPOST) application or a LPOST application of imazethapyr at 70 g ha^{-1} plus bispyribac at 34 g ai ha^{-1}. A uniform standard treatment of clomazone at 211 g ha^{-1} was applied preemergence. All postemergence applications were applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations for the study included barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and red rice (*Oryza sativa* L.) control at 14 days after the VEPOST (DAVEPOST) application and 21 days after the LPOST (DALPOST) application. Rough rice yields were obtained and adjusted to 12% moisture.

At 14 DAVEPOST, barnyardgrass was controlled 91 to 93% when treated with a prepackaged mixture of imazethapyr plus quinclorac. All other herbicide combinations applied VEPOST controlled barnyardgrass 74 to 87% at 14 DAVEPOST. At the 21 DALPOST rating date, barnyardgrass was controlled 45 to 76% across all herbicide mixtures applied VEPOST with no LPOST application; however, when a LPOST application imazethapyr plus bispyribac was applied barnyardgrass control was 85 to 92% at 21 DALPOST. Red rice was controlled 72% at 21 DALPOST when treated with a prepackaged mixture of imazethapyr plus quinclorac at VEPOST with no LPOST application. All other herbicide combinations applied VEPOST not fb a LPOST application resulted in 45 to 58% control of red rice at 21 DALPOST. Red rice treated at VEPOST fb LPOST was controlled 68 to 82% at 21 DAL. These results suggest to overlay residual herbicides throughout the growing season in upland rice production. This study indicates the addition of a prepackaged mixture of imazethapyr plus quinclorac at the VEPOST application timing provides an extended period of residual control before a LPOST herbicide application is needed.

Does Dicamba Exposure during Rice Reproductive Development Affect Maturity and Grain Yield?

Castner, M.C., Norsworthy, J.K., France, O.W., Beesinger, J.W., and Lancaster, Z.D.

Engenia and XtendiMax with VaporGrip are labeled for preemergence and postemergence (POST) use in XtendFlex cotton and Roundup Ready 2 Xtend soybean. Despite its efficacy, labeled applications of Engenia and XtendiMax in both cotton and soybean have presented major concerns for off-target movement, primarily to non-dicamba-resistant soybean. Extensive research has been published regarding the effects of sublethal concentrations of dicamba at different growth stages in soybean; however, there is limited research investigating the impact of dicamba on reproductive rice. In order to determine the potential consequences of dicamba drift rates on reproductive rice, an experiment was conducted near Stuttgart, Arkansas in 2018 and 2019. Simulated drift rates of dicamba at 1, 1/10, 1/100, and 1,1000X rates, with 1X being 560 g ae ha^{-1} of dicamba were applied to rice at three reproductive growth stages. Treatments were arranged as a two-factor factorial, with the first factor being dicamba rate, and the second being rice growth stage. There were no significant treatment effects observed with 100-seed weight, although dicamba rate played a significant role on the relative average panicle weight with a 15 and 39% reduction at the 1/10 and 1X rate, respectively. The same trend translated to both average number of seeds per panicle and grain yield, with a decrease of approximately14 and 35%. An interaction was observed between dicamba rate and growth stage as well, with 1/10 and 1X rates of dicamba hastening rice maturity roughly 2 and 3 days, respectively. With severe consequences only being observed at high dicamba concentrations, the threat off-target movement poses to rice is far less severe than what has been observed in soybean.

Response of Rice (*Oryza sativa*) to Drift Rates of Glyphosate and Dicamba Applied at Multiple Growth Stages

France, O.W., Norsworthy, J.K., Piveta, L.B., Beesinger, J.W., and Houston M.M.

The recent introduction of dicamba technologies such as Xtend™ soybean and cotton has resulted in an increase in application of dicamba during the growing season. Subsequently greater unintentional injury from dicamba from volatilization, drift, and tank-contamination has been common. While not considered injurious to rice, the effect of glyphosate, a herbicide capable of severe injury to rice, plus dicamba at low rates is not known. Research was conducted to evaluate the response of rice to low rates of dicamba plus glyphosate. The study was designed as a two-factor factorial with factor A being growth stage at application, including a nontreated, one-tiller, half-inch internode, and boot; factor B being rate applied, including a nontreated, 28 g ae ha^{-1} plus 56.35 g ae ha^{-1} (1/20x rate of both herbicides), 7 g ae ha^{-1} plus 14.06 g ae ha^{-1} (1/80x rate), and 0.8315 g ae ha^{-1} plus 1.485 g ae ha^{-1} (1/320x rate) of dicamba plus glyphosate, respectively. Visible injury ratings were taken weekly for 8 weeks following the one-tiller growth stage application, and yield data were taken at harvest. Until the half-inch internode growth stage application was made injury ratings were minimal and of no biological significance. Following the half-inch internode application, there was a significant interaction between both factors, with injury to these plots averaging 25% the week following the application. There was no other significant injury. An identical interaction was observed in relative yield data, with plots receiving the highest application rate at the half-inch internode growth stage having significantly reduced yield. The only other treatment to have reduced relative yield received the middle rate of herbicide applied at the one-tiller growth stage and was 89% of the relative yield.

Halosulfuron plus Prosulfuron for Residual Weed Control in ACCase-resistant Rice

Kelly, F.R., Lawrence, B.H., Edwards, H.M., Peeples, J.D., and Bond, J.A.

The introduction of acetyl coA carboxylase (ACCase)-resistant rice (*Oryza sativa* L.) cultivars has allowed producers to use alternative herbicide modes of action to combat early-season grass species. Palmer amaranth (*Amaranthus palmeri* S. Wats.) and hemp sesbania [*Sesbania herbacea* (P. Mill.)] are problematic and difficult to control in rice production in the midsouthern U.S. Halosulfuron plus prosulfuron is an acetolactate synthase (ALS)-inhibiting herbicide mixture that has been a viable option for postemergence (POST) control of broadleaf species in rice. Residual herbicides applied preemergence (PRE) are important tools to manage problematic weeds in Mississippi rice production and in recent years saflufenacil applied PRE has been the foundation herbicide treatment for problematic broadleaf weed species. The addition of the halosulfuron plus prosulfuron mixture to saflufenacil could increase the spectrum of broadleaf weed species controlled with PRE treatments in midsouthern U.S. rice production. Therefore, research was conducted to evaluate residual control of broadleaf weeds with PRE applications of different herbicide mixtures in ACCase-resistant rice.

Research was conducted in 2019 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to compare broadleaf weed control with different residual herbicides applied PRE. Soil texture was a Sharkey clay with a pH of 7.5 and 2.4% organic matter. The experimental design was a randomized complete block with four replications. Treatments included clomazone (Command) at 420 g ai ha^{-1} alone and in combination with halosulfuron plus prosulfuron (Gambit) at of 55, 83, and 11 g ai ha^{-1}, and saflufenacil (Sharpen) at 50, and 75 g ai ha^{-1} applied at time of planting. A non-treated control was included for comparison of weed control. Visible estimates of above ground rice injury and control of hemp sesbania, Palmer amaranth, and ivyleaf morning glory (*Ipomoea hederacea* Jacq.) were recorded at 14, 21, and 28 d after treatment (DAT). All data was subjected to ANOVA, and estimates of the least squared means were utilized for mean separation with $p \leq 0.05$

No rice injury was observed at any evaluation. All treatments including halosulfuron plus prosulfuron and/or saflufenacil controlled broadleaf weeds greater than clomazone. Hemp sesbania control 21 and 28 DAT with halosulfuron plus prosulfuron at 11 g ai ha^{-1} was greater than with the two lower rates of halosulfuron plus prosulfuron and saflufenacil at 75 g ai ha^{-1}. The addition of either rate of saflufenacil to halosulfuron plus prosulfuron did not improve hemp sesbania control 21 and 28 DAT compared with halosulfuron plus prosulfuron alone. All treatments that included halosulfuron plus prosulfuron controlled ivyleaf morningglory ≥ 96% 21 and 28 DAT. Saflufenacil at 50 and 75 g ai^{-1} controlled less ivyleaf morningglory than all treatments with halosulfuron plus prosulfuron. Palmer amaranth control 21 and 28 DAT was greater with any treatment containing saflufenacil compared with halosulfuron plus prosulfuron at 55 and 83 g ai ha^{-1}. By 28 DAT, only treatments with saflufenacil controlled Palmer amaranth ≥ 80%.

The suggested treatment for residual control of Palmer amaranth in Mississippi rice production is saflufenacil at 50 g ai ha^{-1} mixed with glyphosate and clomazone. These data indicated that saflufenacil at 50 g ai ha^{-1} alone or in mixture with halosulfuron plus prosulfuron provided better control of Palmer amaranth than halosulfuron plus prosulfuron at 55 and 83 g ai ha^{-1}. However, treatments containing halosulfuron plus prosulfuron controlled more hemp sesbania and ivy-leaf morning-glory than saflufenacil at 50 g ai ha^{-1}. Mixture of halosulfuron plus prosulfuron with saflufenacil were required for control of all three species evaluated. Although PRE applications containing halosulfuron plus prosulfuron and saflufenacil could be cost prohibitive, this treatment would provide residual control of broadleaf weeds common in Mississippi rice.

Evaluation of a Seed Treatment for Safening Rice to Formulations of Soil-applied Acetochlor

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

Warrant® (microencapsulated, ME) and Harness® (emulsified concentrate, EC) are both formulations of acetochlor. Currently, no acetochlor formulation is labeled for use in rice (*Oryza sativa*) production; however, pretilachlor, a less efficacious, chloroacetamide herbicide, is labeled for use in Asian rice production systems when combined with applications of fenclorim, a product developed by Ciba Geigy in the 1980's. Field trials were conducted in 2019 at Fayetteville, AR to evaluate the safening effects of fenclorim as a seed treatment when applying acetochlor. The experiment was setup as a split plot randomized complete block design with the split-plot factor being fenclorim seed treatment (0, 0.25, and 2.5 g $kg\text{-}seed^{-1}$) and whole-plot factors being two acetochlor formulations (ME and EC) and three acetochlor rates (315, 630, and 1260 g ai ha^{-1}) applied delayed preemergence (DPRE). Non-herbicide treated plots also included fenclorim at each rate. As rate of acetochlor increased, injury to rice likewise increased. Higher rates of fenclorim decreased injury to rice, indicative of a safening effect. As acetochlor rate decreased stand loss diminished and was comparable to the non-treated at the highest rate of the safener. Likewise, switching from EC to ME formulation caused less injury to rice. The highest rate of fenclorim (2.5 g $kg\text{-}seed^{-1}$) in combination with the ME formulation of acetochlor at 1260 g ai ha^{-1} resulted in only 9% injury to rice whereas the EC formulation at the same acetochlor rate caused 56% injury in the absence of fenclorim. This research clearly shows that fenclorim applied as a seed treatment in combination with a ME formulation of acetochlor can result in commercial safety to the herbicide in drill-seeded rice.

Abstracts of Papers on Breeding, Genetics, and Genomics
Panel Chair: Ed Redona

Curating the USDA-ARS Rice Germplasm Collection: Efficient Accession Management and Characterization through Phenotyping and Genotyping

Huggins, T.D., McClung, A.M., Edwards, J.D., Jia, M.H., Bockelman, H.E., Ali, M.L., and Eizenga, G.C.

Genebanks are an important source of genetic diversity for food crops world-wide and offer valuable information that can be used by plant breeders to improve agricultural productivity and nutritional quality. The National Small Grains Collection (NSGC) was established for this purpose. Currently the rice portion of the collection, henceforth referred to as "Rice-NSGC", maintains 19,031 accessions of cultivated Asian rice (*Oryza sativa* L.), 193 African cultivated rice (*O. glaberrima* Steud.) and 54 *Oryza* wild species. Challenges facing genebank management include providing sufficient and accurate information to facilitate searching the collection, dealing with redundant accessions, seed mixtures, mis-identified accessions, and gaps in diversity, as well as lack of resources to thoroughly characterize the collection. To partially address these issues, a random set of 1,993 Rice-NSGC accessions, henceforth called the "2K set", were phenotypically characterized for two phenological traits, plant height, 13 morphological traits, six grain quality traits, four production traits, resistance to three diseases, and two stress related traits and were genotyped with 11 fingerprint markers (FPM), one subspecies marker, and 14 trait specific markers (TSM). TSM were used to validate phenotypic data for fragrance, pericarp color, blast disease resistance, leaf and hull pubescence, apparent amylose content, starch pasting properties and gelatinization temperature, and plant height. Utilizing these markers, accessions were classified by species, *O. sativa* or *O. glaberrima*; subspecies, *indica* or *japonica*; subpopulation, *aromatic*, *indica*, *aus*, *temperate* or *tropical japonica*; and often by cultivar.

Three panels were developed from the 2K set using the phenotypic and genotypic data to address specific genebank management issues. The Red Bran panel included the 164 of the 2K accessions where the red bran color did not agree with the *Rid12* marker for the *Rc* gene on chromosome (chr.) 7 for red pericarp. The Aroma panel included 115 accessions from the 2K set where the aromatic classification in the GRIN-Global database did not agree with the BADH2 gene. The Redundant by Name (RBN) panel consisted of 164 of the 2K set and 64 additional accessions from the Rice-NSGC that appear multiple times by cultivar name in the GRIN-Global database and were genotyped with the FPM. In addition, 190 accessions designated as *O. glaberrima* in the Rice-NSGC were included in the Glaberrima panel and were genotyped with RM215 and RM154 that have private alleles unique to these species.

The Red Bran panel was genotyped for the chr. 1 *Rd* markers locus which affects *Rc* for red pericarp, this combination of *Rd* and *Rc*, as well as visual phenotyping effectively resolved 56 of the discrepancies, however for the remaining 108 accessions, it is possible that there are other mutations in the *Rc* or *Rd* loci as well as other genes involved. The Aroma panel was subjected to a sensory test and scored as aromatic (2 acetyl-1-pyrroline present) or non-aromatic by two phenotypes using dehulled grain. In over 90% of the sensory tests, the phenotypes agreed with the *BADH2* marker. The RBN panel included 85 sets that were phenotyped and genotyped, then classified into four categories: CAT1, different genotype and phenotype; CAT2, similar genotype and phenotype; CAT3, different genotype but similar phenotype; and CAT4, similar genotype but different phenotype. Based on these classifications, 20 RBN sets were CAT2 and thus, could be reduced to a single accession, resulting in 27 accessions removed from active distribution and rejuvenation. . The Glaberrima panel genotyping verified 146 were *O. glaberrima*, 44 were most likely *O. sativa*, and 14 were from a cross between *O. sativa* (WAB56-104) and *O. glaberrima* (CG14).

Lastly, the U.S. Advanced Varieties (USAV) panel was analyzed which included 97 varieties that have been grown commercially, used as parents of mapping populations, or are historical parents in the U.S. rice pedigree. The accessions were genotyped with the TSM, *Als*653, *Sd1*del/*Sd1*gap, FPM, RM249 and RM404. This small panel of markers was adequate for differentiating most varieties. The TSM including *Als*653 and *Sd1*del/*Sd1*gap can add value to a breeder's toolbox, especially when deployed in marker assisted selection breeding. Based on this study, FPM and TSM descriptors will be added to the Rice-NSGC database, redundancies reduced, and mis-identified accessions corrected, thus increasing the value of Rice-NSGC for breeding programs and providing new opportunities for gene discovery.

Evaluation and Utilization of Novel Genetic Variation in Rice

Tai, T.H.

Induced plant mutants are important resources for the breeding of new and improved varieties. The development of powerful, high throughput sequencing-based strategies for mutation detection has further increased the value of these resources, enabling functional genomics of agriculturally important traits. The major goals of our research are to identify novel mutations and traits to further the understanding of rice grain quality and agronomic performance and to develop novel genetic resources for breeding new varieties and for dissecting gene function. Towards these ends, traditional chemical mutagenesis has been employed to generate mutant populations in the japonica rice varieties Nipponbare, Kitaake, and Sabine. Using the reverse genetics method Targeting of Induced Local Lesions in Genomes (TILLING) by sequencing, mutations in genes involved in seed phytic acid content, silicon/arsenic uptake and accumulation, and starch biosynthesis have been identified. Forward genetics has also been employed to complement the TILLING by sequencing approach and to identify morphological and developmental mutants. Characterization of the phenotypic effects of mutations identified via TILLING and progress towards isolating the genes underlying mutant phenotypes obtained by forward genetics screens will be presented using examples involving silicon/arsenic uptake, grain quality, and cuticular wax synthesis and accumulation.

Gene Disruption by Structural Mutations Drives Selection in U.S. Rice Breeding Over the Last Century

Vaughn, J.N., Stein, J., Korani, W., Edwards, J., Peterson, D., Simpson, S.,
Grimwald, J., Ware, D., McClung, A., and Scheffler, B.

The genetic basis of general plant vigor is of major interest to food producers, yet the trait is typically impossible to map to gene level resolution due to the number of loci involved, their small effects, and linkage. Observations of heterosis in all major crops suggests that recessive, malfunctioning versions of genes are a major source of poor performance. The source of these broken genes has yet to be extensively characterized in an agronomic context. We generated a long-read assembly of a tropical japonica rice variety, Carolina Gold, to identify gene scale structural events and orient them with respect to their ancestral state using the outgroup, *Oryza glabberima*. Supporting prior work, we find substantial genome expansion in the *O. sativa* lineage. While transposable elements (TEs) account for the largest share of size variation, the majority of events are not directly TE-mediated. Tandem duplications are the most common source of insertions and are highly enriched among 50-200 bp mutations. To explore the relative impact of various mutational classes on crop fitness, we then track these structural events over the last century of US rice improvement using 101 resequenced varieties developed across the Mississippi valley. Within this material, a pattern of temporary hybridization between medium and short-grain varieties was followed by recent divergence. During this long-term selection, >50 bp structural events that impact gene exons have been removed at a greater rate than intronic indels and even single-nucleotide mutations that introduce stop codons. These results support the use of *ab initio* estimates of mutational burden as an additional predictor in genomic selection, and they illuminate research gaps that currently hinder such estimates.

Public Rice Breeding at Crossroads – Challenges and Opportunities

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

Rice is one of the most important food crops in the world. In the United States, Arkansas ranks first among the six major rice-producing states, and accounts for over 45 percent of the U.S. rice production in last decade. Rice ranks the second in cash value and first in export among the state's agricultural commodities. Public rice breeding program funded by both state and the Check-off has played and will continue to play an important role in improving rice production in Arkansas and southern United States. The average farm yield in Arkansas has increased from 6.3 t/ha in 1989 to 8.4 t/ha in 2018 (USDA-ERS, 2019). Although the advancement of rice production technology played an important role on the yield increase, the majority can be attributed to the new varieties developed by the public rice breeding program.

In last two decades, rice production in the southern United States has gone through dramatic changes with the successful introduction and widespread adoption of hybrid rice, as well as the development of proprietary herbicide resistance traits such as Clearfield and more recently Provisia. Public rice breeding programs are challenged to develop varieties with different proprietary traits and public hybrids in addition to their traditional duties to keep up with the genetic gain achieved in current commercial hybrid rice while maintaining the competitive edge of superior milling and grain quality of pureline varieties. Success of plant breeding depends on accurate selection of rare genotypes that possess new or improved attributes due to superior combinations of alleles at multiple loci, in the context of a target set of environments. The rapid advancement of rice genomics and technology has enabled rice breeders to integrate new knowledge and technologies into their breeding programs to improve both efficiency and effectiveness. Traditional breeding works best when involving few traits, therefore, introduction of diverse germplasm into crossing programs is discouraged, because this usually upsets the balance of desired quality traits, such as amylose content and gelatinization temperature. However, with the advancement of affordable, high-throughput genotyping and sequencing technology, a great number of molecular markers among the closely related pre-breeding germplasm will become available for the simultaneous improvement of multiple agronomic traits such as greater biomass, higher yield potential, and multiple resistances while maintaining the standard U.S. rice quality. Technologies such as GPS guided auto-pilot and tripping, the automated weighing and moisture measuring system like the HarvestMaster, computerized data capture, management, and analysis tools such as Agrobase should lead to much improved efficiency, huge saves in labor, and much shorter turnaround time. Breeding is a number's game, and the improvement in efficiency and effectiveness of selection and trials through the integration of the cutting-edge technologies makes it possible to accommodate the additional breeding tasks without scarifying the chance of success.

A New Haplotype of Rice Blast Resistance Gene *Ptr* in Weedy Rice Confers Resistance to the Most Virulent Race of *M. oryzae*

Zhao, H., Jia, Y., and Liu, Y.

Blast disease of rice caused by the filamentous fungus *Magnaporthe oryzae* (syn. *Maganporthe grisea*) and weedy rice (*Oryza sativa indica*) are two of the most significant constraints of rice production worldwide. Major resistance (*R*) genes are the primary means of preventing infections by *M. oryzae* strains carrying the cognate avirulence (*AVR*) genes. However, the instability of *M. oryzae AVR* genes often challenges the stability of deployed *R* genes. Searching for more effective blast *R* genes from different genetic resources is essential to manage rice blast disease. In our previous evaluation of germplasm, we determined that rice blast *R* gene *Ptr* confers resistance to several US blast races resistance except for the most virulent blast race, IB33. *Ptr* is a new class of blast resistance gene. In the present study we show that the Ptr protein with minor amino acid variation encoded by the *Ptr* allele, Ptr^{BHA} in a late-flowering black hull weedy rice, MS-1996-9 (PI 653419), here referred to as RR20, from Mississippi is responsible for resistance to IB33. The resistance gene to IB33 was mapped between single nucleotide polymorphic markers (SNP) 10.633,942bp and 10.820,033 bp with the closest SNP at 10.724,430 bp, excluding *Pi-ta* which is also near this region. A gene specific marker for *Ptr* was developed to examine the existence of Ptr^{BHA} in each individual of a mapping population derived from RR20 x (DGWG) through disease reactions using IB33. The presence of the gene specific marker of Ptr^{BHA} was correlated with the resistant reaction to IB33 suggesting that Ptr^{BHA} in RR20 is responsible for resistance against IB33. These findings suggest that a natural allele of *Ptr* in RR20 is a novel and effective blast *R* gene for breeders to deploy for resistance to this race of blast that currently does not exist in any US cultivar.

A Practical Implementation of Genomic Selection for Louisiana Rice Variety Development

Hernandez, C., Robbins, K., and Famoso, A.

Current work is aimed at finding a practical implementation of genomic selection (GS) for LSU rice variety development. Modern marker technologies allow for the development of customized marker panels that can be used to economically genotype large breeding populations, which enables the use of GS. Simulation, cross-validation, and empirical studies have demonstrated the superiority of GS over other methods for achieving genetic gain in quantitative traits; however, there are few examples in the literature that address the challenges of integrating GS in an existing field-based program. Towards this end, we leverage breeding data from the LSU program to determine the best strategies for incorporating predictions into the breeding pipeline.

Initial work focused on creating an optimal marker set for routine genotyping. Illumina SNP-Chip data were used to develop a set of markers for testing across breeding material. Marker data were down-sampled randomly and according to various methods that relied on capturing LD structure in the breeding program. Ultimately, a method was chosen that relied on tagging haplotype blocks segregating in the breeding material. Markers chosen with this method were then tested on thousands of breeding lines spanning trial data from 2017-2019. This set of genotyped lines was used to access the predictive ability of whole-genome models for important agronomic traits such as yield, maturity, and plant height. Milling and quality-related traits were also tested. Predictive abilities were correlated with trait heritability and deemed sufficient for implementation of GS. Genetic parameters and predictive abilities estimated from the breeding program were used for simulating different breeding schemes using AlphaSim. Results from simulation will be used to guide the implementation of GS in the LSU rice breeding program. Although results are specific to the LSU program, our approach for establishing a workable GS-based breeding pipeline provides a practical example that may be useful to other programs.

Ricebase Update: Comparative GWAS Annotation for Gene Discovery and Marker Development

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

Ricebase, an integrative genomic database for rice, bridges the gap between the “big data” of rice genomics and the practical needs of rice breeders and researchers. There are vast rice genomic data sets and many published genotype-phenotype associations available to employ toward new genetic discovery and the development of marker assisted selection (MAS) tools. However, the volume and complexity of the data are obstacles that restrict one from making full use of these information resources. Finding and combining information from diverse sources for simultaneous evaluation is challenging because of varying data structures and a lack of a common coordinate system to facilitate comparison. Ricebase overcomes the information overload by curating and structuring information that is particularly relevant to rice breeding from multiple sources using a well-structured database schema and a common coordinate system based on the reference genome assembly.

The Ricebase interface is a web application that requires only a browser to access. The code that runs Ricebase is an adaptation of Breedbase, a plant breeding-focused platform that grew out of the Sol Genomics Network. Breedbase is intended for comprehensive breeding management and analysis. Its functions include collection and storage of phenotypic data along with corresponding experimental designs, storage of high-density genotypic information, and analysis for Genomic Selection and prediction. It supports the BrAPI standard for exchanging phenotypic and genotypic data between crop breeding applications. Breedbase has been implemented for diverse crops, including cassava, sweet potato, banana, tomato, rice and several others.

The Ricebase implementation of Breedbase focuses on connections between germplasm, genetic diversity and molecular markers that are relevant to rice improvement. Data types stored include accession records, pedigrees, phenotypes, genotypes, and molecular markers. Ricebase uses the genome browser JBrowse to display the locations of various genomic features on chromosome coordinates from the MSU7/IRGSP-1.0 assembled rice genome as zoom-able and scroll-able tracks. These browser tracks include the sequence itself, annotated genes, SNPs, SSRs, and QTLs. SSR marker positions are displayed on genome browser tracks along with combined SNPs from the 700K HDRA and 3,000 rice genome resequencing studies, providing continuity between past and current marker technologies.

Ricebase has recently been updated to present the results of recent biparental and genome-wide association (GWA) mapping studies as tracks identifying genomic regions associated with the traits. Currently, genome browser tracks are available for biparental QTL mapping of chalk and fissure resistance, and GWA-QTL mapping of salt tolerance, cold tolerance, grain quality, and yield components. Genome browser track features are clickable to bring up links to additional information about the feature, relationships to other features, and database records. For example, SSRs link to accessions that are genotyped with the SSR and their allele states, and QTLs link to literature citations and reported candidate genes.

The curated phenotype-genotype associations highlight recent U.S. focused rice research and facilitate interpretation of new mapping studies in the context of previous research and meta-analyses across studies. The combined capabilities of Ricebase linking phenotypes with genetic markers, genome context, and allele states across diverse rice germplasm serve as a community resource for genetic discovery and breeding in rice.

Prospective Genomic Regions with Superior Alleles for Seedling Stage Salt Tolerance Identified via GWAS in the USDA Rice Mini-core Collection

Rohila, J.S., Edwards, J.D., Tran, G.D., Jackson, A.K., and McClung, A.M.

Rice seedlings are sensitive to salt when the electrical conductivity (EC) of growing media reaches higher than 2.0 dS m^{-1}. Saltol, a major QTL from the rice variety Pokkali, when deployed in various mega varieties in Asia was found insufficient in providing the desired level of salt tolerance in rice seedlings. Search for novel germplasm with different salt tolerance mechanisms and identification of associated QTL/SNPs could help rice breeding programs in developing salt tolerant varieties by the gene pyramiding approach. The objectives of this study were to (i) evaluate the natural genetic variation available in 123 accessions from the USDA rice mini-core (URMC) for early vigor traits under EC 6.0 dS m^{-1} salt stress, (ii) identify genomic regions for seedling-stage salt tolerance using genome-wide association (GWAS) approach, and (iii) to compare salt tolerance levels of URMC germplasm with varieties developed from a salt-tolerance rice breeding program in Vietnam that has incorporated Saltol QTL effectively.

A total of 162 accessions representing four rice subpopulations: *tropical japonica* (TRJ), *temperate japonica* (TEJ), *indica* (IND), and *aus* (AUS) were evaluated using a hydroponic system under greenhouse conditions. The salt stress was applied at 3-4 leaf stage for 16 days and measurements were taken on eight traits at two time points 10 (d10) and 16d (d16) after treatment including: salt stress injury (SSI) score-d10, SSI score-d16, Δ plant height (PHT)-d10, Δ PHT-d16, Δ green leaf number-d14, total biomass $plant^{-1}$, shoot biomass $plant^{-1}$, and root biomass $plant^{-1}$. Six cultivars were used as salt-sensitive (IR29, Nerica 6, A69-1) and salt-tolerant (Pokkali, IR45427-2B-2-2B-1-1, IR65196-3B-5-2-2) checks. GWAS was performed utilizing 3.2 million SNPs available for the URMC accessions. SNPs were grouped into chromosomal regions by processing GWAS results with custom Perl scripts. Based on p-values and allele effects, chromosomal regions and corresponding peak SNPs that were highly predictive of SSI scores and related phenotypes were selected for detailed analysis. Allele effects, significance, and R^2 values for each of the selected SNPs were calculated separately for each subpopulation by ANOVA in JMP 14.0.0. A distribution of similar alleles among a larger panel of rice lines than the URMC alone was also determined. The allele frequency information was computed by using RiceVarMap, which contains genotype information on 4,726 rice accessions.

Among the four subpopulations in the URMC, TRJ was identified as the most sensitive, and the IND subpopulation (and two accessions in the TEJ) was the most tolerant to salt stress. Among the tested entries, 59.4% of the accessions were identified as sensitive, 23.9% were identified as moderately tolerant, and 16.7% were identified as highly tolerant. Pokkali was the most tolerant variety, while Nerica-6 was the most sensitive. Based on SSI score, plant height gains, green leaf number gains and total biomass $plant^{-1}$ after 16 days of salt stress, several accessions (e.g. 4484, A36-3, Bogarigbeli, Chin, CM1_HAIPONG, Doble Carolina, K8C-262-3, Krachek Chap, M202, SOC NAU, SORNAVARI) were identified in the URMC with comparatively high salt-tolerance. Pearson's correlation coefficient revealed that all traits were highly correlated with each other and contributed to the growth and senescence factors that influence the SSI scores. The Δ green leaf number had a strong negative correlation with SSI scores ($r = -0.86$, $p < 0.0001$) and a strong positive correlation with the other measured traits such as shoot biomass ($r = 0.71$, $p < 0.0001$) and root biomass ($r = 0.72$, $p < 0.0001$). From the GWAS analysis, nine genomic regions of interest were identified, mapped to five different chromosomes, and nine significant SNPs associated with superior alleles were identified as useful for marker-assisted-selection. None of the selected regions were found residing in the known Saltol QTL region suggesting different probable genes and mechanisms responsible for salt tolerance in the URMC. Six highly significant loci, with 16 candidate genes in their vicinity were also identified. There were several genes identified in this study that have not been implicated as having a direct role in salt tolerance but were previously shown to have broader roles in abiotic stress tolerance. These genes may serve as novel targets in improving our understanding of salt tolerance in rice at the seedling stage. Several accessions in the URMC performed better than the advanced salt tolerant varieties from Vietnam utilizing Saltol allele indicating that there is the opportunity to pyramid diverse alleles to make for further genetic gains in salt tolerance.

The Use of an Enriched-GWAS for the Refinement of a Major QTL for Anaerobic Germination Tolerance

Septiningsih, E.M., Tnani, H., Chebotarov, D., Thapa, R., Ignacio, J.C., Dixit, S., and Kretzschmar, T.

A previous attempt to fine map a QTL for tolerance of anaerobic germination (AG), *AG2* (*qAG7.1*) spanning a region of ~7 Mb around the centromeric region of chromosome 7, derived from an *indica* variety Ma-Zhan Red (MR), was halted due to poor recombination events and the unreasonable amount of time and efforts needed to develop the near isogenic lines (NILs). Taking advantage of the 3000 Rice Genomes (3K RG) project, an alternative strategy was sought to delimit the QTL region by developing an enriched GWAS panel carefully selected based on the *AG2* genotype.

A total of 16,193 SNPs identified between MR and the susceptible parent, IR42, within the AG2 region was used to select 351 accessions from the 3K RG for AG GWAS analysis. The AG2 QTL was successfully narrowed down to a ~0.7Mb region located around the Rc gene which controls red pericarp color. Transcriptomic analysis of the tolerant donor and susceptible parents helped in identifying several candidate genes potentially controlling *AG2*. This effort clearly demonstrates a novel strategy for efficient fine mapping of challenging QTL regions using an "enriched haplotype" GWAS.

Identification of a Novel Gene Controlling *Cercospora* Resistance and the Characterization of Resistance within U.S. Breeding Germplasm

Addison, C.K., Angira, B., Dartez, J., Groth, D.E., and Famoso, A.N.

Cercospora janseana is a fungal disease of rice that causes Narrow Brown Leaf Spot (NBLS). Under favorable conditions *Cercospora* can result in severe leaf necrosis, reduced yield, and a reduction in grain quality. In Louisiana, it is especially detrimental to the ratoon yield potential and crawfish production. Although *Cercospora* is a major disease in the Southern U.S., little is known about the genetic architecture of resistance in rice. In this study, a recombinant inbred line (RIL) population was scored for *Cercospora* resistance under natural disease pressure in the field across three years. A single, large effect QTL, *CRSP-2.1*, was identified that explained 81.4% of the phenotypic variation across all three years. Screening of recombinants from the RIL population delimited the QTL region to a 532kb interval on chromosome 2. A set of 13 informative SNPs was selected across this region and used to characterize the haplotype diversity across a panel of 387 U.S. rice breeding lines that were phenotyped over two years. A total of 14 haplotypes were identified, with six haplotypes accounting for 94% of the panel. The susceptible haplotype from the RIL population, Hap 1, was the only susceptible haplotype in the panel. A single SNP was identified that distinguishes the susceptible haplotype from all resistant haplotypes. This SNP explained 52.7% of the phenotypic variation for *Cercospora* resistance in the panel across two years of phenotype data. Pedigree analysis and haplotype characterization of historical germplasm demonstrated that the susceptible haplotype was introduced into Southern U.S. germplasm through the variety Cypress, which inherited the allele from the California line L-202. Cypress was extensively used as a parent over the last 25 years and the susceptible *CRSP-2.1* allele has increased from a frequency of zero to 44% in our modern breeding germplasm panel.

GWA Mapping of Cold Tolerance Traits at the Seedling Stage and Validation in Two Rice Biparental Mapping Populations

Eizenga, G.C., Shimoyama, N.S., Jackson, A.K., Edwards, J.D., Jessel, A.R., and Schlappi, M.R.

Cold stress at the seedling stage causes poor stand establishment, necrosis and injures plants. Improved seedling cold tolerance in rice (*Oryza sativa* L.) would enable earlier planting in the spring in the southern USA, thus potentially reducing the stress of summer high night time temperatures and allowing a longer season for the ratoon crop. The overall goal is to understand the basic genetic and cellular mechanisms responsible for seedling cold tolerance. The specific objective of this study was to identify seedling cold stress QTL and the underlying putative candidate gene(s) by conducting genome-wide association (GWA) mapping with two association mapping panels and QTL mapping with two biparental populations.

Previously, the USDA Rice Minicore Collection (RMC) which includes 202 diverse accessions, was evaluated for five traits designed to mimic cold stress response in the natural environment, two traits were associated with cold stress at germination and three at the seedling stage. GWA mapping was conducted with 157 markers including 148 SSR markers, three InDel markers and six SNP markers. This study uncovered 48 GWA-QTL at 39 chromosome regions distributed across all 12 rice chromosomes. Recently, 173 RMC accessions were genotyped with 3.2 million SNPs, thus the GWA mapping was conducted with this high-density genotyping and the same trait data utilizing the mixed linear model in Tassel 5. To further validate the RMC GWA-QTL, 354 accessions from the Rice Diversity Panel 1 (RDP1) were evaluated for two traits allied with seedling stage cold tolerance, Low Temperature Seedling Survivability (LTSS) and Electrolyte Leakage (EL), to identify GWA-QTL and the underlying candidate genes. For LTSS, the one week of cold stress was performed at four different temperatures (8, 10, 12 and 16^0 C) and for EL, the one week of cold stress also was performed at four temperatures (4, 10, 12 or 16° C). Using the LTSS and EL data collected across the different temperatures and the 700K SNP genotypes for the RDP1 accessions, GWA mapping was conducted with the association mapping pipeline developed for the RDP1. Perusal of the significant SNPs identified across the different temperatures for LTSS and EL uncovered 40 GWA-QTL, identified as Multiple Chilling Phenotype (MP) QTL. Six of these GWA MP-QTL, *qMP3-1*, *qMP6-2*, *qMP9-4*, *qMP10-1*, *qMP10-4* and *qMP11-2*, overlapped with previously reported RMC GWA-QTL. Database searches revealed eleven candidate genes near *MP3-1*, *MP6-2*, *MP9-4* and *MP10-4*.

To further validate these GWA-QTL, two biparental mapping populations were developed from three RMC accessions. Carolino 164, an *aus* accession, was the cold susceptible male parent, and the *temperate japonica* accessions, Krasnodarskij 3352 and Wir911 were the cold tolerant female parents of the recombinant inbred line (RIL) and backcross inbred line (BIL) populations, respectively. The parents and progeny were genotyped with 7K SNPs and phenotyped for LTSS and EL at 10° C. QTL mapping of 93 Krasnodarskij 3352/Carolino 164 F_7 RILs with QTL IciMapping identified six LTSS QTL (*qLTSS3*, *qLTSS4-1*, *qLTSS4-2*, *qLTSS6*, *qLTSS8*, *qLTSS9*) and *qEL6*. Only *qLTSS4-1* was not co-located with a previously identified GWA-QTL and candidate genes associated with various stress tolerances were found in the *qLTSS3*, *qLTSS4-2* and *qLTSS8* regions. A vacuolar H- translocating inorganic pyrophosphatase 1 gene (*OVP1*), associated with cold stress, was located in the *qEL6* region.

QTL mapping with 93 BC_1F_5 (Wir911/Carolino 164)/Carolino 164 BILs genotyped with 7K SNPs and phenotyped for LTSS and EL, identified three QTL below the permuted LOD threshold, *qLTSS1*, *qLTSS8* and *qEL8*. Only *qLTSS8* overlapped with RMC and RDP1 GWA-QTL but no relevant candidate genes were discovered.

The next steps are to validate selected candidate genes with transgenic studies, the CRISPR/Cas9 system, and/or by overexpression approaches. SNPs found to be associated with cold stress in the GWA and biparental mapping studies will be selected for marker development. Once developed and verified, these markers will be available for rice breeders to use in varietal development programs to select for improved seedling cold tolerance.

Identification of Genomic Regions Associated with Traits Directly Affecting Yield and Yield-Related Traits in Rice

Sanchez, D.L., Samonte, S.O.PB., Alpuerto, J.B.B., Holgate, L.C., Croaker, P.A., Thomson, M.J., Morales, K.Y., Yang, Y., Tabien, R.E., Wilson, L.T., Yan, Z., Christensen, E.F., Martin, L.N., Septiningsih, E.M., and Pellois, J-P.

Main culm panicle node number (MCPNN, the node number on which the panicle is borne) and maximum node production rate (MNPR) are primary phenotypic plant traits having significant positive direct effects on yield and yield-related traits in rice. Degree-days to heading (DDH) is one of the traits influenced by MCPNN and MNPR. However, genetic studies on MCPNN and MNPR are limited. The objectives of this study were to: (1) assess the phenotypic and genetic diversity for MCPNN, MNPR, and DDH in a rice diversity panel; and (2) identify genomic regions associated with each trait using genome-wide association studies (GWAS).

A total of 220 diverse rice accessions consisting of *indica* and *japonica* cultivars, landraces, inbred lines, and hybrids were grown in Texas A&M AgriLife Research Center at Beaumont in 2018 and 2019 for phenotypic characterization. Data collection consisted of observing tagged plants at weekly intervals. MCPNN was estimated as the number of leaves on the main culm plus one for its panicle. MNPR (number of leaves that emerged per degree-day > 10°C) was estimated through regression using 3rd to 7th-leaf stage data. Data on degree-days >10°C to heading were also collected. DNA extracted from leaf tissues of the 220 entries were sent to Texas A&M AgriLife Genomics and Bioinformatics

Service (TxGen) for genotyping-by-sequencing, and 854,832 single nucleotide polymorphic (SNP) markers were used in the analyses.

Wide variation was observed among the three traits. MCPNN ranged from 8.1 to 20.9 nodes in 2018 and from 9.9 to 21.0 nodes in 2019. MNPR ranged from 0.009 to 0.020 nodes/degree day > 10ºC in 2018 and from 0.009 to 0.019 nodes/degree day > 10ºC in 2019. DDH ranged from 713 to 2,345 degree days > 10ºC in 2018 and from 778 to 2,404 degree days > 10ºC in 2019.

GWAS was conducted using three models to offset false positives/negatives. Preliminary results showed that multiple SNPs were found to be associated with the three traits. Using the general linear model (GLM), significant associations ($p \leq 5.85 \times 10^{-8}$) were detected between one SNP in chromosome 5 (S05_3047747) and MNPR, and between two SNPs, located in chromosomes 1 (S01_31768182) and 10 (S10_18525393), and DDH. Understanding the genetic bases of MCPNN, MNPR and DDH is expected to increase genomic selection efficiency for improved rice grain yields.

Mapping Quantitative Trait Loci for Alkalinity Stress Tolerance in Rice

Singh, L., Bhattarai, U., Chapagain, S., Garcia, R., Concepcion, J., Pruthi, R., and Subudhi P.K.

Alkaline stress is a major abiotic stress that drastically reduces rice productivity all over the world. It is mainly caused by high concentration of $NaHCO_3$ and Na_2CO_3 in soil and water. Alkali soils cover 25% of earth's surface. Rice is very sensitive to alkaline stress at seedling stage and injury to rice plants could be more severe compared with salinity stress. Absorption of Na^+ by plants under alkalinity stress inhibits the absorption of other nutrients resulting in ionic imbalance. The tolerance mechanisms underlying alkalinity tolerance is not yet clearly elucidated. The physiological traits such as root length, shoot length, dry weight, and Na^+/K^+ in roots and shoots, are crucial for alkalinity tolerance. Therefore, elucidation of tolerance mechanisms through quantitative trait loci and candidate genes analysis for these tolerance traits will be helpful for development of alkaline tolerant cultivars.

A recombinant inbred line (RIL) population developed from a cross between Cocodrie and N22 was evaluated for alkaline tolerance at seedling stage. One hundred ninety-three RILs along with both parents were subjected to 0.15 % Na2Co3 (alkali stress) and water (control) for 7 days and observations were recorded on salt injury score (SIS) (1-9 scale), shoot length, root length, and root to shoot ratio, and chlorophyll content 5 days after transfer to water to assess alkaline tolerance. Cocodrie and N22 were scored as moderately tolerant and highly susceptible, respectively with significant different for SIS, chlorophyll content, root and shoot length and root to shoot ratio. SIS scoring was negatively correlated with chlorophyll content, shoot and root length, and root to shoot ratio. Shoot and root length were positively correlated. Further, Na^+ and K^+ concentration in roots and shoots will be evaluated by using flame photometry. Genotyping by sequencing was performed at Cornell University. Single Nucleotide Polymorphism (SNP) markers were identified by using Tassel pipeline. Linkage map construction and QTL analysis will be done in R/qtl. Candidate gene analysis will be identified within the QTL intervals by using MSU rice reference genome annotation release 7.0. Negative correlation between SIS and other traits showed that tolerant lines showed less reduction in chlorophyll content, root and shoot length, compared with moderately susceptible and susceptible lines. Identification of QTLs and candidate genes for these above traits as well as for Na^+ or K^+ content in root and shoot will help in elucidating the molecular basis of alkali tolerance.

QTL Mapping and Genomic Prediction of Seedling Root Architectural Traits in a Rice RIL Population

Sharma, S., Edwards, J.D., Gealy, D.R., and Pinson, S.R.M.

Rice root system architecture (RSA) is crucial for resource acquisition in both stress and non-stress environments. However, these traits are very difficult to phenotype. High-throughput automatic root image analysis systems can help expedite the genetic study of RSA. Greater understanding of the genetics controlling RSA and the interactions with important agronomic traits could lead to new marker assisted selection (MAS) and genomic selection (GS) tools for breeders. These tools could be especially important for difficult to phenotype traits like roots.

The objectives of this study were to (1) genotype and phenotype rice seedlings for RSA in a population derived from parents differing in root architecture, (2) to discover quantitative trait loci (QTL) for RSA traits, (3) to evaluate the accuracy of genomic prediction methods for RSA traits, and (4) to model the network of interactions among the RSA traits, RSA QTLs, and their interactions with above-ground agronomic traits.

A recombinant inbred line (RIL) population (PI312777 x Katy) was genotyped with a 7K SNP array and phenotyped for seedling RSA and agronomic traits. QTL mapping and genomic prediction were used to study variance in RSA traits evaluated on agar plates with WinRHIZO, along with their associations with agronomic traits measured in the field. The filtering of SNPs for non-redundancy and QTL mapping were performed with the inclusive composite interval mapping (ICIM) method implemented by the ICIMAPPING program. The genomic prediction methods evaluated included rrBLUP, GBLUP and BRR as implemented in the R packages rrBLUP, Sommer and BGLR respectively. QTLs for multiple quantitative traits and trait interactions were modeled using the "Bnlearn" Bayesian network analysis package in R and evaluated with k-fold validation.

Two QTLs for percent root hair surface area (of the total root surface area) were detected on chromosomes 11 and 5 explaining 33.9% of the variance. Two QTLs for root surface area were detected on chromosome 11 explaining 29.6% of the variance. One QTL for percent root hair length (of the total root length) on chromosome 5 and one QTL for number of root tips on chromosome 12 were detected explaining 34.3 and 14.9% of the variance respectively.

The genomic prediction accuracies for percent root hair surface area were 58.6, 58.3 and 58.2% and root surface area was 32.3, 27.5 and 34.1% by rrBLUP, GBLUP and BRR method respectively. The prediction accuracies for percent root hair length (of the total root length) were 59.2, 57.9 and 54.1%; and 47.3, 37.0, and 55.2% for number of root tips. Among the root and agronomic traits, we found that cross-validated genomic prediction methods had greater accuracy (explained higher proportion of genetic variance) than single or multi-QTL models. However, the identified QTL regions can be used for MAS with a small number of markers, and the QTLs may be further investigated for fine mapping and gene cloning.

Bayesian network analysis revealed multi-trait QTLs and the relationships between traits. Between the RSA traits, root length, surface area, volume and number of root tips showed significant relationships as well as root hair length, root hair surface area, and number of root hair tips. These relationships were expected because of the mathematical dependence in calculations of the RSA traits. Across RSA and agronomic traits there were significant relationships between root hair length and yield, between root tips and heading date, plant height and number of root hair tips. Some of the same RSA QTLs found by single trait ICIM were found by the Bayesian network analysis, including QTLs for percent root hair surface area on chromosome 11. The Bayesian network analysis also revealed QTLs for RSA traits that were not detected by single trait ICIM. These include a QTL on chromosome 1 for root length proximal to the *OsLax1* gene and a QTL on chromosome 4 affecting root length, root hair tips number and leaf width proximal to the *NAL1* gene. The genomic prediction accuracies for some traits, such as tiller angle and yield, were improved using the multiple-trait Bayesian network method. The fitted Bayesian network model could be further useful for predicting or imputing missing phenotypic data from related phenotypes and/or genotypes.

The results of this study reveal QTLs influencing RSA in rice and further dissect their influence into pleiotropic and direct effects on specific traits. We demonstrated the effectiveness and prediction accuracy of MAS and genomic selection for RSA traits, reducing the need for time consuming and difficult root phenotyping. Further, we showed the value of multi-trait networks incorporating RSA for prediction and in the study of complex above and below-ground phenotypic relationships.

Identification, Characterization, and SNP Marker Validation for *GS3* and a Novel Grain Shape Gene in U.S. Rice

Angira, B., Cerioli, T., Ham, J.H., and Famoso, A.

Grain size is an important breeding target in U.S. rice breeding programs and there is demand for both long and medium grain rice varieties. The genetics underlying grain shape in U.S. rice were explored through QTL mapping using IciMapping software V 4.1. A RIL population ($n = 286$) developed by crossing long grain Trenasse and medium grain Jupiter rice varieties, was used for the mapping. Two major QTLs were mapped on rice genome. First QTL *GL3.1* was mapped on chromosome 3 from 16,733,441 to 23,999,431 position and the second QTL *GL7.1* was mapped on chromosome 7 from 24,845,026 to 25,319,809 position (IRGSP V.1). GS3, a major grain size gene in U.S. rice germplasm, was identified in the *GL3.1* QTL region. Next, haplotypes were characterized for GS3 gene using IRRI 3k rice database and a high-throughput KASP marker was identified and validated in U.S. rice germplasm to be used in the rice breeding programs. Another QTL *GL7.1* was a mapped to a novel region that has not been previously reported. A high-throughput KASP marker was identified and validated for this novel QTL in U.S. rice germplasm to be used in U.S. rice breeding program.

Hybrid Rice Breeding at Texas A&M AgriLife Research - Breeding for Quality and Heterotic Groups

Samonte, S.O.P.B., Sanchez, D.L., Alpuerto, J.B.B., Holgate, L.C., Croaker, P.A., Wilson, L.T., Yan, Y., Christensen, E.F., Tabien, R.E., Harper, C.L., and Thomson, M.J.

In hybrid rice breeding, positive heteroses in grain yield and yield-related traits are desired. The development of heterotic groups or the genomic selection for genetically distant parents is an approach being studied and applied by the hybrid rice breeding project of Texas A&M AgriLife Research in order to efficiently produce hybrids that are highly heterotic in grain yield and yield-related traits. Of equal importance is high grain quality in terms of low chalky grain percentage and high total and whole milled percentages. Knowing the degree of correlation between hybrids and their parents is important in efficiently selecting and breeding for high grain quality hybrids. The objectives of these studies were (1) to determine and compare the correlations between hybrids and their parents in terms of percentages of chalky grain, and total and whole milled rice, and (2) to evaluate heteroses in grain yield and yield-related traits of hybrids produced from genomically-distant (HDP) versus -near parents (HNP) and evaluate the standard heterosis in each group of hybrids.

The grain quality and yield trial studies were conducted at the Texas A&M AgriLife Research Center at Beaumont. The grain quality study was conducted in 2018 and included 59 experimental hybrids and their 66 parental lines grown in rows. Rice samples were harvested at maturity and were evaluated for chalky grain, and total and whole milled rice percentages. The yield trial study was conducted in 2019 and included the evaluation of 14 experimental hybrids (consisting of 5 HDPs and 9 HNPs), their 21 parental lines, and check cultivar Presidio in a grain yield trial laid out in a randomized complete block design with two replications. Heterotic groups for the 21 parental lines were based on genetic distances calculated as 1 minus identity by state (IBS) similarity, and groupings were determined using the neighbor-joining method. There was a significant difference between the mean genetic distance of parents of HDPs and parents of HNPs (0.588 vs. 0.041) based on a 5% level LSD test.

Results from the grain quality study indicated that there were significant positive correlations between the hybrid and both its chalkier parent (r = 0.36**) and midparent value (r = 0.33**) in terms of chalky grain percentage. There was a negative correlation between chalky grain percentage of hybrids and whole milled rice percentage of its parents, and there was a significant positive correlation (r = 0.45**) between whole milled rice percentages of hybrids and midparent values.

Results from the yield trial indicated that the mean values for tiller density and grain yield were significantly higher in the HDP (14.3 tillers/plant and 357 g/m^2) than in the HNP (11.8 tillers/plant and 314 g/m^2) group. The parental group had significantly lower means for these traits (9.7 tillers/plant and 206 g/m^2) than both HDP and HNP groups. The HDP group had a 21 and 47% heterotic advantage in tiller density over the HNP and parental groups, respectively, and a 14 and 73% advantage in grain yield, respectively.

Genomic selection can be used as a tool to efficiently select for genetically distant parents for crossing to produce heterotic high-tillering high-yielding hybrid rice. Low-chalky rice parents must be selected to produce hybrids with low chalkiness and high whole milled rice percentages.

Development and Evaluation of Elite Germplasm for Louisiana Hybrid Rice

Gaspar, L.M., Famoso, A.N., Angira, B., and Oard, J.H.

U.S. hybrid rice acreage significantly increased since its introduction in 2000 due to higher yielding capacity compared to conventional varieties. Successful hybrid breeding relies on genetically divergent but complementing breeding populations called heterotic groups. *Indica* and *japonica* sub species of rice have been put forward by different researchers as possible heterotic groups for hybrid rice breeding. Genetic incompatibility and adaptability issues prevented the commercial exploitation of these putative heterotic groups. The goal of this study is to identify and characterize elite germplasm that will help form female and male heterotic pools for Louisiana hybrid rice.

A cluster analysis was conducted to identify subgroups of a Native Trait Panel representing the diversity of U.S. variety breeding programs. A total of 23 native traits and genome-wide SNP marker data of 400 lines from the Native Trait Panel were used in the analysis. Test cross hybrids were generated by crossing selected lines with key female lines through an isolation-free method. The response of male and female inbreds to GA3, a PGR used in hybrid seed production, was also measured. A nucleus seed increase and purification nursery was established for key female lines to improve genetic purity. Genome-wide and native trait SNP markers along with morphological traits were used to identify true-to-type plants. All traits observed in this study were recorded using an efficient data collection system composed of open-source plant breeding apps, barcode scanner, digital scale, weather resistant labels, and QR/barcode.

The result of the cluster analysis revealed four major clusters: *indica*/other long-grain breeding lines, temperate *japonica*/medium grain/CA breeding lines, AR breeding lines, and LA/TX breeding lines. Sixty lines were selected to represent the diversity and structure of the original population. No lines were selected from the temperate *japonica*/medium grain/CA cluster due to adaptability issues and requirements of LA grain quality standards. A total of 200 inter- and intra-group test cross hybrids were generated for yield testing in Summer of 2020 and for quantifying magnitude of within and between-group heterosis. GA3 application enhanced panicle exsertion, widened flag leaf angle, and increased plant height for some, but not all, hybrid combinations. Off-type plants in female seed increase nursery were identified and culled using phenotype and genotype data. Only true-to-type plants were allowed to produce seeds. Genetic purity of key female lines significantly increased after undergoing the nucleus seed increase process. The deployment of an efficient data collection system for plant height, panicle length, flag leaf angle, harvest weight, breeder's comments and other traits resulted in faster data turn-around and reduced man hours required in data gathering.

Development of Candidate Provisia® Hybrids for the Louisiana Rice Industry

Rebong, D.B., Groth, D.E., Famoso, A.N., Angira, B., and Oard, J.H.

Effective control of certain noxious weeds such as red rice presents a formidable challenge to the southern U.S. rice industry. Clearfield® rice technology was first developed in 2002 for control of red rice and other weeds leading to high adoption rates for both inbred varieties and hybrids. Natural outcrossing between Clearfield® rice and biotypes of red rice has resulted in development of weedy rice resistant to imidazolinone herbicides and subsequent reduction in effectiveness of the Clearfield® technology.

The BASF Corporation recently launched Provisia® rice as a control measure for grassy weeds and as a complement in rotation to the Clearfield® technology. The LSU AgCenter recently released Provisia® varieties PVL01 and PVL02. Rice hybrids resistant to the Provisia® herbicide would help establish effective measures for control of weedy/red rice and prolong effectiveness of the existing Clearfield® platform.

The objective of our research was to develop and evaluate hybrid rice that is resistant to the ACCase inhibitor quizalofop-p-ethyl (QPE). In 2018 and 2019, a total of 229 and 129 Provisia® experimental hybrids, respectively, were evaluated at a single location in Louisiana. Two hybrids in 2018 and 10 hybrids in 2019 trials produced a 10-50% yield advantage over the highest yielding conventional and Provisia® varieties. Height, maturity, milling yields, and percent endosperm chalk showed desirable outcomes. Results from this study suggest that potential high yielding QPE-resistant hybrids with good grain quality can be developed to complement Clearfield® rice technology for control of weedy/red rice in southern U.S. environments.

Characterization and Application of Arkansas Male Sterile Lines for Hybrid Rice Production

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

Hybrid rice production using the two-line system requires environmental genetic male-sterile (EGMS) lines which become sterile in certain environmental (photoperiod, temperature, or both) conditions. Eight EGMS lines were tested including four lines – 236s, 801s, 805s, and 811s – developed by the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (RREC) Stuttgart, Ark.; and four mutant, male-sterile lines – GSOR 1, GSOR 2, GSOR 3, and GSOR 4 – developed by the Dale Bumpers National Rice Research Center (DBNRRC-USDA-ARS) Stuttgart, Ark. This study benefits the University of Arkansas' hybrid rice breeding program by determining the environment and management needed for hybrid rice seed production in Arkansas.

The lines were screened in growth chambers using different temperatures and day lengths to identify the genetic source(s) and sterility thresholds. A two-year field test was conducted to determine an optimum planting date for sterile conditions in Arkansas. In 2017, the lines were planted during three dates at RREC. In 2018, the RREC lines were planted during three dates at RREC, Pine Tree Research Station (PTRS) Colt, Ark., and Rohwer Research Station (RRS) Rohwer, Ark. In 2018, 811s was planted using three different seed rates - 2, 4, and 8 seeds/m^2 - to determine an optimum rate for hybrid seed production.

The growth chambers results revealed that the RREC lines are TGMS. The sterility threshold for 801s, 805s, and 811s is when high temperatures >29.4˚C, and for 236s when high temperatures >32.2˚C. The GSOR lines expressed mostly pollen fertility and sterility was inconsistent, thus the source(s) of sterility and thresholds could not be determined. The two-year field study suggests that April 25th is the optimum planting date for sterile conditions in Arkansas. The seed rate study of 811s suggests that the different seed rates do not affect late, fertile tiller production, however, 4 seeds/m^2 is the best choice for hybrid seed production.

Development and Evaluation of Louisiana Clearfield® Hybrids

Mosquera, P.A, Famoso, A.N., Angira, B., and Oard, J.H.

Clearfield® rice released by LSU in 2002 was the first herbicide option with imidazolinone herbicides for control of grassy weeds such as red rice. Commercial rice varieties resistant to these inhibitors can help establish effective control measures for weedy pests such as red rice and complement the new Provisia® herbicide technology.

Commercial rice hybrids in the U.S. typically produce up to 20% more grain than the best inbred varieties grown under similar conditions. Rice is an autogamous plant, but for commercial production of hybrids a specific male sterile line must be used as a female parent. A major objective of the LSU AgCenter Hybrid Breeding Program is to develop elite Clearfield® cross combinations (hybrid varieties) with genic male sterile lines using both the two and three-line breeding methods. A specific research goal was to develop and evaluate hybrid rice that is resistant to imazethapyr, the active ingredient in Newpath® herbicide

For female line development, some 20 advanced S lines with broad spectrum of maturity, plant type, grain type, and cooking characteristics were crossed to 66 pollinators based on flower synchronization and resistance to imazethapyr. Performance of 258 experimental hybrids was evaluated in a 2019 test cross nursery at a single Louisiana location using an augmented RBCD design. Statistical analysis was carried out using the R package *Agricolae.* Two Clearfield® experimental long-grain hybrids produced over 10,800 kg/ha with a 32-38% yield advantage compared to Clearfield varieties CL111 and CL153. Both hybrids produced acceptable values for height, maturity, milling yields, and low percent endosperm chalk. Results from this study suggest that the selected male sterile lines can be used to produce imidazolinone-resistant hybrids with high yields that complement the Provisia® technology for control of grassy weeds in southern U.S. environments.

Yield, Apparent Amylose Content, Pasting Properties, Cooking Quality, and Fatty Acid Profile of High Protein Rice

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

Hundreds of millions of people around the world who depend on rice and eat it three times a day don't get enough nutrients from their food. Their access to protein is very limited by availability and cost. High-protein rice can help alleviate this worldwide problem across social, cultural, and economic issues. Following a release of the first high protein rice cultivar 'Frontière' (CV-150, PI 647794, PVP No. 201500310, and Patent No. 9,888,637 B2) with an average protein content of 10.6% (an increase of 53% from its parents' protein content), it became apparent that its high protein content has changed its cooking/baking quality. Rice is an important source of natural gluten-free food product. With this newly acquired quality traits, the high protein rice can perhaps enter into wider markets like baking industries that are previously not available.

Breeding a crop for more nutrients like protein caused yield to go down. Our goals were to recover or improve the yield while continue improving protein contents and other grain quality traits, such as apparent amylose content, pasting properties, cooking quality, and fatty acid profiles. Two promising advanced high protein lines with improved yield are in the pipeline. Data from the PY and multi-location trials will be presented. In addition, a total of 20 new lines of high-protein rice developed has their yield potential improved by 11-17% compared to the yield of the first high-protein cultivar. They have improved protein contents, ranging from 12-15% (w/w). Their amylose contents range from 20-21% and milling from 60/68% to 63/71%, with an intermediate gelatinization temperature characteristic. These lines perform consistently well when grown in various areas in Louisiana.

Cultivar Differences in Inorganic Arsenic Accumulation in the Grain as Influenced by Irrigation Management and Soil Amendments

McClung, A.M., Green, C.E., Codling, E.E., and Chaney, R.L.

Arsenic is a naturally occurring element found in the soil, however exposure to high levels can result in serious health effects in humans. Numerous reports have demonstrated that rice which is generally grown in flooded paddies where anerobic conditions in the soil can result in arsenic to be made available for plant uptake can result in high levels of arsenic in the grain. Although milling and cooking rice in excess water are methods which reduce arsenic in the grain prior to consumption, other methods which reduce the accumulation of arsenic in the grain are more desirable. Irrigation practices like alternate wetting and drying (AWD) which result in rice fields being subjected to repeated anerobic and aerobic conditions have been shown to effectively reduce arsenic uptake in rice plants. In addition, research has shown that rice cultivars differ in the amount of arsenic that is accumulated in the grain. This study was conducted to determine differences among US rice varieties for grain arsenic accumulation in response to two irrigation management systems using native soil and fields amended with monosodium methyl arsenate (MSMA), an arsenic-based broad spectrum herbicide. The study was conducted across two years at Stuttgart, AR and included 48 southern US cultivars, three commercial hybrids, and three international cultivars arranged using an RCB design with three replications. Adjacent experiments were conducted using conventional flood management and AWD on native and MSMA amended soils. Plots were evaluated for days to heading, plant height, days to maturity, grain yield, and straighthead rating (scale of 0 resistant to 8 very susceptible). Rough rice samples were dehulled and approximately 25 g of brown rice were ground to a fine powder using a UDY Cyclone Sample Mill (0.8mm mesh). A sample size of 0.7g was weighed out and mixed with 10 ml of 0.28 M HNO3; digested in a preheated DigiPrep Hotblock at 95°C for 90 minutes, filtered and brought to a 20 ml final volume with 0.28 M HNO3. Inorganic arsenic (iAs) in the extractions was measured using a modified ICP-OES hydride generation method. Initial analysis for iAs was performed only on the native soil treatment and results are reported here.

Analysis of variance performed by irrigation treatment demonstrated that the variety effect was 2 to 16 fold greater than the year x variety interaction, thus the data were pooled across years. Varieties were significantly different for all traits measured. In general, the flooded treatment as compared to the AWD resulted in plants being about 2 d earlier, 5-7 cm taller, and yields being 11-14% greater. However, the study conducted using the native soil showed no difference in iAs in brown rice between the two irrigation treatments. In addition, the range in iAs among the varieties was 2.4 fold under the flood+native soil treatments with Zao 402 having the highest (257 ppb) and Saber the lowest (108 ppb). These results were similar to the AWD+native soil treatments where there was a 1.7 fold difference in iAs with Jefferson being the lowest (122 ppb) and CL XL745 being the highest (203 ppb). Correlations between iAs with heading (r= -0.39), with height (r= 0.37) and with grain yield (r=0.50) when grown under flood+native soil conditions indicate rapidly growing varieties with high yield potential tend to accumulate greater amounts of iAs in the grain. Of the five indica cultivars included in the study, four were ranked in the top nine for mean level of iAs, regardless of irrigation treatment. However, significant variation among the cultivars indicated that varieties having both high yield and low arsenic accumulation could be identified under native soil conditions, regardless of irrigation treatment. These results demonstrate that there is significant variability among US cultivars for iAs in brown rice suggesting genetics can be used as a means to reduce grain As accumulation.

Genetic Loci and Agronomic Traits Impacting Grain-Arsenic Concentrations Revealed by GWA and Biparental QTL Analyses

Pinson, S.R.M., Edwards, J.D., Jackson, A.K., Heuschele, D.J., Barnaby, J.Y.,
Tarpley, L, Green, C.E., Codling, E.E., and Smith, A.P.

There is global concern that rice grains and foods can contain harmful amounts of arsenic (As). While U.S. rice nearly always meets the CODEX limit of 0.2 ppm inorganic As (iAs) in milled rice, not all US rice meets the more stringent limit of 0.1 ppm iAs for baby food products. We conducted a series of studies to identify rice genes and physiological factors that can be used to develop rice varieties with lower grain-As. Arsenic is also toxic to plants, with rice straighthead disease being associated with As-toxicity. Known variance in straighthead resistance suggests that plants have evolved mechanisms that reduce As toxicity, possibly via regulation of As uptake, transport, sequestration/detoxification or a combination of all three. Because these mechanisms could also be contributing to the wide (200-fold) differences in grain-As observed among diverse rice accessions, we considered associations between grain-As, days to heading (DHD), and straighthead resistance in our gene identification studies.

During the initial study of 1,763 widely diverse rice accessions (the USDA Rice Core), association between late heading and increased grain-As was observed in rice produced in flooded paddies, but not when the same rice accessions were grown unflooded. This observation is consistent with the redox conditions in flooded paddies converting soil iAs from arsenate into the more bioavailable form of arsenite. Flooding also encourages growth of anaerobic bacteria that scavenge oxygen from soil minerals, thereby releasing mineral-bound As. Bacteria can also synthesize and release organic As compounds (e.g., DMA). Producing rice without a flood for all or part of the season can reduce grain-As up to 10-fold. Early maturity could also reduce grain-As concentrations.

From the USDA Rice Core, eight accessions with higher than average grain-As concentrations (a.k.a. "grain-As Accumulators") plus eight accessions with low grain-As (a.k.a. "Excluders") were selected for further study, including 'Lemont' and 'Jefferson' as Excluders. All of the Accumulators proved highly susceptible to straighthead, while most but not all Excluders were resistant, suggesting that some mechanisms that reduce grain-As also impart straighthead resistance. When the Accumulators and Excluders were compared for As concentration and metabolism in leaves and roots under field and hydroponic conditions, data indicated that reduced grain-As concentrations were not due to reduced root uptake or root-to-shoot transfer rates, but were associated with more efficient sequestration of As in leaves, a process that involves chelation with multiple sulfur (S) molecules per As molecule. While this suggested that increased S in plants might decrease grain-As by increasing As-sequestration, a follow-on study showed that foliar application of S-fertilizer increased grain-S but did not reduce grain-As or straighthead severity.

Linkage between grain-As and SSRs among F_2 progeny from four Excluder × Accumulator biparental crosses indicated QTLs on chromosomes 8, 10 and 11 whose effects on grain-As were not due to DHD. QTLs were also mapped in the USDA Rice Minicore population using high resolution genome wide association studies (GWAS). Phenotypic data for 16 grain elements and hull-Si came from previous studies, and resistance to MSMA-induced straighthead disease was rated in 2015 and 2016, two replications/year. Since reduced As uptake or enhanced As detoxification and sequestration would be expected to reduce both grain-As and straighthead, we anticipated finding some straighthead QTLs co-located with grain-As QTLs. Arsenic enters roots through phosphorus (P) and silica (Si) transporters, and As-detoxification involves S. Therefore, overlap with grain-P, grain-S, or hull-Si QTLs would provide additional knowledge on the mechanisms underlying grain-As and straighthead QTLs. While GWAS indicated multiple QTLs (from 3 to 21) for each of these traits, there was little co-location of QTLs among the traits. Of the four QTLs most strongly associated with straighthead, none were also associated with grain-As, grain-P or hull-Si. One straighthead QTL on chromosome 3 was associated with grain-As under both flooded and unflooded conditions, but not associated with hull-Si or grain-P, suggesting that this locus affects As detoxification, not uptake. It was not, however, associated with grain-S. The chromosome 10 grain-As QTL identified from biparental mapping was again associated with grain-As under flooded conditions, but not unflooded, among the Minicore, and was associated with straighthead and hull-Si; furthermore it coincides with the *Lsi3* Si-transporter gene. Prior GWAS in the Minicore, using lower marker density, detected a hull-Si QTL on chromosome 2, and suggested the candidate gene *Lsi1*, which is known to affect root uptake and efflux of Si and As. High-density GWAS identified co-located hull-Si, grain-As, and straighthead QTLs in a region near (9 Mb proximal) but not encompassing the *Lsi1* gene, suggesting a different underlying gene. The combination of GWAS and biparental mapping has been effective for validation and genetic dissection of pleiotropic effects and physical clustering at complex As-QTLs.

Genomic Association Study of Protein Concentration in Milled Rice

Alpuerto, J.B.B., Samonte, S.O.P.B., Sanchez, D.L., Holgate, L.C., Croaker, P.A., Wilson, L.T., Martin, L.N., Christensen, E.F., Tabien, R.E., Yan, Z., Harper, C.L., and Thomson, M.J.

Increased nutritional value of staple crops is considered one of the major crop improvement objectives worldwide. Milling, cooking, and eating qualities of rice are affected by several factors, one of which is grain protein concentration. Reports have shown a negative correlation between high grain protein concentration and head rice percentage similar with cooking and eating quality. However, elevated grain protein concentration leading to better nutritional value can increase consumer preference for rice.

This study aimed to 1) evaluate phenotypic and genotypic variations for protein concentration in milled rice and 2) identify genomic regions associated with these variations. A rice diversity panel of 217 accessions compiled at the Texas A&M AgriLife Research Center at Beaumont was used in a genome-wide association study (GWAS) conducted in 2018 and 2019. Milled rice samples of all accessions were evaluated for grain quality traits, including protein concentration estimated using Dumas method. Leaves from each accession were sent to the Texas A&M AgriLife Genomics and Bioinformatics Service in College Station for genotyping-by-sequencing and a total of 854,832 single nucleotide polymorphisms (SNP) markers were selected for further analyses.

Results showed wide variation in milled rice protein concentrations among accessions with a range of 4.6 to 10.3% and a mean of 6.9%. GWAS general linear model ($p \leq 5.85 \times 10^{-8}$) resulted in the identification of two SNPs significantly associated with grain protein concentration located in close proximity to each other in chromosome 7. Validation of these SNPs is necessary to confirm if these are in the same region containing previously reported candidate genes. Currently, the second year of phenotypic and genotypic analysis for the same trait is being finalized. Moreover, validation and/or identification of new candidate genes associated with protein concentration in milled rice are in the analysis pipeline.

The results of this study will provide valuable information that aid in the enhancement of breeding selection and cultivar development of our hybrid rice breeding program. Our overarching objective is to find associations between genomic regions and grain quality, including yield-related traits followed by mining for candidate genes correlated to these regions.

Will the Rice Genotype-specific Screening Tools Developed in the Current Environment be Suitable for Present and Future Climates?

Reddy, K.R, Walne, C.H., Jumaa, H., Kakar, N., and Redoña, E.D.

Crops grown either in the current and future climates will be subjected to a variety of abiotic stress conditions such as higher temperatures and ultraviolet-B radiation and intensities of salt and drought stress conditions. The major difference between the current and projected climates will be the changes in atmospheric carbon dioxide levels. In this study, we tested the hypothesis that elevated CO_2 will modify the stress responses to abiotic stresses, and therefore, the screening methods in current climatic conditions will be obsolete in the future elevated CO_2-grown plants. An experiment was conducted in sunlit plant growth chambers to characterize early-season morphology and physiology of 14 Indica and Japonica lines, hybrids, and cultivars. All rice genotypes were at optimum conditions, 30/22°C, zero UV-B, and salt stress with optimum water and nutrient condition either in current (420 ppm) or future CO_2 (720 ppm) levels. Then, various abiotic stress conditions such high temperature (38/30°), elevated UV-B (10 kJ m^{-2} d^{-1}), and increased salt stress (electrical conductivity, 10 dS m^{-1}) and reduced water (50% of the control) were imposed at ambient and elevated CO_2–grown plants 13 days after sowing. Several morphological parameters, including root traits, were measured at harvest, 41 d after sowing. Significant stress × genotype interactions were found for most of the parameters measured both at ambient- and elevated-CO_2-grown stress treatments. Elevated CO_2 enhanced all growth and developmental parameters in all rice lines. A genotype-specific cumulative stress response index (CSRI) was derived as a ratio of treatment values to control for each trait at ambient and elevated CO_2 conditions under each abiotic conditions. Then, regression analysis was performed between ambient and elevated CO_2-grown CSRIs. A significant ($P<0.0001$) and positive linear correlation ($R^2=0.75$) showed the stress response indices relative to the respective controls in the current and future climatic conditions were not modified. The results show that the genotype-specific screening tools used in the current environments for multiple stress conditions will also be suited for future elevated CO_2-environments.

Performance of Popular Arkansas Rice Varieties under High Night Temperature Treated at R2 and R5 Reproductive Stages

Esguerra, M.Q., Hemphill, C.C., and Counce, P.A.

High night temperature (HNT) has been reported to cause significant yield and quality reductions in rice. Although, varieties have been screened in the past, HNT performance of recently released varieties of Arkansas is yet to be determined, hence, this study. In addition, this experiment also intends to validate the HNT susceptibility and tolerance of reported varieties and identify the most sensitive reproductive stages for HNT yield and quality. Two recently released Arkansas varieties: Diamond (high-yielding, long grain) and Titan (high-yielding, medium grain) together with four other varieties: Jupiter (popular medium grain), N22 (HNT tolerant check), Zhe 733 (susceptible check) and Kaybonnet (long-grain, reportedly HNT tolerant check) were subjected to (1) HNT (28 °C) and (2) Control (23 °C) night temperature treatments using large walk-in, growth chambers. Critical reproductive stages under HNT was identified by conducting two experiments: (1) commenced at the at the R2 growth stage (flag-leaf collar formation); and a second experiment (2) commenced at the R5 stage (elongation of at least one grain on the panicle). Plants were grown under the same conditions in the greenhouse and transferred to the growth chamber when the plants reached R2 for the first experiment and R5 for the second experiment. Experimental units were tubs containing 35 individual plants. The size of the plots allowed standard milling procedures to be used including grain quantity, precision drying and McGill No. 2 milling. There were three replications per variety arranged as randomized complete blocks in both the HNT and control chambers. Parameters investigated included grain yield, 100 seed-weight, spikelet fertility, pollen fertility, head rice yield, seed length, seed width, seed thickness and chalkiness. Only the R2 experiments have been completed at the time of writing this abstract and the complete set of responses for the experiments are still being determined. Initial results for the R2 experiment, however, showed Diamond, Kaybonnet and ZHE 733 to have reduced spikelet fertility (filled grains/total grains) in response to HNT. Also in the R2 experiment, Jupiter, N22 and Titan had very low or no reduction in spikelet fertility. Reductions in spikelet fertility lead to similar dramatic yield reductions. Results of these experiments will be beneficial for the conduct of screening procedures for HNT tolerance in rice as well as the development of mapping populations for marker discovery, and will ultimately assist breeders in developing lines/varieties with both higher yield and better quality under HNT conditions.

Pyramiding of Seed Dormancy and Longevity Genes to Improve Resistance to Pre-harvest Sprouting and Germinability of Rice

Gu, X.-Y., Wang, J., Korkmaz, U., Charif, A., and Guo, M.

Incorporation of seed dormancy (SD) and longevity (SL) genes into varieties, including hybrid parents, can improve their resistance to pre-harvest sprouting and germinability of hybrid seeds, provided that the selected genes have little negative impact on agronomic traits and practices. In the previous research, allelic variants at the quantitative trait loci *SD1-2*, *8* and *10* from weedy and cultivated rice (*Oryza sativa*) were isolated as single Mendelian factors. This research aimed to address genetic issues (e.g., epistasis, linkage drag or association) likely encountered in a gene pyramiding project. *qSD1-2* is identical to *semidwarf1* (*sd1*), with the dormancy-enhancing allele reducing plant height (PH). *qSD8* tightly links to the awn length locus *AL8*, with the dormancy-enhancing allele increasing percentage of awned seeds. *SD10* was collocated with *FT10* for flowering time (FT), with the dormancy-enhancing allele promoting flowering. The functionally differentiated alleles from individual loci were assembled into digenic systems segregating for *qSD1-2* and *8* or *qSD1-2* and *10* in a genetic background fixed for *SL9*, a major gene for seed aging tolerance. *SD1-2*, *8* and *10* all had significant effects on FT, PH, and SD in the digenic systems. The time to flowering was correlated positively with germinability and negatively with PH in the *qSD1-2* and *8* system, or negatively with germinability and positively with PH in the *qSD1-2* and *8* system. Genotypic variance for each of the traits was partitioned into the additive (*a*), dominance (*d*) and epistatic ('*i*'s) components. Epistatic effect on SD was detected in the *SD1-2* and *10* system ($i_{a1\text{-}2a10}$), but not in the *SD1-2* and *8* system. This research demonstrated that pyramiding SD genes could cause a linear or non-linear increase in primary dormancy and genetic improvement of semidwarf cultivars (*sd1*) for the PHS resistance involves selections for such agronomic traits as PH and FT.

Progress in Development of Salt-Tolerant Rice Varieties

Subudhi, P.K., Famoso, A., Chapagain, S., Garcia, R., Coronejo, S., Concepcion, J., Singh, L., De Leon, T., Rao, V.R., and Ontoy, J.

Salinity is a major abiotic constraint that threatens global food security. Rice is a major food crop for more than half of the world's population. Since rice is highly sensitive to salinity at both seedling and reproductive stages, development of salt-tolerant varieties is necessary to continue rice farming in salt affected areas. The major bottleneck is the narrow genetic base of U.S. germplasm. However, abundant natural genetic variation existing in the world rice germplasm provides us opportunity for making progress on this front. Numerous studies reported identification and utilization of QTLs for salt tolerance to accelerate the breeding efforts. We report here the progress made in both basic and applied research at the Louisiana State University Agricultural Center towards the development of rice varieties with enhanced salt tolerance.

Several mapping populations were developed from crosses involving known salt-tolerant donors, and cultivars adapted to the southern rice growing regions of the USA. Evaluation of these populations was done for salinity tolerance at both seedling and reproductive stages in greenhouse experiments. Genotyping was done by both simple sequence repeat (SSR) and genotyping by sequencing based SNP markers. Apart from mapping of QTLs for salt tolerance attributes in multiple mapping populations, several QTLs were validated using introgression lines.

Using several exotic salt tolerant donor, we successfully developed salt tolerant breeding lines, which are now being evaluated for agronomic traits including yield in replicated field trials. The QTLs for seedling stage and reproductive stage tolerance have been mapped in four and two mapping populations, respectively. Since the level of salt tolerance needs further improvement, we are now pyramiding the superior alleles of the QTLs/genes from multiple donors. To accomplish this goal, we are making crosses between salt tolerant introgression lines carrying the salt tolerant QTLs to introgress multiple QTLs to several high yielding U.S. varieties. Several mini-multi-parent advanced generation inter-cross populations were also developed to accumulate superior alleles from multiple donors. Our preliminary evaluation indicated that some selected breeding lines showed salt tolerance even better than the donor lines. While advancing these populations, plants with desirable agronomic traits are selected for multiplication and salinity screening. 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.

Abstracts of Posters on Breeding, Genetics, and Genomics
Panel Chair: Ed Redona

Characterization of Latin American Quality Parameters

Guerra, R.A., Angira, B., and Famoso, A.N.

Louisiana´s most important export rice markets are Mexico and Central America, and demand should be increasing given the Dominican Republic-Central American Free Trade Agreement. Instead, demand has been stagnant since 2010, even decreasing as much as 46% per year in the case of Nicaragua. This is largely due to shifting consumer preference and competition from South American exporting countries.

The objective of this project is to facilitate the identification and development of U.S. rice varieties that meet the quality expectations for the Latin American market, to be grown in the U.S. and exported to these markets. This project will collaborate with members of U.S. and Latin American rice industries to create a consensus of the desired grain quality parameters for US rice being exported to Latin America. Single nucleotide polymorphism (SNP) markers will be developed and validated across breeding germplasm for use in selection of key traits, such as amylose, gelatinization temperature, gel consistency, whiteness, and chalk.

The most popular varieties from Latin America will be evaluated for key grain quality parameters following the American Association of Clinical Chemistry's (AACC) method for the determination of pasting properties of rice with the Rapid-Visco Analyzer, 61-02.01. By creating a quality profile for all the quality parameters, the project will identify which common properties the "high quality" Latin American varieties share and define clear breeding targets and minimum thresholds for acceptability. The project will explore, develop, and validate KASP SNP markers for traits that are directly relevant for breeding high-quality varieties for export markets in Latin America.

Chalky and Whole Milled Grains in Rice Cultivars Harvested at Different Moisture Concentrations

Samonte, S.O.P.B., Sanchez, D.L., Alpuerto, J.B.B., Holgate, L.C., and Croaker, P.A.

Chalky and whole milled rice percentages are used to evaluate a rice cultivar, crop, and its management. Rice crop surveys may report annual cultivar acreage, grain yield, and whole milled rice percentage, but do not include chalky rice percentage data. Knowledge of how a rice cultivar's whole milled and chalky grain percentages change as it dries down during and after maturity is essential in breeding for high-quality cultivars and in planning harvests at the proper moisture concentration (MC). Recently, low-chalky grain percentage has been gaining importance as a targeted grain quality trait in addition to high whole milled rice percentage. The objective of this study was to determine the effects of harvest MC on whole milled and chalky grain percentages of rice cultivars.

Five rice cultivars (Antonio, Cheniere, Cocodrie, Colorado, and Presidio) were planted in 4-replication field experiments at the Texas A&M AgriLife Research Center at Beaumont in 2018 and 2019. Grain samples were harvested from each plot on two dates - at maturity and one week after maturity. Percentages of whole milled rice and chalky grain (using the S21 grain analyzer) were estimated.

Since harvest MCs across rice samples varied from 16.7 to 24.8% in 2018 and from 18.0 to 24.4% in 2019, linear regression was used to estimate whole milled rice percentages at 20% MC, which were 60.4, 62.4, 63.0, 52.2, and 60.4% for Antonio, Cheniere, Cocodrie, Colorado, and Presidio, respectively in 2018, and 55.6, 57.0, 60.1, 56.4, and 58.2%, respectively, in 2019.

Chalky grain percentages at 20% harvest MC that were estimated using linear regression for Antonio, Cheniere, Cocodrie, Colorado, and Presidio in 2018 were 8.1, 1.8, 7.0, 7.8, and 1.4%, respectively, and in 2019 were 4.0, 1.0, 2.4, 1.5, and 0.7%, respectively. In contrast, estimates for chalky grain percentages at harvest MC of 23% were generally lower at 5.9, 0.7, 5.4, 5.8, and 1.5%, respectively in 2018, and 4.0, 0.6, 2.1, 0.7, and 0.7%, respectively, in 2019.

This 2-year study suggests that harvesting at 23% has the potential of resulting in a rice crop with better grain quality in terms of lower chalky grain percentage. Scattergraphs of percentages of whole milled rice and chalky grain of the five cultivars at different harvest MCs will be presented in the poster for the 2020 RTWG Meeting.

Variation in Grain Quality of Top, Middle, and Bottom Portions of Panicles in Chalky and "Chalkyless" Rice Cultivars

Samonte, S.O.P.B., Alpuerto, J.B.B., Sanchez, D.L., Holgate, L.C., and Croaker, P.A.

Grain quality is a major factor affecting the commercial adoption and production longevity of rice cultivars. Existing variation among grains within a panicle may be due to their differences in dates of flowering and carbohydrate stress levels during grain filling. The objective of this study was to evaluate the variation in grain dimensions and percentages of milled and chalky grain in top, middle, and bottom panicle portions of chalky and "chalkyless" (low chalkiness) rice cultivars.

Two chalky (Leah and LaGrue) and two "chalkyless" (Presidio and Kaybonnet) rice cultivars were grown and evaluated in a randomized complete block designed field experiment with three replications at the Texas A&M AgriLife Research Center at Beaumont in 2019. Panicles were picked from plots at 30 days after heading, and each panicle was partitioned into top, middle, and bottom portions based on each panicle's number of primary rachis (branches). The partitioned rice samples were estimated for grain length and width, and percentages of chalky, total milled, and whole milled rice.

Total milled rice percentages were not significantly different among the four cultivars, which ranged from 68.1 (Leah) to 70.1% (LaGrue), nor among the three panicle portions, which ranged from 68.1 (bottom) to 70.1% (top). With regards to whole milled rice percentages, Presidio (62.0%) and Kaybonnet (61.8%) had significantly higher values than the other cultivars. There were no significant differences among panicle portions, which ranged from 51.2 (middle) to 53.3% (bottom).

Whole milled grain length and width were significantly affected by cultivar and panicle portion. Leah (6.4 mm) was significantly longer than Presidio and LaGrue (both 6.1 mm), which were significantly longer than Kaybonnet (6.0 mm). There were significant differences in grain width between all cultivars, which ranged from 1.83 (Kaybonnet) to 2.06 mm (Leah). Mean grain length of the bottom panicle portion (6.1 mm) was significantly shorter than that of the top portion (6.3 mm). Mean grain width significantly differed among the bottom panicle portion (1.90 mm), middle (1.92 mm), and top (1.96 mm) panicle portions. Whole milled grain length/width ratios were not significantly different among panicle portions.

Cultivar was the only factor significantly affecting chalky grain percentages, with estimated values of LaGrue, Leah, Presidio, and Kaybonnet being 20.9, 7.6, 3.0, and 2.6%, respectively. Although not significantly different, the middle panicle portion (10.2%) had more chalky grain than the top (8.5%) and bottom (7.1%) portions. Cultivar significantly affected chalky area percentage, which ranged from 14.0% (Kaybonnet) to 34.8% (LaGrue). Although not significant, chalky area percentage ranged from 20.4% (bottom panicle portion) to 23.3% (middle portion).

In summary, rice grains in the bottom panicle portion were significantly shorter and narrower than those in the top portion. In addition, there was a trend for the middle panicle portion to have higher chalky grain percentage. Minimizing the reduction in grain size or the increase in chalkiness in certain panicle portions may improve overall rice grain quality.

Characterization of Epicuticular Wax-Deficient Mutants of Rice

Tai, T.H., Butterfield, T.S., and Kim, H.

Epicuticular waxes form the outermost protective barrier of the aerial surfaces of land plants and work in concert with other components of the plant cuticle to prevent uncontrolled loss of water and provide protection against an array of external environmental stresses. Approximately 4,750 M2 families, derived from chemical mutagenesis of seeds of the variety Sabine were screened for adhesion of water droplets to leaves resulting in a wet leaf/glossy (wlg) phenotype. Sixteen independently derived mutants with altered water adhesion were identified. All mutants with the exception of SAB-1558 exhibited the wlg phenotype due to coalescence of water droplets. The SAB-1558 mutant exhibited a distinct phenotype characterized by the adherence of small, discrete water droplets. An additional wlg mutant was identified in the mutant line KDS-2249D, which is derived from the variety Kitaake. Preliminary genetic analysis has revealed that at least five of the 17 mutants result from single gene recessive mutations. Targeted exon capture and sequencing identified a nonsense mutation in the OsGL1-1 gene in KDS-2249D. SEM analysis has confirmed the association of the wlg phenotype with a deficiency in epicuticular wax crystals. In contrast, the SAB-1558 mutant appears to have larger epicuticular wax crystals than wild-type Sabine but these crystals also appear to be at a much lower density. Progress towards identification of the underlying mutations, determination of wax composition and quantification using GC/MS analysis, and phenotypic evaluation of the effects of the cuticular wax deficiencies of these mutants on stress tolerance will be presented.

Identification and Characterization of Rice Mutants Altered in Uptake of Metalloid Elements

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

Using reverse and forward genetics approaches, the uptake and accumulation of the metalloid elements silicon (Si), arsenic (As) and germanium (Ge) in rice (*Oryza sativa* L.) was examined. Novel mutations in rice genes involved in Si and As transport (*Lsi1*, *Lsi2*) and vacuolar sequestration of As (*OsABCC1*) were identified using TILLING by sequencing. A population of chemically induced mutants (n = 2048) was screened resulting in the detection of 61 putative mutations. Following removal of mutations predicted to be synonymous or residing in introns, Sanger sequencing confirmed 21 nonsynonymous mutations and 13 M3 lines harboring homozygous mutations (three *lsi1*, nine *lsi2*, and one *Osabcc1*) were identified for phenotypic evaluation. Altered sensitivity to germanium (Ge), a phytotoxic analog of Si, was observed in three lines. NM- E1746 and NM-3403 (both *lsi1*) had increased tolerance whereas NM-3036 (*lsi2*) was more sensitive, however, this appears unrelated to the mutation. Analysis of the straw from field grown plants revealed that NM-E1746 and NM-3403 were the only lines with significant reductions in total Si. Both mutants also had significant increases in total As and NM-3403 exhibited higher grain total As. The third *lsi1* mutant (NM-3380) and two *lsi2* mutants (NM-2902 and NM- 2249) had increased straw total As. Increased grain total As was observed in NM-2902, NM-2249, and a third *lsi2* mutant NM-E2244. Interestingly, NM-4903 (Osabcc1) had the highest total *Si* and was also the only line to have significantly less straw and grain total As. Confirmation of these results from a second year of field grown plants is underway.

In Si accumulators like rice, low concentrations of Ge (μM) can result in toxicity which manifests itself in the form of necrotic lesions, leading to chlorosis and possibly mortality. This attribute of Ge was employed by researchers in Japan to identify rice mutants defective in Si uptake and the subsequent cloning of the first Si transporters in plants. In this study, a population of mutants in the temperate *japonica* cultivar Kitaake (n = 855) was subjected to Ge screening to identify rice mutants with altered response phenotypes. Six mutant lines were isolated, four of which were more tolerant and two that were more sensitive to Ge than wild-type Kitaake. The mutant line KDS-557B was found to be hypersensitive to Ge, exhibiting a more rapid development of necrotic lesions even at 5 μM GeO_2, a 10-fold lower concentration than used for screening. A single gene recessive mutation model was supported by genetic analysis of mapping populations derived from crosses of KDS-557B with the cultivars Kitaake ($\chi 2 = 2.63$, df = 1, P = 0.105, not significant at $P \leq 0.01$) and Sabine ($\chi 2 = 0.04$, df = 1, P = 0.841, not significant at $P \leq 0.01$).

The novel mutant alleles identified by TILLING of known uptake and accumulation genes and the altered Ge-response mutants identified by forward screening represent useful resources for understanding the interaction of metalloid elements and plants in the environment.

Identification and Characterization of Rice Mutants with Altered Alkali Digestion Trait

Tai, T.H., Kim, H., and Imatong, R.V.B.

The gelatinization temperature (GT) of rice is the critical temperature at which about 90% of rice starch gelatinizes or transforms from a semicrystalline structure to a gel-like, edible form. GT is an important component of eating and cooking quality (ECQ) of rice. As direct measurement of GT is cumbersome, the alkali spreading value (ASV) test is a robust method commonly used to rapidly identify different GT types. In this study, we employed a modified ASV assay to screen a population of chemically-induced rice mutants in the variety Kitaake (n = 405). Two mutant families, KDS-1623B and KDS-1824B, with significantly lower ASV (higher GT type) than wild-type Kitaake (low GT type) were isolated. A nonsynonymous homozygous mutation in the isoamylase-type starch debranching enzyme gene *ISA1* was identified in KDS-1623B. The mutation (G2709T) is predicted to change a valine at position 354 to a leucine in the α-amylase catalytic domain of ISA1. This result is consistent with the shrunken endosperm exhibited by KDS-1623B grains and the replacement of starch with phytoglycogen in *isa1* (*sugary-1*) mutants. The altered ASV trait in KDS-1824B appears to be controlled by a single recessive mutation, however the causal genetic lesion remains to be determined. These mutants will be useful resources for elucidating the complex nature of starch metabolism and its influence on ECQ of rice.

Genetic Mapping and Characterization of Awns in a Segregating Population of Rice

Borjas, A.H., Famoso, A.N., Angira, B., Oard, J.H., and Mosquera, P.A.

A bristle-like appendage (awn) found on spikelets of different grass species is considered one of the most important domestication traits in rice. Because presence of awns is considered undesirable for harvest and milling purposes, the genetic basis for this trait has been studied in detail. Several QTLs associated with presence or length of awns in rice have been identified using different mapping populations developed from crosses between wild and cultivated rice. A major effect QTL (*Awn3-1*) has been reported on chromosome 3 at 17.4 Mbp when using a BC_4F_2 population derived from a cross between long-awn SLG (*japonica*) and awnless Nipponbare (*japonica*). In addition, two major genes *An-1* and *LABA1*, involved in formation of awn primordia and awn elongation, have been cloned on chromosome 4.

The main objective of our research was to identify quantitative trait loci (QTL) associated with presence and length of awns in a segregating population developed from a cross between Louisiana variety Cypress and a Provisia™ breeding line. The initial population consisted of 300 F_2 individuals grown under greenhouse conditions during the summer of 2018. One panicle from each plant was collected to determine presence and length of awns at seed maturity. One leaf was collected from each individual at the seedling stage to extract DNA and genotype 118 SNP markers evenly distributed across the genome. Due to marker segregation and level of polymorphism, the final analysis consisted of 192 F_2 individuals and 63 polymorphic markers.

Single marker analysis to detect main effect QTL was performed to establish associations between markers and phenotype. A one-way ANOVA identified 24 QTL over nine chromosomes for presence of awns. The number of QTL per chromosome varied from one to twelve with phenotypic variation of each QTL ranging from 3% to 37%. A large proportion of the QTL detected (50%) was clustered on chromosome 3, including four large-effect QTL each explaining >10% of total phenotypic variation. The QTL with the highest R^2 of 37% on chromosome 3 at 6.3 Mbp was located ~11.1 Mbp from *Awn3-1* reported by Yao *et al*. In our study the new QTL detected for presence of awns on chromosome 3 was also associated with awn length having an R^2 of 33%. Results from this study suggest that chromosome 3 is a hot spot for genes that play a role in presence and length of awns in Louisiana rice. Further field research is needed to evaluate the consistency and stability of the QTLs found in our study with additional populations and lines.

RNA-Seq Reveals Differential Expressed Genes in Two Rice Genotypes with Contrasting Response to Nitrogen Stress

Garcia, R., Coronejo, S., Tapia, R., and Subudhi, P.K.

Nitrogen (N) is the major nutrient used to enhance crop production. But indiscriminate use of N-fertilizers to boost productivity in rice and other crops causes serious environmental and health concerns due to air and water contamination. Since rice is a major field crop grown all over the world, enhancing its ability to utilize nitrogen efficiently will positively impact the global food security and environmental sustainability. A thorough understanding of the genetic basis of nitrogen use efficiency (NUE) using the available germplasm resource would facilitate development of rice varieties which will maintain high yield potential with reduced application of N-fertilizers.

A set of *japonica* and *indica* rice genotypes were screened for NUE using chlorate-uptake and response to nitrogen-stress as criteria. Based on the measurements of chlorophyll content, shoot length, root length, and biomass, 'Pokkali' was selected due to its positive response to nitrogen stress. On the contrary, the US cultivar 'Bengal' was least responsive to N stress. To further understand the genetics of nitrogen uptake, both 'Pokkali' and 'Bengal' were grown in a hydroponic experiment under full nitrogen (control) and low nitrogen (Nitrogen stress) condition. Root tissues of both genotypes were collected from control and N stress treatments. RNA-seq analyses revealed differences in expression profiles of 'Pokkali' compared with 'Bengal' under nitrogen stress. There were 215 differentially expressed (DE) genes which comprised of 84% up-regulated and 16% down-regulated genes. From these set of differentially expressed genes, few transcription factors and transporter genes affected by nitrogen stress were validated in qRT-PCR. Genes showing response under nitrogen stress can be exploited in breeding program to develop rice cultivars with improved NUE.

Characterization and Identification of Salt-Tolerant Breeding Lines from Several Mini MAGIC Populations in Rice

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

Soil salinity is one of the major abiotic stresses affecting rice production globally, especially in the coastal areas. Seedling stage salinity tolerance is crucial for better crop establishment in rice. Therefore, development of salt tolerant varieties is the most logical approach to increase rice productivity in saline prone area.

Multi-parental advanced generation intercross (MAGIC) is a recently developed tool to accumulate desirable alleles from multiple parents to improve yield and abiotic stress tolerance in crop plants. In this present study, we developed mini-MAGIC lines in the background of US rice cultivar using multiple salt tolerant donors in various cross combinations and evaluated seedling stage salinity tolerance in both sand culture and hydroponics.

Two different BC_3F_3 populations (Mermentau/Hasawi//Mermentau/Pokkali and Hasawi/Cheneire//FL478/Dular/// Jupiter) were selected for this study. Among them, 27% and 52% of breeding lines were highly tolerant, respectively. Significant differences were observed among parents and breeding lines for all morphological traits such as root length, shoot length, dry weight, root-shoot ratio, and chlorophyll content. Correlation analysis revealed that chlorophyll content was significantly decreased with increased susceptibility level. Moreover, selected tolerance lines showed no significant difference in terms of salt injury score with donors under hydroponics screening at 12 dS/m salt stress, indicating enhanced salt tolerance level in selected lines. Significantly negative correlation was observed in shoot length and shoot-root ratio with increasing susceptibility in Cheniere/FL478//Chenier/Dular///Jupiter population at 12 dS/m salt stress after 7 days under hydroponics. These results suggested that different tolerance mechanisms may be involved in different crosses due to use of different donors. We will measure Na^+ and $K^{+.}$ from both stressed and control plants to confirm the level of tolerance in selected lines and to understand tolerance mechanisms. These selected advanced breeding lines could be used for identification of superior salt tolerant alleles that can be used for rice improvement program to develop climate resilient rice varieties.

Sensitivity among Iraqi Rice Varieties to High Night Temperature

Mohammed, A.R, Alawadi, H., Harper, C., Tabien, R., and Tarpley, L.

The impact of climatic change on crop production is a major global concern. One of the climatic factors, night temperature (NT), which is increasing as a part of global warming, can alter crop productivity and quality. Previous research has shown that rice yields are decreased due to high night temperature (HNT). Heat stress can decrease spikelet fertility of rice with a subsequent reduction in seed-set and grain yield and can increase grain chalkiness. There is a strong negative linear relationship between number of fertile spikelets per m^2 and the increase in NT and a strong relationship of NT with grain chalkiness.

Many Iraqi rice varieties are native to hot nighttime conditions. The yield of the Iraqi rice varieties used in this study vary from low to high. The objective of this study was to screen 15 varieties (Amber43, Ambercoar, Amber type, Amber33 type, Anber 33-Iraqi, Choul, Ghraiba, Halwa gose, Nayima45, Nema, Sadri type, Shim balte, Shima, Shimla early, WC1006) for HNT tolerance. At the Texas A&M AgriLife Research Center at Beaumont, a study was conducted to evaluate the effects of HNT on plant height, productive tillers, biomass, spikelet fertility, yield and grain chalkiness of the 15 Iraqi rice varieties (all are subspecies *Indica*). Plants were grown under ambient night temperature (ANT) (25ºC) or HNT (30ºC) in the greenhouse. Plants were subjected to free-air temperature enrichment of a zone within a greenhouse and were exposed to 25ºC or 30ºC NT from boot stage until harvest; they were subjected to HNT through use of continuously controlled (+/- 0.5ºC) infrared heaters, starting from 2000 h until 0600 h. Plant height was measured, number of productive tillers was counted, biomass and yield were determined at harvest. In this study, spikelet fertility was defined as a ratio between filled grain number to total grain number in a panicle and was measured at harvest. Grain chalkiness was determined using a WinSeedle grain image analysis system.

Results from our study indicated differential response of Iraqi rice varieties to HNT with respect to plant height, productive tillers, biomass, spikelet fertility, yield and grain chalkiness. Most of the Iraqi rice varieties used in this study were tolerant to HNT with respect to plant height, productive tillers, biomass, spikelet fertility, yield and grain chalkiness. The susceptible varieties showed decreased plant height, productive tillers, biomass, yield, spikelet fertility and increased chalkiness. These data should contribute to understanding the physiological differences among varieties showing susceptible versus tolerant responses to high night temperatures. The Iraqi varieties provide a pool of previously uncharacterized high night temperature-tolerant material that can be used as a part of breeding programs striving to improve environmental stress tolerance of rice.

Significant Shift of Ambient Nighttime Air Temperature during Rice Growing Season in Major U.S. Rice States: A Synthesis of Historical Data

Mendez, K.V., Larazo, W.M., Adviento-Borbe, A., Massey, J.H., and Lorence, A.

High nighttime air temperature stress on rice growth is continuously studied in both field and greenhouse condition because of its significant effect on grain quality and yield. Elevated night-time ai temperature treatments depend on calculated trends and selected weather stations. Currently, there has been no report on actual shift of night-time air temperature in rice fields of the United States for the past decades. This study elucidated the trend of night-time ai temperature in four major rice growing states including Arkansas, California, Louisiana and Texas using open-accessed weather databases: National Oceanic and Atmospheric Administration – National Climatic Data Center (NOAA-NCDC), National Aeronautics and Space Administration – Prediction of Worldwide Energy Resources (NASA-POWER), California Irrigation Management Information System (CIMIS) and Integrated Agricultural Information and Management System (iAIMS). Hourly and daily night-time air temperature from 8:00 p.m. to 6:00 a.m. were mined from 1940 to 2018. Data mining was narrowed to rice growing months starting from May to September. Our findings proved variation in night-time air temperature change among US rice growing states. Increase in night-time air temperature ranges from 0.4 to 1.5°C. California rice areas have the highest increase in air temperature. Approximately 48% of the considered weather stations are located in California. To advance field observation of the shift of high night-time air temperature in rice areas, there is a need to establish more local weather stations with emphasis on the Mississippi Delta and Gulf Coast Region. Likewise, hourly air temperature is inconsistently recorded resulting to skewed distribution of data. It is imperative to continuously monitor and store weather data in order to improve future weather calculations. Enhanced knowledge about actual weather condition in the field will help growers and researchers in understanding climatic factors that are critical to rice production.

Fast-Tracking Variety Development in a Rice Breeding Program

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

With such a competitive market, breeders have searched for ways to make their programs more efficient and effective at producing high yielding, high quality rice varieties. With the ever increasing need for better disease packages, herbicide resistant weed control, tolerance to high temperatures, and better milling quality, breeders need more effective tools in their toolbox. The use of greenhouse plantings and the winter nursery in Puerto Rico have dramatically increased a breeder's ability to go from a cross to variety release in as few as seven years. Technology has vastly improved efficiency and the reliability of the data produced. The implementation of global positioning systems along with the use of data recording systems on plot equipment allow data to be not only more reliable but be retrieved for analysis immediately after harvest so that selections can be made faster.

Application of Heterotic Groups for Parental Selection in Hybrid Rice Breeding

Sanchez, D.L., Samonte, S.O.P.B., Alpuerto, J.B.B., Holgate, L.C., Croaker, P.A., Tabien, R.E., Harper, C.L., Wilson, L.T., Yan, Z., Christensen, E.F., Martin, L.N., and Thomson, M.J.

In hybrid varieties, heterosis (hybrid vigor), is maximized when their parents are genetically different. Classifying the parental lines into genetically-distinct heterotic groups will result in more efficient parental selection and crossing management. This study aimed to: (1) determine the genetic distance between potential rice parental lines of hybrids, and (2) classify these parental lines into heterotic groups.

A total of 34 rice varieties and breeding lines were selected for their long grain size (length/width ratio ≥ 3) and low chalkiness from the 2018 hybrid rice breeding nurseries at Texas A&M AgriLife Research at Beaumont. The groups were determined using 23,700 single nucleotide polymorphism (SNP) markers using three approaches: 1) genetic distance calculated as one minus identity by state (IBS) similarity, followed by clustering using the neighbor-joining method, 2) model-based population structure inference, and 3) principal component analysis.

All three approaches consistently classified the 34 rice genotypes into two major groups. Twenty-seven accessions, most of them belonging to *japonica* subspecies, were classified as Group 1. Most of the US varieties (e.g., Presidio, Antonio, Cocodrie) were also in Group 1. Group 2 was composed of seven varieties, with most of them belonging to the *indica* subspecies (e.g., IR64-Sub1, Minghui 63, Rondo). The average IBS-based genetic distances between pairs of accessions within Group 1 and Group 2 were 0.27 and 0.30, respectively, while that of pairs between the two groups was 0.51. The results of this study are being evaluated in a preliminary yield trial of hybrids produced from parents with high and low genetic distances. This heterotic group approach will be advantageous in the efficient selection of parental lines to develop high-yielding hybrids.

Genomic Prediction for Main Culm Panicle Node Number, Maximum Node Production Rate, and Degree Days to Heading in Inbred and Hybrid Rice Lines

Sanchez, D.L., Samonte, S.O.P.B., Alpuerto, J.B.B., Holgate, L.C., Croaker, P.A., Tabien, R.E., Harper, C.L., Wilson, L.T., Yan, Z., Christensen, E.F., Martin, L.N., and Thomson, M.J.

Complex traits such as grain yield are controlled by numerous loci with small effects and are greatly influenced by environmental variables. Genomic prediction makes use of genome-wide markers to predict the performance of untested (non-phenotyped) individuals based on marker-phenotype associations established in previously observed populations. This study aims to determine the accuracy of genomic prediction in three traits: main culm panicle node number (MCPNN), maximum node production rate (MNPR), and degree-days to heading (DDH) in order to identify potentially high-yielding rice genotypes.

The ridge regression best linear unbiased prediction (RR-BLUP) method was performed on 220 diverse rice genotypes for MCPNN, MNPR, and DDH with 3,316 unimputed single nucleotide polymorphic (SNP) markers. Out of the 220 genotypes, 132 (60%) were randomly assigned to the training set, while the remaining 88 (40%) were used as the validation set.

Preliminary results showed that prediction accuracies using the 220 diverse rice accessions were 0.17 for MNPR, 0.19 for DDH, and 0.23 for MCPNN after 1,000 iterations of cross-validations using RR-BLUP. The low prediction accuracy can be attributed to the diversity of the population, which was composed of released *japonica* and *indica* varieties, elite breeding lines, landraces, and hybrids.

Improving the prediction accuracy, by using improved varieties and breeding lines, as well as increasing the marker coverage, is on-going. Data on DDH from 96 hybrids from the 2018 nurseries with available genotype data will be used as a training population to predict the flowering dates of the hybrids from the 2019 nurseries. The genomic prediction approach is potentially useful in efficiently decreasing the number of hybrids that will be made from parental cross combinations and evaluated in the field experiments or nurseries.

Field and Data Collection Practices of the LSU Rice Breeding Program

Guidry, G.J., Williams, B.L., Angira, B., Dartez, J.P., and Famoso, A.N.

The LSU Rice Breeding Program develops improved varieties of rice for the Louisiana rice industry. These varieties include conventional, herbicide-resistant, medium-grain, and specialty rice. As part of the variety development process, the breeding program plants and maintains 60,000-70,000 progeny rows and 8,500 yield plots each year. These plots are located on the H. Rouse Caffey Rice Research Station and all throughout the state of Louisiana. In order to plant, harvest, and process the rows and plots many different types of tools and equipment are utilized. The purpose of this poster is to provide an overview of the field activities and the various equipment and tools used within the breeding program.

Estrela × NSFTV199 Germplasm Selected for Panicle Architecture Traits

Eizenga, G.C., and McClung, A.M.

Since most U.S. rice cultivars are derived from the *tropical japonica* rice (*Oryza sativa* L.) genepool, understanding the genetic variation for yield related traits in this subpopulation is important to U.S. rice breeding efforts. The 'Estrela' × NSFTV199 recombinant inbred line (RIL) mapping population was developed from two phenotypically and genotypically diverse *japonica* rice accessions in the Rice Diversity Panel 1. Although the Estrela parent was initially classified as a *tropical japonica,* subsequent SNP genotyping reclassified it as an admixture of *japonica*. The NSFTV199 parent is classified as a *tropical japonica*. Phenotypically, Estrela is a long grain with low amylose content and high gelatinization temperature, is pubescent and has blast genes, *Pi-z* and *Pi-ks*. On the other hand, NSFTV199 is a medium grain with intermediate amylose content and intermediate gelatinization temperature, is glabrous and has the blast gene, *Pi-ks*. The population was phenotyped for eight agronomic traits (days to heading, plant height, flag leaf length and width, leaf pubescence, culm habit, awn presence and seed shattering), six panicle architecture traits (panicle length; number of primary branches, florets, seeds and sterile florets per panicle; and percent fertility), and nine grain traits (seed length, width, and length to width ratio with and without the hull; percent chalk in brown rice with and without the broken kernels, and 100-seed weight). For QTL mapping, 256 Estrela × NSFTV199 RILs were genotyped with 134 SSR markers and 70 QTL were found for these traits. The population exhibited transgressive variation for panicle architecture traits as well as grain traits. The objective of this study was to select RILs with panicle architecture traits that could be used to improve yield, which also had acceptable grain size, maturity, plant height and grain yield for use in U.S. breeding programs.

The phenotypic data collected from the 256 RILs was utilized to select 38 RILs that were evaluated in single 1.5 m rows with four replications in 2017. The RILs were selected based on desirable days to heading, height, culm habit, adequate fertility and lack of seed shattering, while considering grain length and width, grain weight, panicle length, and number of grains, florets and primary panicle branches. Four checks were included in the trial, the two parents Estrela and NSFTV 199, Mermentau, a long grain developed in Louisiana, and Titan, a medium grain developed in Arkansas. The data from 2017, heading date, plant height, culm habit, lodging, tiller number, grain weight, dehulled grain length and width, chalk in brown rice, and marker data for amylose content, pubescence and *Pi-z* presence was examined. Also, the parental phenotypes and genotypes based on SSR markers in the regions of known genes for grain length and width on chromosomes (chr.) 3, 5, 7 and 8, and for panicle architecture (panicle length, number of florets, grains and primary panicle branches) on chr. 1, 4, 7 and 8, were considered. Six RILs were selected for yield trials in 2018 and 2019. The yield trials were planted in plots 3 m^2 with four replications along with the four checks, Estrela, NSFTV199, Mermentau and Titan. In addition to the aforementioned data collected on the RILs and the 38 selections, milled whole and total kernel weight, and kernel thickness were recorded in both years. In 2019, total chlorophyll (SPAD units), and flag leaf length and width were recorded. Also, in 2019 two of the six RILS included panicle derived sub-selections, thus a total of eight RIL entries were evaluated. DNA was isolated from leaf tissue collected from panicle rows of these eight selections and the four checks for genotyping. All the entries and checks were genotyped with 27 SSR markers and the *Glab* marker for pubescence. The markers spanned across all 12 chr. Also, 18 recently developed SNP markers for grain length and width, grain weight, panicle branching, flag leaf width, panicle length and days to heading on chr. 1, 3, 4, 5, 6, 7, 8, 9 and 11, were used to genotype these same lines.

The recently developed SNP markers for grain length and width, flag leaf width, panicle branching, and panicle length corresponded well to the phenotypic data. Based on the phenotypic and genotypic data, RILs will be identified from the eight entries evaluated that optimize the best agronomic and grain quality traits expected for the U.S. market and include novel QTL for panicle architecture and yield component traits. The selected RIL entries will be released as improved germplasm for U.S. breeders.

Identification and Characterization of Rice Blast Resistance Genes in Minghui 63 - a Restorer Line Widely Used in Hybrid Rice Production

Jia, Y., Box, H., Jia, M.H., Sites, A., Herring, N., Yan, Z.-B., and Bianco, T.

Significant numbers of rice growers in the Southern U.S. have been growing hybrid rice since 2003. Minghui 63 is one of the most widely used cultivars in hybrid rice production as a fertility restorer. The genome of Minghui 63 was recently determined with PacBio long-read and Illumina paired-end sequencing method by other researchers. In this study, we evaluated Minghui 63 with 7 commonly found U.S. blast races, IB45, IB49, IC17, ID1, IE1, IG1 and IH1 and found that Minghui 63 has different degrees of resistance to the tested blast races. A cross of Minghui63 with the blast susceptible rice variety M202 was made and a recombinant inbred line population was developed consisting of 275 individuals using single seed descent breeding method under greenhouse conditions. This Minghui63/M202 population was genotyped with 156 polymorphic single sequence repeat (SSR) markers and 6, 16, and 3 lines of which were removed due to non-parental allele, heterozygosity and missing data, respectively. A linkage map with 1022.84CM was constructed using QTL mapping and inclusive composite interval mapping (ICIM) software. We are continuing to evaluate the entire population with three more blast races and blast resistance genes identified will be presented.

Recent Commercial Production of High Protein Rice and Their Prospects beyond Its Conventional Use

Wenefrida, I., Zaunbrecher, G., Dugas, H., and Utomo, H.

The health benefit components of rice, such as the glycemic index (GI) and antioxidant γ-oryzanol in its bran oil, and its baking quality can readily be enhanced to have broader appeals in the new markets. In pursuit of higher yield, modern breeding often pays little attention to these specific traits. As a result, these properties that were originally found in wildrice are not retained in modern cultivars. The need for more nutritious rice is growing. Hundreds of million people are under-nourished and more than two-thirds of them live in places that consume a lot of rice. Rice bred for extra protein could hold the answer to boosting nutrient intake.

Marketing high protein rice (new product) is a gradual process. However, it started gaining track, especially in retail chains in the north under a trade name “Cahokia”. This year a Louisiana farmer started growing the high protein rice, aimed for consumers in the south. It will be marketed under name “Prairie Acadian Rice”. As the production of high protein rice increased, the availability of newer high protein cultivars is needed to push the increase. The new high protein rice with higher yield will help Louisiana farmers and other growers improve their profit margin.

There is no need to adjust cultural practices to grow high protein rice. Therefore, it can readily be scaled-up. With cultivar Frontiere, for example, planting this high-protein rice can produce an additional 160 lbs/A of natural protein with no extra cost. This additional protein is equivalent to the same amount of protein from 610 lbs of meat or 1,420 gallons of milk. This is one of the most efficient ways to produce additional plant-based natural protein with no extra cost. Many products, from rice flour used in baked goods to rice milk, baby foods, cereals, and crackers, contain rice. They can benefit from more protein. The demand in gluten-free baked products continues to grow and this presents another opportunity for rice growers to give people what they are looking for.

Rice is one of the most important cereals that is naturally gluten-free, highly digestible, and hypoallergenic. The gluten-free products market is a multi-billion-dollar industry and growing fast. It is a great opportunity for rice to enter this market. The objective of this research is to enhance these natural nutritional quality or rice grain using conventional breeding, genomics, and DNA markers allowing rice to enter beyond its conventional use and markets.

Effect of Low Sink Demand on Grain Quality of Chalky and "Chalkyless" Rice

Alpuerto, J.B.B., Samonte, S.O.P.B., Sanchez, D.L., Holgate, L.C., and Croaker, P.A.

A key factor in rice grain development is the accumulation of starch, which is synthesized from glucose transported from leaves and leaf sheaths during grain filling. Grain filling involves the activity of several carbohydrate-synthesizing and transporting enzymes which function to develop grain components. Changes in sink (panicles) demand during grain filling contribute to variation in total carbohydrate levels and overall grain quality of rice. The objective of this study was to evaluate the grain quality traits of chalky and less chalky ("chalkyless") rice cultivars under normal (control) and low sink (trimmed panicles) demand during grain filling.

In this study, we evaluated grain quality traits of LaGrue, Leah, Kaybonnet, and Presidio under normal and low sink demand. These four cultivars were grown in six-row plots replicated three times in a randomized complete block experiment at the Texas A&M AgriLife Research Center at Beaumont in 2019. In three of the six rows of each plot, the bottom half of all panicles were trimmed or cut off at 75% panicle exsertion. Panicles were harvested 30 and 35 days after flowering (DAF).

Based on analyses of variance and student's t-tests, there were significant variations among the four cultivars and treatments (control vs. trimmed panicles) for percentages of chalky, total, and whole milled rice. At 30 DAF, Kaybonnet and Leah showed significantly different total milled rice percentage in the trimmed (63% and 65%, respectively) versus control panicles (67% and 67%, respectively). Only Leah showed significantly different whole milled rice percentage in trimmed (34%) versus control (39%) panicles. The other cultivars showed no significant differences in total and whole milled rice percentages between control and trimmed panicles. Moreover, there were significantly lower chalky grain percentages in trimmed panicles of Leah (-4%), Presidio (-3%), and LaGrue (-12%). At 35 DAF, there was no significant variation in whole milled rice percentage among all cultivars. However, total milled rice percentage in Presidio was higher in trimmed panicles (69% vs. 67%). Significant reductions in chalky rice percentages were observed at 35 DAF in Leah (-6%) and LaGrue (-17%).

The results of this study showed that reducing the carbohydrate demand of rice panicles caused significant variation in grain quality traits. These results highlight the importance of trade-offs in source-to-sink relationships, particularly in vital stages of plant growth and development. In addition, these results shed light on considering the balance between panicle length and grain quality during parental selection for yield and yield-related traits.

Phenotypic Evaluation of a Potential Stay-Green Rice Accession

Alpuerto, J.B.B., Samonte, S.O.P.B., Sanchez, D.L., Holgate, L.C., and Croaker, P.A.

Crops undergo leaf senescence in response to stress stimuli and throughout physiological maturity. This biological process is correlated with chlorophyll degradation and loss in green leaf color. Grain filling in rice involves translocation of carbohydrates, proteins, and amino acids from the leaves (particularly from the flag leaf) to the developing grains resulting in leaf senescence. The *stay-green* trait, which is the ability to retain leaf greenness during and beyond rice grain filling may correlate to the ability to retain carbohydrates and proteins in leaves. This trait can be tapped for better yield in the main crop and potentially for second (ratoon) crop as it relates to nutrient remobilization. In addition, it can potentially minimize lodging and maintain structural integrity of the plant's top portion. This study aimed to evaluate a potentially stay-green accession, H256-76-1-1-1, by estimating chlorophyll levels from booting to grain filling stage. In addition, grain quality traits under normal and reduced source-to-sink ratio were evaluated.

H256-76-1-1-1 and Presidio (check cultivar) were grown in six-row plots replicated three times in a randomized complete block experiment at the Texas A&M AgriLife Research Center at Beaumont in 2019. At booting stage, all leaves of rice plants in three rows of each plot were cut off excluding the flag leaves, while the uncut rows served as control rows. Chlorophyll estimation using Field Scout SPAD 502 Chlorophyll Meter was performed on 10 flag leaves per replicate at weekly intervals, starting at panicle exsertion and ending at 46 days after panicle exsertion. Grains were harvested 30 days after heading for grain quality analysis.

A significant difference between estimated chlorophyll levels was observed in control rows of Presidio and H256-76-1-1-1, with the latter having higher overall estimated chlorophyll levels. There was a 39 to 90% chlorophyll reading advantage in H256-76-1-1-1 over Presidio from 14 to 35 days after panicle exsertion. Mean chlorophyll readings estimated from control rows of H256-76-1-1-1 and Presidio at 35 days after panicle exsertion were 22.24 and 15.99 SPAD units, respectively. Cutting off leaves resulted in increased chlorophyll readings in both accessions. Based on Student's t-test, there were no significant differences in chalky grain percentages between cultivars and treatments. Preliminary results of this study showed the potential of H256-76-1-1-1 to maintain relatively higher chlorophyll levels (compared to a check cultivar) during grain filling, which is a stay-green characteristic. These results also provided information on the initial groundwork for evaluating potential stay-green accessions from our candidate parental lines for hybrid rice development in a field plot setting. Further studies will be conducted to include the evaluation of sink size and grain yield of additional stay-green cultivars with other check varieties.

The Art of Crossing Rice

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

New rice varieties are initiated and selected from crosses among pre-breeding germplasm. Because rice is a self-pollinated plant having a perfect flower, all plants can be used as either the male or female. In this process, selected female and male plants are crossed together to produce desired F_1 seeds. For best results, this occurs in a protected area, which in our case is inside the greenhouse. Parental lines are planted in the field at certain time interval for the synchronized flowering. Female plants are potted and taken to the greenhouse at late boot stage for the emasculation process. During the emasculation, the male parts of the flower, which are called anthers, are removed or sterilized for a successful cross to take place. A hot water method is used that consists of placing the plant in water that is at a 45ºC temperature for 5 minutes. The plant is then removed from the water and the excess water shaken off to allow the anthers to emerge from the florets. Then the florets with the anthers exposed 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 taken to the greenhouse 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 make the cross. The glycine bag is put back over the newly pollinated panicle and left to produce hybrid seeds, which you should be able to see in approximately a week. A successful cross will be ready to harvest in about 30 days from the date of pollination.

Exploring Naturally Existing Genetic Variation in Grain Chalk Formation in Response to Temperature and Carbon Dioxide

Barnaby, J.Y., McClung, A.M., Kim, W.J., Ziska, L.H., Fleisher, D.H., and Reddy, V.R.

Climatic factors such as increased atmospheric CO_2 levels are associated with global warming which is projected to dramatically impact the production and quality of food crops. Specifically, heat stress is known to significantly increase grain chalkiness in rice which reduces milling quality, cooking properties, and grain appearance. Over the last several years, the USA rice industry has been concerned about the increasing prevalence of undesirable chalky rice which has resulted in a loss of some international markets, particularly in South America and Central America. However, research has shown that some rice cultivars are more susceptible to heat induced grain chalk development than others. This indicates that there is a genetic component that could be used in breeding to mitigate the negative effects of climate change on rice grain quality. Using a KZ RIL mapping population from KBNT-1-1, a translucent, low phytic acid (LPA) mutant derived from the US long grain variety Kaybonnet, crossed with Zhe733, a chalky, long grain variety from China, Edwards et al (2017) identified 10 QTLs impacting grain chalk. In this study, the two parents and seven KZ-RILs selected based presence and/or absence of 4 major chalk QTLs were evaluated to understand the impact of genotype and environment interactions on heat-induced chalk formation as well as rice yield production. Plants were grown under ambient and elevated atmospheric CO_2 levels (i.e. 400 and 600 ppm, respectively) in controlled growth chambers and half of the plants were subjected to heat treatment during anthesis. The genotypes were evaluated for 1) photosynthetic adjustment, A, gs, A/Ci, grain yield, in response to heat, 2) agronomic traits (i.e. yield, grain length, width, etc), 3) % chalk, and 4) grain elements (i.e. P, K, Ca, Mg, S, Na, Fe, Mn, Zn, Cu, B, As, C, and N). Our results showed natural genetic variation in heat-induced chalk formation and grain elemental contents in response to a changing climate, i.e. high temperature with elevated atmospheric CO_2.

LSU AgCenter High-throughput Molecular Breeding Laboratory Overview

Angira, B., Dartez, J., and Famoso, A.

Single nucleotide polymorphism (SNP) marker-assisted lab was established in February 2016 through the support of the Louisiana Rice Research Board and the LSU AgCenter at the H. Rouse Caffey Rice Research Station as part of the Variety Development Program. The lab facilitates the integration of molecular breeding as a core element to an applied breeding program and offers tangible benefits to our variety development efforts in terms of speed, accuracy, throughput, and uniformity. About 55,000 individual leaf samples are processed through the lab in a year. The lab consists of high-throughput instruments that allow us to run ~36,000 data-points per day and. Since establishment, the lab identified high-throughput KASP marker for about 20 major rice genes and 72 genome-wide informative markers in the U.S. germplasm. These markers are continuously used in the LSU AgCenter rice breeding program. The major molecular breeding activities of the lab are testing true breeding crosses (F1), marker assisted selection, testing yield plots (preliminary yield plots and advances tests), and breeding line and variety purification using the trait and genome-wide markers. In 2019, the lab tested 275 F1 populations, performed marker assisted selection on 38,000 plants of 106 breeding populations, tested 7,000 breeding lines, and purified four release candidate lines using molecular markers.

Genotype by Environment Interaction of Hybrid Rice Lines in the Philippines

Manangkil, O.E,. and Banting, M.D.M.

Stable yield is one of the most desirable characters of a rice cultivar to be released as a variety, which allows varieties to be adapted in a large area. Genotype adaptation is usually assessed on the basis of yield responses, and indicated by a consistently good yield response across locations. Field performance trials have been conducted across different test sites as part of the National Cooperative Test (NCT) conducted by the Philippine Rice Research Institute (PhilRice) and partner agencies to evaluate elite hybrid rice lines prior release to identify potential varieties with wide or specific adaptation in the Philippines.

Data on yield of 10 hybrid genotypes during 2017 wet season to 2018 wet season across 18 test sites were analyzed using the Additive Main Effect and Multiplicative Interaction (AMMI) and Genotype & Genotype x Environment Interaction (GGE). Agro-morphological characteristics, resistance to insect pests and diseases, and grain quality traits were also observed.

Test locations contributed to the 88.9% of the total variation as reflected by the partitioning of sum of squares, while the significant Genotype by Environment Interaction (GEI) ($Pr < 0.0001$) indicates the differences in genotypes' response to different environments. Generally, the genotypes were early maturing, semi-dwarf, and have excellent milling potential. Furthermore, intermediate to resistant reaction to major insect pests and diseases were observed. Genotype 3 (G3) was found to be the highest yielding and most stable genotype across sites and seasons, with mean yield of 6,400 kg/ha and 13.23 AMMI stability value (ASV).

Highly stable and adaptive genotypes can improve the productivity of wide areas and may be recommended as national or location specific. Additional information from the statistical models can be positively utilized in varietal development for different locations that may aid in fulfilling "A Rice-secure Philippines".

The Rice Varietal Release in the Philippines

Manangkil, O.E., and Abdula, S.E.

Rice breeding institutions in the Philippines perform line improvement targeting all rice growing ecosystems in the country. Public and private breeding organizations backstopped and contributed to rice varietal development.

The National Cooperative Trial (NCT) is a nationwide multi-environment testing scheme that confirm the performance and stability of elite rice lines submitted by rice breeding institutions prior to become new varieties. It identifies superior varieties that confer high yield, resistance to current insect and disease problems, climatic stresses and new-market demands. It is the last post-breeding stage before a rice line is approved for commercial cultivation

The Philippine Rice Research Institute (PhilRice) and Bureau of Plant Industry (BPI) are responsible for the overall coordination and conduct of the mandatory procedure for testing candidate varieties. In coordination with the Rice Technical Working Group (RTWG) and the National Seed Industry Council (NSIC), a climate adaptive trialing system under designed-managed environs to make sure that they are challenged by diverse environmental conditions encountered in the farmers' field is done. RTWG serves as the body which recommends or rejects rice lines based on NCT results. Lines that passed the NCT standards are recommended to NSIC chair for approval. An officially released variety will constitute as new variety and made available to the public for commercial cultivation.

NSIC had released a total of 292 rice varieties for different rice growing ecosystems from 1990 to 2018. Hybrid varieties topped the number of releases with 103 followed by irrigated lowland with 93 releases. Rainfed released 42 varieties while 54 for the stressed environments which include saline, upland and cool elevated areas.

In Search of DNA Markers Associated with Milled Rice Amylose Concentration

Samonte, S.O.P.B., Sanchez, D.L., Alpuerto, J.B.B., Holgate, L.C., Croaker, P.A., Wang, Y.J., Wilson, L.T., Yan, Z., Christensen, E.F., Martin, L.M., Tabien, R.E., Harper, C.L., and Thomson, M.J.

Rice grain types based on amylose concentration include the waxy (1-2%), very low (2-12%), low (12 to 20%), intermediate (20 and 25%), and high (greater than 25%) amylose rice. Genetic markers associated with grain amylose concentration need to be identified in the rice genome for application as a component of an efficient marker-assisted selection tool, especially in the selection for high amylose rice that has potential as a low glycemic index food.

In 2018, 217 diverse rice genotypes (*indica* and *japonica* cultivars, landraces, inbred lines, and hybrids) were grown at Texas A&M AgriLife Research Center at Beaumont. Leaf DNA extracted from all entries underwent genotyping-by-sequencing at Texas A&M AgriLife Genomics and Bioinformatics Service (TxGen), and 854,832 single nucleotide polymorphic (SNP) markers were selected for use in this study after filtering out low-quality SNPs.

Whole milled rice samples of all rice entries were estimated for amylose concentrations using iodine colorimetry at the Department of Food Science at the University of Arkansas. Based on amylose concentration, 4 genotypes were classified as waxy, 22 were very low, 93 were low, 58 were intermediate, and 40 were high amylose rice grain types.

The GWAS-GLM (genome-wide association study, general linear model), using principal component analysis (PCA) to account for population structure, was used to identify the SNPs that are closely associated with amylose concentration. Preliminary results of the GWAS analyses indicated that two (2) SNPs in chromosome 10 were suggestive of being associated with amylose concentration at $p \leq 1.17 \times 10^{-6}$. Peaks were also detected in genomic regions close to known QTL associated with amylose concentration (e.g., *Wx* gene in chromosome 6).

Additional analyses to be conducted include using a 2^{nd} round of grain amylose concentration data obtained in 2019 and the exploration of other GWAS models such as the mixed linear model and the fixed and random model circulating probability unification (FarmCPU). An efficient selection method for amylose concentration is desired, and the identification of SNPs closely associated with this trait is an initial approach towards developing a functional genomic selection tool for high amylose rice.

Towards Development of Stem Rot Resistant Rice

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

Integral to plant variety development is improvement of plant's defense system. In rice, extensive research and improvements were done to combat several common diseases caused by bacteria, viruses, and fungi. Several disease resistance genes were incorporated to rice varieties but no resistance genes for stem rot disease has been introduced yet. Despite the knowledge of the causal pathogen for stem rot disease, there is very limited studies and information of stem rot resistance in rice to date. The main objective of the study is to incorporate stem rot disease resistance genes to California rice varieties. In this study, we characterized several genotypes and mapping populations for stem rot disease resistance. Disease evaluations were conducted in the greenhouse and in the field. Our results indicated that there is no high degree of stem rot resistance existing in California rice varieties. However, few promising lines previously derived from *O. rufipogon* cross can be used to introduce resistance to cultivated rice varieties. Genetic mapping for stem rot disease resistance is underway.

Development of Multi-parent Rice Lines from Eight United States Elite Varieties

Cerioli, T., Angira, B., Dartez, J., and Famoso, A.N.

A successful breeding program relies on the availability of genetic variability from which the breeder can select improved varieties that possess desirable traits for crop production. Eight elite US rice varieties were selected to develop complex multi-parent populations. The eight founder lines were selected to represent released varieties that possess exceptional characteristics for the key US breeding traits, including yield and ratooning capacity, milling, chalk, and fissuring resistance, blast and sheath blight resistance, early maturity, and lodging resistance. 2, 4, 6 and 8-way populations have been created to develop complex populations with balanced allele frequencies of the founders within each population. After multiple sets of hybridizations, the populations have been selfed through rapid generation advancement following single seed descent method. We were able to achieve up to 3.5 growing cycles a year in our greenhouses. Four bi-parental populations with 300 lines each were grown as F_3:F_4 in the field in 2019 for a seed increase and phenotyped for days to 50% heading and plant height. Six 4-way populations, with 200 lines each, have been planted in November 13 2019 as F_4:F_5 panicle rows at the Puerto Rico winter nursery for a seed increase. All 2 and 4-way populations have been genotyped at the generation of derivation (F_3 and F_4 respectively) with 1200 genomewide and trait markers selected for informativeness in US rice germplasm. 6 and 8-way populations, each composed by 600 lines, are currently growing in greenhouse to be genotyped as F_4 and will be planted as F_4:F_5 panicle rows in 2020 growing season.

500 lines selected within the four bi-parental populations and 500 lines from the six 4-way populations will be tested in a yield trial as F_3:F_5 and F_4:F_6 , respectively, in the 2020 growing season. The experiment will investigate the potential of genomic selection as a tool for efficient selection for highly quantitative traits. Genomic selection employs genotypic and phenotypic data of a portion of the population, the training set, to assign an effect for the allele of each marker, for each trait. With all these marker effects it is possible to obtain genomic estimated breeding values (GEBVs) that will help in the selection of improved lines with desired traits. The relatedness of the different multi-parent populations facilitates predictions across populations and we will investigate the prediction accuracy of the predictive models both within and across populations for a range of traits with differing heritabilities. Experiments will also be conducted to test the optimal marker density and optimal training set sizes to optimize the prediction accuracy for different traits and populations. Finally, these populations will also be utilized to conduct QTL analysis and compare the efficiency of QTL mapping and marker assisted selection vs. genomic selection for applied breeding applications.

Determining Rice Blast Disease Resistance Conferred by the *Pi-40* Gene

Boyett, V.A, Belmar, S.B., Thompson, V.I., Kelsey, C.D., Xue, J., McCarty, D.L.,
Northcutt, C.H., Wisdom, D.K.A., and Moldenhauer, K.A.K.

Four F_2 breeding populations were generated by crossing an IRRI line (donor of rice blast resistance gene *Pi-40)* with four different elite long grain lines. The goal is introgression of a new gene for rice blast resistance while developing new lines with desirable agronomic characteristics that are adapted to Arkansas' environment.

The *Pi-40* gene, located on the short arm of chromosome 6, was reported to have broad-spectrum resistance to many races of the pathogen in previous studies conducted in South Korea and Turkey. Through DNA marker analysis, the *Pi-40* donor parent was determined also to have *Pi-ta* and *Pi-b*. The *Pi-ta* gene confers resistance to all the common races of the blast pathogen found in Arkansas with the exception of the race IE1K. The *Pi-b* gene confers resistance to IE1K, partial resistance to IB49, and most of the races protected by *Pi-ta* with notable exceptions the races IA45 and IB54.

Molecular analysis on the four populations used fourteen DNA markers linked to the rice blast resistance genes *Pi-40*, *Pi-b*, *Pi-i*, *Pi-k*, *Pi-ta*, and *Pi-z* to screen 880 progeny and five parental lines. Marker analysis revealed that two of the populations were homozygous for rice blast resistance at the *Pi-ta* locus while two populations were segregating. Two populations were segregating at the *Pi-k* locus. All four populations were segregating at the *Pi-40* and *Pi-b* loci. None of the populations had resistant alleles at either the *Pi-i* or *Pi-z* loci.

From the two populations that were segregating for rice blast resistance at the *Pi-40*, *Pi-b*, and *Pi-ta* loci, plants representing eight different genetic combinations were harvested for seed. A blast differential experiment was conducted using the eight test groups of: only *Pi-40,* only *Pi-ta*, only *Pi-b*, *Pi-40* + *Pi-ta*, *Pi-40* + *Pi-b*, *Pi-ta* + *Pi-b*, *Pi-40* + *Pi-ta* + *Pi-b*, and no known rice blast resistance genes. The cultivars Templeton and M206 were included as positive and negative checks, respectively.

Seed of the eight genotypes and checks were planted resulting in 150 pots of three seedlings each. At the 3-4 leaf stage the pots were divided into inoculum groups and tissue samples were collected so that further molecular analysis could be conducted to confirm genotype. As standard protocol, the plants were drought stressed prior to inoculation with individual spore suspensions of five races of the blast pathogen: IB54, IB49, IE1K, IH1, and IG1. After inoculation, plants were placed in a dew chamber overnight so that the high humidity would encourage leaf infection. The plants were visually scored for lesion development at ten days post inoculation.

Plants having the *Pi-40* resistance gene developed blast lesions on rice sprayed with either IB49 or IB54 races. Dual combinations of resistance genes provided protection to all races tested except IB49 and IB54. The gene stack of all three genes confirmed little to no disease. These results indicated that *Pi-40* by itself was not able to combat all of the known races of rice blast found in Arkansas. The *Pi-40* gene by itself did not confer any resistance not already covered by both *Pi-ta* and *Pi-b* genes. More testing is needed to confirm these findings.

An RGA Method for a Single Seed Descent-Based Rice Breeding System

Smith, W., Glenn, J., Lanford, C., Tradesco, T., Lanford, S., and Redoña, E.

The vast majority of rice breeding programs worldwide utilize the pedigree and bulk breeding methods or their modified versions to develop new varieties. In Mississippi, all of the eight conventional varieties released thus far by the MSU rice breeding program have been developed using the pedigree method. On average, one new variety has been released every 3.9 years since a dedicated in-state rice breeding program was established in 1986. However, to fast track variety development, the program has required access to a rice nursery in Puerto Rico to be able to plant at least twice a year. Virtually all of the varieties released in Mississippi were at some point advanced, selected or increased in the Puerto Rico rice nursery.

The development of a greenhouse-based rapid generation advance (RGA) method for growing rice could allow the implementation of a single-seed descent (SSD) breeding system to complement the pedigree method. Under controlled climatic conditions in the greenhouse, rice could potentially be planted up to three times a year, without a need for a winter rice nursery. Also, an SSD breeding system that has each individual plant barcoded in the greenhouse would allow the implementation of marker-aided selection work. In this case, the specific location of plants in the greenhouse could correspond to specific locations in a DNA sample plate used for marker assays.

We have therefore explored the possibility of developing a greenhouse-based RGA method for implementing SSD in Mississippi. Briefly, F1 seeds from a single cross are first planted in large pots to produce the F2 generations. For each F2 population, seeds are planted individually in 1-inch diameter cones filled with a 50:50 mix of Metro Mix 900 potting soil and topsoil. The cones are arranged in cone trays of 98 units, mirroring DNA sample plates used for marker-based assays. Plants are fertilized one time with urea at the 2-3 leaf stage. The greenhouse is kept between 20-30 degrees C with grow lights running for three extra hours each morning to extend the daylight hours during the winter months. Cone trays are placed in larger greenhouse trays and are sub-irrigated. One panicle from each cone is harvested, and one seed from each panicle is then planted as the next generation in a single cone. The procedure is repeated in the next generations until plants reach the F5 when they are planted in bigger cones to produce enough seeds for an initial field panicle row. Potentially, rapid generation of up to three generations per year could be implemented in the greenhouse. Using the SSD method reduces the amount of panicle field rows needed each year for advancing early generations, both in the main breeding station and in the winter nursery. Undertaking the SSD method could also potentially expedite variety development by at least a year.

Genetic Variation of Resistant Starch, Baking Characteristics, and Lipid Content among Advanced High Protein Rice Lines

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

Rice is an excellent food product that can be enhanced into more suitable products for new markets, such as the gluten-free baking industry and emerging markets associated with health-conscious consumers. Some of the health benefit components of rice, such as glycemic index and antioxidant γ-oryzanol in its bran oil, for examples, and its baking quality can be enhanced to meet the industrial standards. Our lab is working on improving genetic variation for important quality traits including resistant starch, baking characteristics, and lipid content. With the advancement of cultural technology, genomics, and DNA markers, these challenges can now be addressed effectively. Last year, we successfully developed several high yielding lines (8,200 lbs/A; PY tests) with lower glycemic index, increased bran oil content, and improved baking quality.

Rice bran oil has a high smoke-point of 254˚C and is perfect for stir frying or deep frying. It can also maintain its nutritive quality even at high temperatures. The demand for rice bran oil has skyrocketed in the last 3 years, especially for use in frying. Rice Bran Oil that have long shelf lives, hold up to commercial frying and economical. Its viscosity is very light allowing foods fried with rice bran oil absorb less oil (20% less). With less oil absorbed, it results in reduced calories and enhanced flavor and palatability. The oil has a balanced amount of monounsaturated, polyunsaturated and saturated fats, a heart-friendly oil. Its antioxidant γ-oryzanol of 2% of crude oil content helps improve cholesterol. New improved lines have shown improvement of 20-40% from their initial bran oil content.

Foods with a high glycemic index (GI) are quickly digested and absorbed, causing a rapid rise in blood sugar. Low-GI diets among people with type 2 diabetes improve insulin resistance, and lower glucose, cholesterol and triglyceride levels. A good portion of rice consumers suffer from type 2 diabetes and the availability of rice with lower GI, therefore, will help. Rice is the most suitable cereal grain flour for production of gluten-free products important to the consumers who are sensitive to gluten or suffer from celiac disease. However, its typical viscoelastic properties result in a liquid batter rather than dough and after baking produces a crumbling texture, less appealing color and poor baking quality. Selecting genetic factors affecting complexation with amylose to increase its viscosity was the focus on improving resistant starch level. The new lines have shown improvement of the resistant starch ranging from 15 to 35% more of their initial levels.

From Cross to Release: The Journey of a Rice Variety through the Arkansas Long-Grain Breeding Program

McCarty, D.L., Northcutt, C.H., Moldenhauer, K.A.K., Wisdom, D.K.A., Belmar, S.B., Kelsey, C.D., and Boyett, V.A.

In the Arkansas long- grain breeding program, there are many steps a variety goes through from the time the initial cross is made until it is released as a public variety to the farmers. The journey begins when two lines are crossed and produce seed. That F_1 seed is then grown in the greenhouse over the winter. The following spring the seed produced from the F_1 plants is grown in the field as F_2 space plants from which panicles are selected to be grown as F_3 panicle rows in the Puerto Rico nursey. A panicle from each row in Puerto Rico is brought back and planted as F_4 P panicle rows in the field. Selected rows are harvested in bulk to be evaluated for kernel size and shape, chalkiness, cooking quality and rice blast. The F_5 seed is then grown in Preliminary plots or L panicle rows. Agronomic data (height, maturity, yield), is collected from the preliminary plots, along with disease screening, milling information and an increased seed supply for replicated yield tests. F_6 seed is produced in the Stuttgart Initial Trial (SIT), planted at Stuttgart and Pine Tree, or again in Preliminary plots. The F_7 seed is then introduced into the Arkansas Rice Performance Trials (ARPT) in multiple locations across Arkansas and the Uniform Regional Rice Nursery (URRN) in multiple states or again in SIT plots for further evaluation. Panicles are collected from the best selected lines for Breeder Head rows the following year. The line is grown again in the 2nd year yield trials of the ARPT & URRN in multiple locations as well as Breeder Head rows. Seed is then planted in the 3rd year trials of the ARPT and URRN, 2nd year Breeder Head rows as well as Foundation seed. The following year the line will be released to seed growers but will remain in the APRT and URRN, Breeders Seed and Foundation Seed programs. The line will be available as Registered seed about the 10th year from the initial cross and as Certified seed in the 11th year. As one can see, the journey of an Arkansas long-grain variety is not a short one. There are many hours and many dollars invested into the development of the varieties that are available to the rice producers of today.

Identification of Genetic Sources of Restorability in Arkansas Restorer Rice Plants

Azapoglu, O., Srivastava, V., Sha, X., Brye, K., and Shakiba, E.

Hybrid rice (*Oryza sativa L.*) breeding offers a significant opportunity to enhance rice production, and the cultivation of a male sterile line is the most important factor for the success of cross-breeding. The objective of this study is to determine target region(s) of *Rf* male sterile gene(s), which can produce male sterile generation. The present research will take place at the University of Arkansas during 2018-2019. The experimental materials include crosses between two restorer lines and three cultivars. Resulting F_2 samples will be genotyped via molecular markers and the location of *RF* male sterile gene will be identified using phenotypic data from the F_3, and genotypic data from the F_2. Meanwhile, the UA CMS line 873A will be grown for test crossing. At the heading stage, panicles from five randomly selected plants from each row will be carefully collected and used for test crossing. If there is only one restorer gene in the restorer line, the phenotypic ratio of fertility restoring of 3R:1S will be expected. If there are two restorer genes in the restorer line, the phenotypic ratio of fertility restoring of 15R:1S will be expected. Once completed, CRISPR (Clustered regularly interspaced palindromic repeats) system will be used to identify the exact *Rf* gene within the target region. When the restorer gene and its location have been identified, molecular marker(s) can be designed for marker-assisted selection to produce male sterile lines.

Field-based Heat Tent and Computer Technology Systems for Phenomics of High Night Air Temperature Stress Tolerance in Rice

Quiñones, C.O., Larazo, W.M., Mendez, K.V., Harris, R.S., Cunningham, S.S., Campbell, Z.C., Aniemena, C.L., Medina-Jimenez, K., Walia, H., Lorence, A., and Adviento-Borbe, A.

Rice (*Oryza sativa* L.) is one of the major sources of calories for people worldwide. The USA is among the top global exporters and Arkansas produces ~50% of all USA rice. The production of rice is highly affected by increasing global air temperatures. High nighttime air temperature stress affects both rice yield and grain quality. The responses of rice to high nighttime air temperature stresses have been tested in few genotypes mostly under greenhouse conditions. One of the limitations in implementing these studies is the lack of high throughput phenotyping methods for field conditions. The physiological responses of rice to high nighttime air temperature stress are not yet fully elucidated, thus, further studies need to be conducted. In this study new infrastructure consisting of six heat tents fitted with phenomics sensors are being established in a state-of-the-art field experimental station in Arkansas. These tents were equipped with retractable roof, solar-powered and fitted with light deprivation features; 320 rice accessions from the Rice Diversity Panel 1 were grown in each tent in a randomized complete block design. At flowering stage three of the tents were heated at night at 3-4ºC higher than ambient air temperature to assess tolerance to high night air temperature stress in the panel. Integrated temperature control, humidity control, and light sensors were deployed to record data throughout the growing period. These studies will lead to the identification of novel markers that can be used by rice breeders and molecular biologists to develop rice varieties that are more resilient to high nigh air temperature stress.

Seed Increase of Six Temperature-Sensitive Genic Male-Sterile (TGMS) Lines for Parental Hybrid Rice

Yan, Z., Wilson, L.T., Christensen, E., Martin, L., and Samonte, S.O.P.B.

The success of a hybrid rice cultivar is often thought to be defined by the cost of producing the hybrid seed and the grain quality and yield obtained by growing a crop planted with hybrid seed. However, the true cost of hybrid production includes not only the hybrid seed but also the production of male-sterile, maintainer, and restorer seed for 3-line breeding, and male-sterile and restorer seed for 2-line breeding. The research presented herein describes results from a replicated study conducted in 2018 and 2019 at the Texas A&M University AgriLife Rice Research Center in Beaumont, Texas, to assess the impact of sowing date on seed production of temperature-sensitive genic male-sterile (TGMS) lines as part of our 2-line breeding program.

Six F_{8-9} TGMS lines, 195s, 212s, 259s, 265s, 277s, and 279s, were evaluated across 4 planting dates in a replicated study in both 2018 and 2019. Each line was produced by crossing a temperate or tropical japonica cultivar with an indica maintainer line. F_2 plants that segregate for semi-dwarf height and TGMS sterility were then crossed with either the original indica maintainer or with another indica maintainer having one or more desirable traits. Segregant F_2 plants from this cross that possess TGMS sterility are further selected and planted during cooling weather to produce seed. The TGMS lines were sown in the greenhouse on July 6, 16, 26 and August 5 in both years, then transplanted into the field when 15 days old, with each plot consisting of two rows spaced 30.5 cm apart with 10 transplants 15.2 cm apart in each row (21.6 transplants/m^2). Panicles were harvested 40 days after heading, with yield (kg/ha), sowing date to crop harvest, percent seed set, and plant height from the base of the plant to the height of the upper most part of the panicle recorded.

The effects of *Year*, *Sowing Date*, *TGMS Line*, and the associated 2-way and 3-way interactions were estimated using a factorial analysis of variance. Tukey's HSD statistic was used to determine significant differences comparing levels within each main effect and within each interaction.

Each main effect and all of the interactions were significant for each of the four response variables. The greatest percent of variability was explained for *Seed Set Percent* (98.2%), followed by *Sowing to Heading Days* (94.9%), *Yield* (94.6%), and *Plant Height* (94.4%). *Year* had the greatest impact on *Yield* followed by *Sowing Date. TGMS line* had the greatest impact on *Sowing to Heading Days*, followed by *Sowing Date*. *Year* had the greatest impact on *Seed Set* followed by *Sowing Date*. So*wing Date* had the greatest impact on *Plant Height* followed closely by *Year*. The level of explained variability was considerably higher than the authors had expected.

The TGMS lines are normally male-sterile during the heat of the summer, allowing for effective crossing with restorers to produce hybrid seed. In contrast, TGMS lines become self-fertile when temperatures cool later in the season allowing self-propagation of the TGMS lines. The last three years experienced high levels of rainfall (> 2.0 m), with the timing of the rainfall having a limited effect in 2018 but resulting in extremely poor seed set in 2019 for five of the six TGMS lines, with the exception of 277s. For the 2018 study, the six TGMS lines averaged 1,259 to 2,155 kg/ha, when averaged across sowing dates, but only 154 to 1,203 kg/ha in 2019. For both years, the highest grain yield was achieved with the earliest sowing dates when averaged across TGMS lines, progressively decreasing with each successive sowing date. These results suggest sowing dates should be tested that are one or two weeks earlier that tested herein. These results also are indicative of the problematic nature of 2-line hybrid breeding during some years due to the unpredictability of late season wet and cooling weather patterns.

Phenotypic Responses of California Rice Varieties to Cold Stress during Seed Germination, Seedling, and Reproductive Stages

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

Cultivated rice variety that is capable of surviving and productive under cold stress is ideal. However, cold tolerance in rice is a complex trait and controlled by several genes. Moreover, rice have different cold tolerance at different rice stages. In an effort to understand the level of cold tolerance existing in California rice varieties, fifty-two genotypes were subjected to cold stress during seed germination, seedling stage, and reproductive stage. Based on seed germination test at 8°C for 30 days, all California rice varieties including the NPE 835 are not capable of seed germination. However, after one week of recovery at 30°C, M5, CH202, Calrose 76, M103, M201, and M205 showed high germination rate indicating cold tolerance. Cold stress imposed during seedling stage indicated that two-week old seedlings are more sensitive to cold stress than one-week old seedlings. Result of seedling stage cold stress screening indicated that M201, M206, M207, M210, M401, CS-S4, CM101, and S-202 have high degree of cold tolerance. For cold stress during reproductive stage, rice genotypes were subjected to 55°C night cold stress in refrigerated greenhouse starting at booting stage until maturity. Significant differences were observed between varieties. Panicle blanking induced by cold stress ranged from 1% to 65% with the majority of California released rice varieties having high degree of cold tolerance.

Abstracts of Papers on Plant Protection
Panel Chair: Jeff Gore and Tom Allen

Rice Pathology Research in Louisiana

Groth, D.E.

Research on sheath blight, blast, bacterial panicle blight, and narrow brown leaf spot have been ongoing for many years. This has included cultural management, host resistance, and chemical control. Thousands of rice lines have been screened for resistance over the years to multiple diseases, and many very susceptible lines have been eliminated. Hundreds of chemical compounds have also been field tested for activity against multiple rice diseases, and a number of these chemical compounds has been labeled for commercial use. Cultural control methods have been developed that significantly reduce the damage rice diseases cause.

Resistance to the major diseases has increased in current varieties. Very few varieties are very susceptible to sheath blight, and the susceptible ones are more tolerant to sheath blight. The percentage of narrow brown leaf spot-susceptible varieties has decreased. New blast resistance sources are being incorporated, and the percentage of varieties rated very susceptible and susceptible to blast has also decreased.

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

EXCALIA™: A New Fungicide for Control of Rice Sheath Blight

Seebold, K.W., Carey, F., Meador, C., Everett, M., and Corbin, R.

EXCALIA™ is a new fungicide under development by Valent U.S.A. LLC for control of major diseases of apple, corn, peanut, potato, rice, soybean, sugar beets, and wheat; seed treatment, foliar, and soil uses are being registered. The active ingredient of EXCALIA is inpyrfluxam, which will be registered as INDIFLIN®, and EXCALIA brands based on INDIFLIN technology will be marketed. Inpyrfluxam is a succinate-dehydrogenase inhibitor (SDHI) and is in the pyrazole-4-carboxamide group (FRAC group 7). Inpyrfluxam is highly active against *Rhizoctonia solani* (including AG1-IA, the anastomosis group that causes rice sheath blight), *Sclerotium rolfsii*, and rusts (including *Phakopsora pachyrhizi* and *Gymnosporangium juniperi-virginianae*). *In vitro* studies have demonstrated strong inhibition of *Rhizoctonia solani* AG1-IA, with EC_{50} values between 0.001 and 0.003 ppm. Inpyrfluxam exhibits local-systemic and translaminar movement when applied to foliage. EXCALIA delivers excellent control of rice sheath blight at use rates between 50 and 100 g ai/ha (0.044 and 0.089 lb ai/A) and has strong residual activity. In 20 field trials conducted between 2014 and 2018, a single application of EXCALIA prior to early boot reduced sheath blight severity by 63% and increased yield by 20% compared to untreated rice. These data included fields where QoI-resistant *R. solani* was documented. EXCALIA provides effective and consistent control of disease as well as excellent yield protection and will be a useful tool for rice growers to use for management of sheath blight, as well as for managing QoI resistance in *R. solani*. Registration of EXCALIA by EPA is anticipated by August 2020 and product launch will be in 2021.

Endigo® ZCX: Enhanced Control of Rice Insect Pests

Jackson, R., Black, B.D., Moore, S., and Koenig, J.

Endigo® ZCX is a novel, optimized formulation of the Endigo® brand that contains three technologies to ensure robust control of rice insect pests. These consist of lambda-cyhalothrin and thiamethoxam, two complementary modes of action that provide quick knockdown and residual activity. Endigo® ZCX also includes the novel Zeon® Technology encapsulation that affords UV protection, improved rainfastness and residual, and stronger adhesion to plant surfaces. Endigo® ZCX is formulated as a ZC type and contains 216 g ai/liter (1.8 lb ai/gal) of thiamethoxam and 108 g ai/liter (0.9 lb ai/gal) lambda-cyhalothrin, and has a proposed use rate of 0.33-0.44 liter/ha (4.5-6.0 oz/acre) in rice. This premix has demonstrated improved efficacy against a broad spectrum of rice insect pests, including certain pyrethroid-resistant insects.

Pest Status of the Stink Bug (Hemiptera: Pentatomidae) Complex Infesting Rice in the Everglades Agricultural Area of Florida

VanWeelden, M.T., Cherry, R., and Karounos, M.

Florida's rice stink bug complex is comprised of three species; *Oebalus pugnax* (F.), *O. insularis* (Stal), and *O. ypsilongriseus* (DeGeer), the latter two of which are invasive and exclusive to Florida within the continental United States. Historically, stink bugs (*Oebalus* spp.) have been the primary arthropod pest of rice in the Everglades Agricultural Area (EAA) of Florida, located southeast of Lake Okeechobee. The most recent surveys in 2009 estimated the relative abundance of each species to be 54% for *O. pugnax*, 20% for *O. insularis*, and 18% for *O. ypsilongriseus*; however, the expansion in rice acreage over the past decade has warranted the need to reassess the relative abundance of each species. Thus, a study was conducted in 2017 and 2018 to determine potential changes in the relative abundance of this pest complex.

Sampling for *Oebalus* spp. Was conducted in 2017 and 2018 in and adjacent to commercial rice fields within Florida's rice production region. A total of 38 sites were sampled across both years. Within each year, sampling was divided among three sampling periods to assess seasonality. Each site consisted of a commercial rice field and an adjacent transect of non-crop graminaceous host plants. Three, 50 sweep samples, were collected at three locations (40, 80, and 120 m from the field edge) within each rice field. Three, 50 sweep samples were collected in each non-crop transect following a linear path adjacent to the rice field. Samples were returned to the lab for identification.

A total of 4,536 stink bugs within the genus *Oebalus* were collected from rice fields and adjacent non-crop hosts. In 2017, species composition as percentages of the total were 52.7 (*O. pugnax*), 44.0 (*O. insularis*), and 3.3% (*O. ypsilongriseus*). In 2018, species composition as percentages of the total were 32.7 (*O. pugnax*), 61.7 (*O. insularis*), and 5.6% (*O. ypsilongriseus*), indicating an increase in relative abundance of *O. insularis*. Densities of *O. pugnax* and *O. insularis* were 2.3 and 2.2 times greater, respectively, in rice than in non-crop hosts; however, densities of *O. ypsilongriseus* did not differ between host types. Areawide populations of *O. pugnax* and *O. insularis* peaked in mid to late summer, while *O. ypsilongriseus* populations peaked towards the latter part of the rice season.

These results suggest that *O. pugnax* and *O. insularis* are now the most abundant stink bug pests of rice in Florida. Managing the three *Oebalus* spp. As a complex should be a priority for rice growers in the EAA. Future studies should focus on developing economic thresholds that reflect injury caused by all three species as a complex, in order to minimize pesticide applications and reduce environmental contamination.

Rice Stink Bug Management in Arkansas Rice Production

Bateman, N.R., Lorenz, G.M., Thrash, B.C., Cato, A.C., Taillon, N.M., Felts, S.G., Plummer, W.A., Plummer, W.P., McPherson, J.K., Floyd, C.A., and Rice, C.

Rice stink bug is a major pest of heading rice and can cause both quality (peck) and yield losses. In 2019, large populations of rice stink bug were observed in Arkansas, and many fields required multiple insecticide applications to achieve an acceptable level of control. Currently there is a limited number of products available for growers to use for control of rice stink bug. Most of these products are pyrethroids, such as Warrior II and MustangMaxx, which have little to no residual control of rice stink bug but are relatively inexpensive. Tenchu, a neonicotinoid, is also labeled for use but is more expensive than pyrethroids. It is imperative that we evaluate all chemical control options for controlling rice stink bug on a yearly basis to keep growers profitable and to ensure sound management recommendations.

In 2019, large block trials were conducted at three locations in Arkansas, where fields were split with Tenchu and Warrior II. Plots were a minimum of 10.1 ha (25 acres) in size. All applications were made with an airplane at 28.1 L/ha (3 gallons/A). Plots were sampled at 3, 7, 10, 14, and 17 days after application. If stink bug populations exceeded threshold after the initial application, the plot was resprayed.

At all three locations, no differences were observed between Warrior II and Tenchu for control of rice stink bug. Similar numbers of rice stink bugs were observed at all sample dates between Warrior II and Tenchu. Only one location had to be resprayed, where rice stink bugs exceeded threshold for both Warrior II and Tenchu at 10 days after application. All other locations never exceeded threshold for either product after the initial application.

Toward Understanding of Rice Innate Immunity to Rice Blast Fungus

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

The fungus *Magnaporthe oryzae* causes rice and wheat blast diseases and both diseases are major threats to global food security. Understanding rice innate immunity to *M. oryzae* can help to prevent rice and wheat crop losses. Major resistance I genes in rice are known to be useful to prevent damage caused by *M. oryzae* strains carrying the corresponding avirulence (*AVR*) genes. In this study, we conducted marker and sequence analysis of *R* genes *Pi-ta/Ptr* and *Pi-k* in US rice varieties and *AVR* genes *AVR-Pita1*and *AVR-Pik* isolated from blast strains found in rice fields over a period of 6 decades where known cultivars were grown. We found that *Pi-ks* and *Pikm/h* deployed in varieties tracing back to 1966 and *Pi-ta/(Pi-ta2/Ptr)* was deployed in varieties grown since 1991 in different areas in the southern United States. We analyzed over 1000 historical blast strains using PCR with *AVR* gene specific markers and found that most blast strains carry *AVR-Pita1* and one third of which carry *AVR-Pik*. Sequence analysis of PCR amplicons demonstrated that there were 32 different AVR-Pita variants of which variant 24 is the most abundant from the 70s to 2010s, and 10 AVR-Pik variants of which variant 2 is the most abundant from the 80s to 2010s. Regression analysis of these two pairs of *R* and *AVR* showed the same trend of papulation shifts, and diversification of *AVR* genes in pathogen approximately 5 years after *R* gene deployment suggesting that host *R* genes influenced genetic changes of the pathogen. Implications of this for crop protection will be presented.

Identification of GWA-QTLs and Germplasm Useful for Enhancing Sheath Blight Resistance

Eizenga, G.C., Pinson, S.R.M., Li, D., Zhang, F., Edwards, J.D., and Jackson, A.K.

Sheath blight (ShB) disease is one of the most economically damaging rice (*Oryza sativa* L.) diseases worldwide, reducing grain yields up to 50%. The causal agent, *Rhizoctonia solani* Kühn, is a soil-borne fungus that spreads by runner hyphae. There are no known major resistance genes, only partial resistance, and many reported ShB-QTL are associated with plant architectural traits detrimental to grain yields such as tall height, late maturity, wide culm angle, or reduced tiller number (TN). To date, only three genes have been fine-mapped, one on chromosome (chr.) 9 at 21.4-21.5 Mb, and two on chr. 11 at 4.8-4.9 Mb and within 27.0-28.3 Mb. Also, a *R. solani* phototoxin gene, *Rsn1*, is on chr. 7 (18.1 Mb). To identify novel ShB QTL not confounded by plant architecture traits, genome-wide association

(GWA) mapping studies were conducted in both Arkansas, United States and Nanning, China, and accessions carrying potentially novel resistance alleles were identified for use as breeding donor parents.

This study included 417 Rice Diversity Panel 1 (RDP1) accessions from the five major subpopulations, *indica* (99 accessions), *aus* (62), *tropical japonica* (109), *temperate japonica* (116), *aromatic* (15) and 16 admixtures. RDP1 was evaluated for ShB disease with the greenhouse microchamber (MC) method (both locations, 3 reps), and field studies in Arkansas (two years, 2 reps) and Nanning (one year, 3 reps) using local *R. solani* isolates. The disease index was calculated from the lesion length for the MC studies. ShB disease was rated on a "0" (no disease) to "9" (nearly dead) scale and days to 50% heading (DH) and plant height (PH) measured for the field studies. RDP1 was evaluated for TN at early and late tillering (3 reps), and panicle number (PN) in the greenhouse in Arkansas.

Using the SAS 9.4 generalized linear mixed model procedure, both Lsmeans and BLUPs were calculated for the ShB, PH and DH data, and BLUEs for the TN and PN data. Summary statistics, correlations and regression analyses were conducted in JMP 14. For RDP1 GWA mapping, the mixed linear model in Tassel 5 was used with the 700K SNP genotypes for 396 accessions. As validation, the GWA mapping of the previously reported ShB MC data on the Rice Minicore Collection (RMC) was analyzed with the 3.2 million SNPs for 173 accessions.

Overall, disease severity was higher in Nanning than Arkansas. Based on MC disease index data, more resistant accessions were found in *indica* than other subpopulations. Arkansas field data identified 21 resistant *indica* accessions but only 11 in Nanning, six of which were resistant in both environments. Eight *tropical japonica* accessions were resistant in Nanning field tests but only two in Arkansas and none in common, suggesting differences between the local *R. solani* isolates. There was a strong correlation for ShB ratings between the Arkansas field trials but a low correlation between the field and MC ShB scores in both environments. Field ShB was highly negatively correlated with height in Arkansas, but positively correlated in Nanning, where RDP1 headed about 19 days earlier, and was shorter overall. Reduced ShB severity was associated with desirable increases in TN and PN.

GWA ShB-QTL were selected from regions with only a few or no significant SNPs associated with PH or DH because many prior ShB-field QTL were confounded with undesirable PH and DH. Significant SNPs were then surveyed to find ShB-QTL regions where field and MC QTL overlapped, Arkansas and Nanning QTL overlapped, or where either the field or MC QTL were supported by multiple SNPs. Ten ShB QTL regions were chosen: *qShB3* (17.7-20.8 Mb), *qShB4* (24.4-24.9 Mb), *qShB5* (7.6-8.5 Mb), *qShB6-1* (6.5 Mb), *qShB6-2* (23.0 Mb), *qShB7* (19.8-24.2 Mb), *qShB9* (21.2 Mb), *qShB10* (4.9-5.3 Mb), *qShB11* (16.4-20.9 Mb) and *qShB12* (14.1-17.7 Mb). Across these ShB-QTL, four were associated with field ShB in both Arkansas and Nanning, supporting the low correlation between the two environments. Seven RDP1 ShB-QTL were validated by RMC GWA-QTL, and four were near ShB QTL recently reported using 299 RDP1 accessions and fewer (44K) SNPs. Previously fine-mapped genes were in the *qShB9* and *qShB11* regions, and *Rsn1* in the *qShB7* region. A brief survey of the candidate genes in the ten ShB QTL regions revealed several putative genes associated with defense response to pathogens or as a response to biotic stress. Of interest is *qShB3* which has several genes associated with plant defense against biotic and abiotic stresses and has been reported in several other studies related to stress.

Five TN-QTL were identified, two each on chr. 4 and 12, and one on chr. 6. The two PN-QTL were co-located with *qTN4-2* and *qTN12-2*, which co-located as well with *qShB4* and *qShB12*. Interestingly, at *qShB4* and *qShB12*, the ShB resistance was coupled with increased TN and PN which could be used to increase both grain yield and ShB resistance. Additional mapping studies are needed to clarify the genes underlying *qShB3*, *qShB4* and *qShB12*. Four resistant RDP1 accessions containing multiple resistance alleles may be particularly useful to breeders.

Development and Characterization of Sheath Blight-Resistant Lines in Rice

Galam, D.C., Sanabria, Y.G., Groth, D.E., Famoso, A.N., Anjira, B., and Oard, J.H.

Sheath blight disease caused by the fungus *Rhizoctonia solani* leads to substantial reductions in grain yield and quality in southern U.S. rice growing regions. The negative impact of sheath blight and blast diseases on commercial production in Louisiana was particularly high from 2016 to 2019. If cool, wet growing seasons are the "new normal", then a renewed effort in disease resistance should be carried out using a combination of traditional and modern breeding approaches. Most commercial varieties are susceptible to sheath blight with the exception of hybrids that show moderate levels of resistance to *R. solani*. The objective of our research was to develop and characterize new elite inbred lines showing resistance to sheath blight, high grain yield, and excellent milling quality.

Three major research areas over 10 years consisted of (1) population development and SNP marker selection (2) marker validation and selection of new inbred and doubled-haploid lines, and (3) development of elite inbred lines with moderate sheath blight resistance, high grain yield, and good grain quality. In the first research area, extreme resistant and susceptible lines from the SB2 RiceCAP mapping population were identified and genotyped with SNP markers. For the second area, a subset of the selected SNP markers was genotyped in several commercial varieties, lines and doubled-haploids with known levels of sheath blight resistance. The third phase leveraged selected SNP markers and traditional breeding methods to develop new lines with sheath blight resistance, high grain yield and good milling quality.

During this research project we found that (1) adapted lines already present in university and USDA seed stocks are useful for elite line development (2) SNP haplotypes for sheath blight resistance are conditional on the source of resistance (3) common genomic regions are present in different resistant parents and progeny (4) genomic selection with genome-wide and selected SNP markers will be the best approach to develop new sheath blight-resistance varieties in an applied breeding program. (5) Pathologists and agronomists will be crucial partners with breeders to develop and characterize training populations for genomic selection and validate elite breeding material.

Evaluation of Water Volume for Coverage in Fungicide Application to Manage Rice Sheath Blight

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

Sheath blight caused by *Rhizoctonia solani* AG1-A is the most prevalent disease of rice in Arkansas where nearly 50% of the United States' rice is produced. Over 57% of rice fields in Arkansas receive at least one fungicide application most of which is to manage sheath blight. However, in some commercial fields that used low water volume to apply the fungicides, disease suppression has been low. In our field experiment in 2019, about 11-, 38-, and 76-liter/ha (LPHa) (i.e., 3-, 10- and 20-gallon per acre (GPA)) rate water were used to deliver Amstar Top and Quilt Xcel fungicides. The former was applied at a rate of 1.5 L/ha (15 oz/A) and the latter at 1.1 L/ha (21 oz/A). These products were applied between panicle initiation and differentiation using a MudMaster sprayer in artificially inoculated rice variety, CL163. About 200 g of *R. solani* AG1-A in a rice and corn carrier were applied to each plot of 13.9 m^2 (150 ft^2). Each treatment was in four replications. The fungicides were applied a week after plots were inoculated. Vertical and horizontal disease ratings were taken three times – 21, 28 days after application (DAA) and a week before harvest. Disease index was calculated to combine the vertical and horizontal ratings. Disease index, grain yield test weight, total and head yield data were analyzed. Overall analysis showed no significant differences between Amistar top and Quilt Xcel in sheath blight suppression. There were significant differences between the unsprayed and the sprayed plots in sheath blight progress throughout the season. There were significant differences in grain yield between the sprayed and unsprayed plots but no significant differences in test weight, total and head yield. Plots that received the fungicides with 11 LPHa water were not significantly different from the unsprayed plots. While plots sprayed with 38 or 76 LPHa water were significantly different from unsprayed plots and those that received 11 LPHa water all across the three disease indices and grain yield. This study confirmed the importance of adequate coverage to increase fungicides efficacy. Coverage as high as 38 LPHa or 76 LPHa water showed clear differences in disease suppression and yield increase from unsprayed check and 11 LPHa treatment.

Recent Advances in USDA's Blackbird Repellents Research

Werner, S.J., and DeLiberto, S.T.

In the last decade, the progress of the Repellents Research Project at USDA's National Wildlife Research Center includes the development of novel repellent formulations for wild birds associated with rice crop damage. Bird pests for U.S. rice are primarily comprised of blackbirds, including red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*) and brown-headed cowbirds (*Molothrus ater*). Wildlife repellents are notoriously difficult to apply at concentrations that cost-effectively protect the commodity while remaining safe for human consumption and the environment. Our research regarding avian repellents and visual cues has resulted in novel formulations that are based upon repellent efficacy and species-specific visual ecology. These formulations provide increased repellency at lower concentrations of the anthraquinone-based active ingredient plus specific combinations of visual cues. These formulations are now being developed with commercial and small business cooperators for the non-lethal management of human-wildlife conflicts and the cost-effective protection of newly planted and ripening rice. USDA's Wildlife Services program will continue to provide Federal leadership and expertise for the management and research of blackbird impacts to U.S. rice production.

Addressing Armyworms in California Rice Through Outreach and Research

Espino, L., and Grettenberger, I.

Armyworms have been considered a secondary pest in California rice. Outbreaks have occurred, but they have not been severe according to those working in the industry for more than 25 years. In late June 2015, a true armyworm (*Mythimna unipuncta*) outbreak caught the industry by surprise, causing severe defoliation in many fields. Growers and pest control advisers tried to control infestations with available insecticides such as pyerthorids, carbaryl, and malathion, with very poor results. The industry was able to obtain a Section 18 registration for the insecticide Intrepid (methoxyfenozide). However, the registration was approved in late August when the outbreak had passed. Several fields suffered yield losses. Since then, armyworm pressure has remained high every year, causing defoliation mid-season and panicle injury during the heading stage. Growers and advisers rely on Intrepid, Dimilin (diflubenzuron) and pyrethroids for control.

Armyworm monitoring is challenging. Moths fly at night, and their eggs are rarely found in rice or surrounding vegetation. Small armyworms are difficult to find and scouting for larger larvae is physically demanding and time consuming. When defoliation is noticeable, armyworms are already on the 5th or 6th instar, and they are much more difficult to control using insecticides. Thresholds for armyworm insecticide applications were developed in California during the late 1970s. The threshold for mid-season infestations recommends an insecticide application only if defoliation is larger than 25% and larvae are still present in the field. Because of fast larval development during the summer months, defoliation can increase very quickly, making the correct timing of treatments difficult.

To improve armyworm monitoring, an armyworm pheromone trapping network was established across the rice production area of the Sacramento Valley in 2018 and 2019. Two armyworm species, the true armyworm and the western yellostriped armyworm (*Spodoptera praefica*), were monitored in fifteen fields weekly from seeding to rice maturity. In each field, three pheromone bucket traps per species were maintained, and the number of moths trapped counted weekly. Lures (Trece Inc.) were changed every two weeks and kill strips every four weeks. In 2019, at three locations, larvae were collected weekly in a basin near one of the traps. Insecticide trials with registered and experimental products were conducted in 2018 and 2019. In 2019, the effect of defoliation on plant height, heading time, and yield was evaluated by cutting 25, 50 or 100% of variety M-206 foliage above the water line (25% per day) in 9 m^2 plots.

The results of pheromone trapping were communicated to approximately 2,500 growers and advisers via e-mail weekly. Each week, monitoring recommendations, armyworm images, and threshold reminders were also shared. These updates resulted in growers and advisers becoming more familiar with armyworm population dynamics, thresholds, and monitoring timing. There was quite a bit of variation among locations in the weekly number of moths caught, but averaging all fields, true armyworm moth numbers started to increase in early June, increased quickly through June, and reached a peak of about 25 moths/trap/day during the first week of July. After this peak, numbers dropped close to zero, and rebound again in early August, reaching a peak of 10 (2019) to 20 (2018) moths/trap/day in mid-August. Western yellowstriped armyworm moth numbers were very low during 2018 and peaked to 30 moths/trap/day during mid-May in 2019; however, both years, western yellowstriped armyworm larvae were not found in rice fields in any significant numbers. True armyworm field larval monitoring showed that the highest number of larvae were found when moth catches peaked in the pheromone traps.

Larvae control 7 days after treatment with Intrepid ranged from 90 to 100%; Prevathon (chlorantraniliprole) resulted in 100% control, Dimilin 80 to 90%, and Warrior (lambda-cyhalothrin) 30 to 70%. Intrepid also had the fastest activity, with significant higher larval mortality 3 or 5 days after treatment. In the defoliation trial, defoliation of rice to the water level resulted in plants that were 20% shorter, a 12-day delay in heading, and a 25% yield reduction with respect to the control. Defoliation of 25 or 50% of foliage did not have a significant effect on plant height, heading time, or yield.

Preference and Performance of the Rice Stink Bug, *Oebalus pugnax* on Different Rice Cultivars

Bhavanam, S., and Stout, M.J.

The rice stink bug, *Oebalus pugnax* F. (Hemiptera: Pentatomidae) is a serious pest of heading rice, *Oryza sativa* L. in the southern United States. The overwintering adults emerge in spring and initially feed on available graminaceous weeds. They move into rice fields when rice plants start to head. Feeding by rice stink bugs on developing rice grains incurs both quantitative and qualitative losses. Because of the brief period that this insect attacks rice, management relies mainly on application of chemical insecticides. However, heavy reliance on insecticides may lead to development of resistance. Therefore, identifying alternate tactics is warranted. Understanding the behavior and biology of rice stink bugs may aid in the development of sustainable pest management tactics. For this purpose, a series of experiments were designed to investigate the preference of *O. pugnax* for rice panicles of different ages. In addition, the growth and development of rice stink bugs on different rice cultivars was examined to determine the resistance of rice cultivars to rice stink bug development. Some studies have been completed and few others are underway.

To investigate the relative attractiveness of panicles of different ages to rice stink bugs, the rice cultivar "Cocodrie" was grown in greenhouse. At heading, panicles were checked daily and tagged on the day of anthesis. Panicles at three different ages after anthesis were selected, that is, 1 d- (flowering stage panicles), 7 d- (panicles in milk and soft dough stage), and 14 d- (panicles in hard dough stage), cut 10 cm below the peduncle of flag leaf and placed in a floral water tube that contained water. PVC cylinders with four holes at the bottom were used to construct arenas for the choice tests. Each panicle was inserted into the arena through a hole up to the panicle axis node and the hole was sealed with a foam plug. Thus, the arena consisted of panicles of three different ages and control (hole with no panicle and closed with foam plug). Then five adult rice stink bugs were released in the center of each arena (equidistant from the three panicles) and the top was covered with metallic fine mesh. After 1 h, 2 h, 4 h, 18 h and 24 h of adult release, the location of the rice stink bugs (on one of the three panicles or on the top or bottom of the arena) was noted. Each arena was considered as a replicate and four replicates were set up each time. The entire experiment was repeated four times.

A laboratory study was conducted to examine the growth and development of rice stink bugs on two experimental rice lines ("cy497-16", "cy009-15") that are high in protein. Cypress was used as check. All three cultivars were grown in greenhouse during summer of 2019. When plants began to head, panicles were tagged daily on the day of anthesis. The panicles that were in milky and soft dough stage (8-15 d after anthesis) were used for the experiment. For each cultivar, a panicle was cut with at least 10 cm stem and placed in a plastic box with the stem inserted into a floral tube with water. Following, each panicle was infested with six second-instar nymphs. After infestation, all plastic boxes were covered with lid that had ventilation holes covered with fine mesh to prevent nymph escape. Nymphs from a single egg mass were split among the cultivars of each replicate. Eight replicates were performed. The panicles were changed every 3rd day until all surviving nymphs molted to adults. For each replicate of each cultivar, nymphal survival and development time was recorded. After emergence, adults were sexed and chilled for 5 minutes at 4^{o}C and their weight was recorded with an analytical balance with an accuracy of 0.1 mg.

Results showed no preference for panicles of different ages between at 1 h and 2 h after adult release. However, after 4h, significantly greater numbers of rice stink bugs were found on panicles at 7d-after anthesis. Nymphal development time, survival to adult stage, and adult male and female weight did not differ among the high-protein cultivars and Cypress. Studies examining the resistance of different rice cultivars (long grain, medium grain and aromatic) to rice stink bug development and *O. pugnax* preference for these cultivars are underway. Future studies will include identification of volatiles emitted by different age panicles. In addition, behavioral responses of rice stink bug to visual cues will be examined.

Seed Treatment Combinations for Management of the Rice Insect Pest Complex in Louisiana

Wilson, B.E., Villegas, J.M., Landry, K.J., and Mulcahy, M.M.

Prophylactic seed treatments are widely used in rice production in the U.S. Mid-South to control early season insect pests and fungal pathogens. There are four insecticide active ingredients for control of the rice water weevil (*Lissorhoptrus oryzophilus*) in addition to several fungicides currently registered as rice seed treatments. The spectrum of insect pests controlled differs among insecticides, as does the level of weevil control achieved. This study aims to identify the combinations of seed treatments that will provide optimal early season plant protection and provide the greatest economic benefit to Louisiana growers.

A series of field trials was conducted during the 2018 and 2019 growing seasons at the LSU AgCenter H. Rouse Caffey Rice Research Station at Crowley, LA that examined effects of rice seed treatments alone and in combination on insect pests and rice yields. No differences in seedling populations were observed among treatments in any of the trials. In the 2018 trial, only treatments containing chlorantraniliprole (Dermacor X-100) reduced weevil larvae compared to non-treated and fungicide only plots. Infestations of stem borers did not differ among treatments in the main crop, but chlorantraniliprole treatments reduced borer injury (whiteheads) in the ratoon crop relative to plots treated with thiamethoxam (Cruiser) alone. In both an early- and late- planted trial in 2019, all insecticidal seed treatments reduced weevil larval densities relative to non-treated controls and fungicide only treatments. The greatest level of control was achieved with treatments containing chlorantraniliprole or a combination of thiamethoxam and cyantraniliprole (Fortenza). Treatments containing chlorantraniliprole alone or in combination with thiamethoxam reduced whitehead density relative to all other treatments in the late planted 2019 trial. Rice yields were greater in plots treated with chlorantraniliprole or cyantraniliprole over plots treated with thiamethoxam alone and non-treated plots. Plots that received fungicide did not improve yield over the equivalent treatments without fungicide in any of the three trials.

Results indicate optimal weevil control is achieved with chlorantraniliprole seed treatment or a combination of cyantraniliprole and thiamethoxam. Thiamethoxam alone does not provide sufficient weevil control and additional products may be needed to protect yields in south Louisiana. Only chlorantraniliprole treatments provide stem borer control, but this may not provide yield benefits in many situations. Benefits of fungicidal seed treatments were not observed under naturally occurring pathogen pressure in our trials, suggesting these may not be economical in some situations.

Update on Rice Planthopper/Delphacid in Texas

Way, M.O., Pearson, R.A., Ruth, K., Eure, P., Badillo-Vargas, I., Martin, J., and Cruz, M.

The rice planthopper/delphacid, [*Tagosodes orizicolus* (Muir)], is native to Latin America and the Caribbean where it is a key pest of rice causing direct feeding damage (hopperburn) and transmission of *Rice hoja blanca virus* (RHBV). This pathosystem can cause up to 100% yield loss in Latin American rice fields. *T. orizicolus* and RHBV symptoms were detected in Louisiana, Mississippi and Florida rice fields in the 1950s, 1960s and 1980s. Recently, the insect has been found attacking Texas ratoon rice in 2015, 2018 and 2019. Texas rice farmers and crop consultants have been alerted and informed of this pest since its recent reappearance in 2015. In response to this threat, the Texas Department of Agriculture and 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 2021 field seasons in Texas. This Exemption was granted based on data provided to the regulatory agencies by the authors showing the actual and potential impact of this exotic pest as well as data from a small plot replicated experiment conducted by P. Eure in an infested field in 2018. Endigo ZC gave over 90% control of both nymphs and adults. In 2015 and 2018, populations of both nymphs and adults were large and damaging. However, in 2019, populations were lower, possibly due to farmers spraying with Endigo ZC when insects were initially detected in their fields.

With the help of I. Badillo-Vargas and J. Martin with Texas A&M AgriLife Research and M. Cruz with the International Center for Tropical Agriculture (CIAT) and the Fondo Latinoamericano para Arroz de Riego (FLAR), insects collected in 2015 and 2018 from infested fields in Texas were tested individually and in pools for RHBV infection and the cytochrome oxidase 1 (CO1) gene from Delphacidae, respectively. No insects tested positive for RHBV; however, all samples yielded amplicons for the CO1 gene. Furthermore, the CO1 gene from five 2015 individuals was sequenced and found to have a 100% match to the Fer26_Argentina isolate and 99.8% match to the DEL074 isolate from Venezuela of *T. orizicolus.*

We are in the process of exchanging germplasm with M. Cruz to quantify resistance/susceptibility to *T. orizicolus* in selected U.S. lines and perhaps incorporating resistance/tolerance into US germplasm. Endigo ZC contains a pyrethroid insecticide which under sustained or prophylactic use can negatively affect populations of natural enemies of *T. orizicolus* causing possible pest resurgence. For this reason, varietal resistance should be a key component in the integrated management of this pathosystem.

Silicon: The Essential "Non-essential" Nutrient for Combatting Biotic and Abiotic Stress in Rice

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

Silicon (Si) is considered a non-essential nutrient but is essential for rice under agronomic conditions. Rice readily accumulates Si at concentrations higher than nitrogen. Silicon is known to increase the resistance of rice to a number of biotic and abiotic stressors. Here we describe some of our work where rice was subjected to different stressors with different levels of Si present. In hydroponic, pot, and field experiments we demonstrate the ability of Si to decrease rice uptake of arsenic, a toxic metalloid, resulting in lower grain arsenic concentrations. In pot and field studies, we examined various Si-rich materials to determine their ability to supply Si over a long-term period. Materials investigated included silicate fertilizers, rice husk, and charred rice husk. All three materials continued to provide additional Si compared to an untreated control 3 years after amendment. In another hydroponic study, we examined the ability of Si to protect rice against rice blast (*Magnaporthe oryzae*) in the presence of a secondary stressor, arsenic. We observed that Si was able to decrease the severity of infection by rice blast with and without arsenic and was able to decrease as uptake with and without *M. oryzae* infection. Collectively, this and other research show that Si plays a crucial role in the robustness of rice and deserves additional attention as a crop nutrient.

Resistance of Hybrid and Inbred Rice to Sheath Blight and Narrow Brown Leaf Spot in Texas

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

Sheath blight, caused by *Rhizoctonia solani* AG1-IA, and narrow brown leaf spot (NBLS), caused by *Cercospora janseana*, are among the most important diseases affecting rice production in Texas and other southern United States. Cultivar resistance can be the most effective method to manage these diseases. With continuing increase of hybrid production acreage, field evaluation to determine and understand resistance of rice cultivars, especially hybrids, to sheath blight and NBLS under local environments is crucial for effective management of these diseases. The objective of this research was to evaluate disease responses of hybrid and inbred cultivars and lines under the Texas environments and characterize the differences in sheath blight and NBLS resistance between hybrid and inbred rice.

A disease nursery was established at Beaumont and Eagle Lake in Texas in each of four years (2016 to 2019) to evaluate disease severity in more than 200 entries that consisted of hybrid and inbred cultivars and breeding lines from Arkansas, Louisiana, Mississippi, Missouri, and Texas. These entries were arranged in a randomized complete block design with three replications. Each plot, 2.7 m long by 1.2 m wide, was inoculated with the sheath blight pathogen inoculum at PD plus 7 days. NBLS developed from natural inoculum in the field. Severities of both diseases were rated on a scale of 0 to 9, where 0 represents no symptoms, and 9 represents most severe symptoms and damage (leaves dead or plants collapsed) at cultivar maturity.

In each four years of evaluations, sheath blight severities in hybrid cultivars and lines were significantly lower ($P < 0.01$) than in inbred cultivars and lines for each location, with an average disease rating across years and locations of 4.8 vs. 6.7. Similarly, NBLS severities in hybrid cultivars and lines were significantly lower ($P < 0.01$) than in inbred cultivars and lines, with an average disease rating over years and locations of 0.1 vs. 2.8. The results demonstrate that hybrid rice is generally less susceptible to sheath blight and has a higher level of resistance against NBLS compared to inbred rice.

In Vitro and Field Evaluation of Fungicides for Control of Rice Kernel Smut

Zhou, X.G., Uppala, S., Liu, B., Guo, Z., Gaire, S., Lei, S., and Wang, L.

Kernel smut, caused by *Tilletia barclayana* (*Neovossia horrida*), has become an economically important disease of rice in California, Louisiana, Texas and other rice-producing states in recent years. The fungus infects and replaces the endosperm of rice grains partially or completely with a mass of black smut spores. The disease reduces rice yield and milling quality, resulting in significant monetary losses. Fungicides could be an effective tool for control of rice kernel smut. However, failures or reduced efficacy of fungicide control of the disease has been frequently reported across the rice-producing areas. The objectives of this study were to screen available fungicides and newly synthesized chemical compounds for control of the fungus *in vitro* and identify the best fungicides and application timing for control of the disease in the field.

Isolates of *T. barclayana* were isolated from infected grain samples. Sensitivity of these fungal isolates to 13 fungicides and 28 newly synthesized chemical compounds were evaluated at various concentrations on PDA plates. These fungicides contained azoxystrobin, fludioxonil, fluxapyroxad, mefenoxam, mancozeb, metalaxyl, tebuconazole and trifloxystrobin alone or in combination. In 2018 and 2019, a field trial was established to evaluate the efficacy of five fungicides and two newly synthesized chemical compounds applied at different growth stages (mid-boot, heading, and mid-boot plus heading) for control of kernel smut. Research plots were spray inoculated with the pathogen inoculum at the boot stage or infected from natural inoculum. Percentage of rice panicles with one or more kernels infected was determined after harvest.

In the *in vitro* study, fungicides containing propiconazole as the only active ingredient (Propimax and Tilt) were highly effective and showed complete inhibition of all the isolates evaluated at concentrations as low as 50 ppm. Other fungicides showed variable responses among the isolates and were not as effective as propiconazole. Among the 28 newly synthesized chemical compounds screened, 11 had antifungal activities similar to or greater than Tilt. In the field trials, azoxystrobin plus difenoconazole (Amistar Top) was most effective in reducing kernel smut incidence and followed by azoxystrobin plus propiconazole (Quilt Xcel), propiconazole (Tilt) and a newly synthesized chemical compound. Applications made at the mid-boot stage were effective in reducing the disease while applications made at the heading stage were ineffective.

ZELTERA 3.2 FS: A New Fungicide Seed Treatment for Rice from Valent USA, LLC

Meador, C.

Rhizoctonia solani is one of the most prominent diseases in Rice production. In past, producers have depended almost solely on Strobilurin chemistries to control this disease. However, in recent years, resistance has become prevalent, especially in the state of Louisiana. Valent is bringing a powerful, new mode of action to the seed treatment market called Zeltera. Zeltera is a Group 7 fungicide that provides excellent control of seedling Rhizoctonia disease and enhanced seedling vigor. The purpose of this presentation is to present data and information on this new SDHI fungicide and educate listeners on its many benefits. The desired outcome of this presentation and discussion is to make listeners aware of their seed treatment options in rice.

Survey of Fungal Pathogens Associated with Rice Seedling Diseases in the Southern U.S.

Gaire, S.P., Zhou, X.-G, Zhou, Y., Shi, J., and Wang, K.

Seedling diseases are a disease complex caused by several seedborne and soilborne pathogens. The pathogens causing seedling disease in rice (*Oryzae sativa* L.) and their distribution in the southern U.S. remain largely unknown. Surveys were conducted during the 2018 and 2019 crop seasons in 70 commercial rice fields located across five southern rice-producing states (Arkansas, Louisiana, Missouri, Texas, and Mississippi). Fungal plant pathogens were recovered from symptomatic diseased tissues and identified based on their morphology, sequencing of the ITS regions of rDNA and pathogenicity tests. *Rhizoctonia solani* and *Fusarium* spp. were isolated from all the five states surveyed in both years. *Sclerotium rolfsii* was isolated only from three states during the 2018 crop season. The frequency of isolation of a given pathogen varied with state. *Rhizoctonia solani* was the most frequently isolated fungus present in approximately 32% of the samples collected, suggesting its major role in the seedling disease complex. The information gained from this survey provides better understanding of the distribution and frequency of fungal pathogens associated with rice seedling diseases in the southern U.S., which will help to develop better management strategies for control of this important disease complex.

Abstracts of Posters on Plant Protection
Panel Chair: Jeff Gore and Tom Allen

Strategies Effective for Integrated Pest Management in Organic Rice in the Southern United States

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

Extensive research activities were conducted in Texas, Arkansas, and South Carolina to develop strategies using cover crops, soil amendments, rice cultivars, and seed treatments for disease, weed and insect pest management to optimize grain yield under organic production in the southern U.S.

Cover crops and soil amendments: Field trials were conducted in Texas and Arkansas to evaluate the performance of winter (annual ryegrass, cereal rye, crimson clover and oats) and summer (cowpea) cover crops. Ryegrass, crimson clover, cereal rye, oats and cowpeas all produced sufficient aboveground biomass and provided benefits of N improvement (67 to 121 kg N/ha) and weed suppression. However, no differences in the damage caused by rice water weevil were observed following any cover crop. Soil amendment with mustard seed meal (1,681 or 3,363 kg/ha, 4.5-1.5-1.2, N-P-K) was an effective biofumigant for controlling soilborne pathogens.

Organic rice cultivars and seeding rate: Twenty, 15 and 12 cultivars were tested at Beaumont, TX; Pine Bluff, AR; and Charleston, SC, respectively. Jasmine 85, PI312777, Rondo, Tesanai 2, XL723 and XL753 were among the best cultivars having good seedling stands, aggressive growth, weed suppression, and high yield potential in the Beaumont and Pine Bluff trials. Arborio, Charleston Gold, Express, and Tesanai 2 were among the best cultivars having highest rice yields in the Charleston trial. Planting at 150% of the recommended conventional seeding rate (135 and 67 kg/ha for inbreds and hybrids, respectively) was an effective method to improve stand establishment and suppress weed growth. Charleston Gold, Jasmine 85, Jupiter, Wells, Rondo, Tesanai 2, XL723, and XL753 had high levels of resistance to narrow brown leaf spot among the varieties. Della 2, Rex, Rondo, and XL753 were less susceptible to rice water weevil while Cocodrie and Presidio were among the cultivars most susceptible to the insect pest.

Seed treatments: A 3-year field study was conducted in Texas to evaluate the impact of seed treatment on plant stands using gibberellic acid (GA) and the biocontrol agents Sonata (*Bacillus pumilus*), Integral (*B. subtilis*), and BioEnsure (fungal endophytes) in Presidio and XL753. Seed treatment with Sonata, Integral, or BioEnsure resulted in a reduction in seedling disease and an increase in plant stand. BioEnsure also improved whole and total milling yields whereas GA seed treatment increased plant height. Weed populations were lower in the plots of XL753 with GA seed treatment compared to Presidio with no seed treatment.

On-farm demonstration: On-farm trials were conducted with established organic growers in 2018 to evaluate a combination of best management practices determined from this research on yield production as compared to the grower's standard practices. The improved management practices were developed for a dry seeded system [Jasmine 85, a high yielding and disease and weed tolerant cultivar, at an increased seeding rate (135 kg/ha) plus GA and Sonata seed treatment] and for a water seeded production system [Jasmine 85 at 135 kg/ha]. Both improved stand establishment, reduced narrow brown leaf spot incidence, reduced weed density, and increased grain yield as compared to the local farm management practices.

The management practices developed from this project can reduce losses caused by disease, weed and insect pests and maximize organic rice productivity in the south. Winter cover crops (annual ryegrass and crimson clover) and brassica seed meal can suppress weeds and diseases and provide N and other nutrients that improve organic rice yields. Selection of rice cultivars (like Jasmine 85, Rondo, Tesanai 2, XL753) tolerant to disease, weed and insect pests is the key to effective management of these pests. Seed treatment with GA and increasing seeding rate can ensure adequate stands for weed suppression and yield potential. Seed treatment with biocontrol agents such as BioEnsure can reduce seedling diseases and improve stand establishment. Based on net returns from our cost-benefit economic analyses, the top rice cultivars for organic management were Tesanai 2 ($1,759/ha), Jupiter ($1,502/ha), Jazzman ($1,450/ha), Wells ($1,324/ha), Presidio ($1,043/ha) and Rondo ($1,038/ha) while top cultivars for conventional management were Jupiter ($672/ha), Sierra ($608/ha), Tesanai 2 ($568/ha), Presidio ($472/ha), and Cybonnet ($385/ha). These findings will help producers better manage input costs and increase economic returns. For more information about this research project, please visit the project webpage at http://bit.ly/299L2W5.

Efficacy of Selected Foliar Insecticides Applied Pre- and Post-flood for Control of Rice Water Weevil

Rice, C., Taillon, N.M., Bateman, N.R., Lorenz, G.M., Thrash, B.C., Felts, S.G., Plummer, W.A., McPherson, J.K., Plummer, W.J., and Floyd, C.A.

Insecticide seed treatments are the most common and reliable control method for rice water weevil (RWW), *Lissorhoptrus oryzophilus.* However, foliar applications may be necessary in cases where an insecticide seed treatment (IST) was not used or in cases where flood was delayed and IST effectiveness was lost. Studies were conducted in 2018 and 2019 at the University of Arkansas Pine Tree Experiment Station to evaluate the efficacy of selected foliar insecticides applied at pre and post flood for control of rice water weevils. Applications were made within 24 hours prior to flood establishment or 24 hours after flood establishment. Larval samples were taken at 18-21 days after flood to estimate control and plots were harvested. Studies indicated that new formulations and insecticides not yet labeled for use may provide equal or better control when compared to the current standards. Belay, Prevathon, and an Experimental performed better when applied per-flood as opposed to post-flood.

Effects of Defoliation on Growth and Yield in Rice

Felts, S.G., Bateman, N.R., Lorenz, G.M., Thrash, B.C., Taillon, N.M., Plummer, W.A., McPherson, J.K., Plummer, W.J., Floyd, C., and Rice, C.

Armyworms are commonly found in rice fields in the mid-southern U.S. 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 (*Psuedoletia unipuncta*) and fall armyworms (*Spodoptera frugiperda*). It is common to see infestations 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.

A trial was conducted at the Rice Research and Extension Center in Stuttgart, Arkansas. Plants in large field plots were mechanically defoliated at 0, 33, 66, and 100% with a weed eater at two-three leaf, early tiller, late tiller, and green ring growth stages across three planting dates. 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, with delays ranging from 2 days when defoliation occurred at the 2-3 leaf growth stage to 28 days when defoliation occurred at the green ring growth stage. Yield loss and delays in heading were greater for the June planting date compared to the April or May planting date. This data will help form a defoliation-based threshold in rice to help rice growers maintain profitability.

Rate Response of Selected Insecticide Seed Treatments for Control of Rice Water Weevil

Plummer, W.A., Bateman, N.R., Lorenz, G.M., Thrash, B.C., Felts, S.G., Plummer, W.J., Taillon, N.M., McPherson, J.K., Floyd, C.A., and Rice, C.R.

Rice water weevil (*Lissorhoptrus oryzophilus*, RWW) is the number one pest of rice in the mid-south. Currently, insecticide seed treatments are the best control strategy for RWW. In recent years, studies evaluating combinations of a neonicotinoid and diamide seed treatment have been conducted and show improved control of RWW and greater yield than single products. The objective of this study was to determine if a reduced rate of Dermacor with a full rate of a neonicotinoid seed treatment would be a cheaper and equally effective option. These studies were conducted on both conventional and hybrid rice cultivars at the University of Arkansas Pine Tree Experiment Station, near Colt, and RiceTec Experiment Station, Harrisburg, AR.

RWW counts, and yield were recorded for each study. Across all locations, a reduced rate of Dermacor plus either NipsIt or CruiserMaxx had improved RWW efficacy and yield compared to the UTC with no difference compared to a full rate of Dermacor. However, a general trend was observed that the any neonicotinoid combined with a full rate of Dermacor had improved RWW efficacy and greater yield, although they did not separate from the half rates of Dermacor.

Insecticide Seed Treatment Combinations for Control of Rice Water Weevil

Plummer, W.J., Thrash, B.C., Bateman, N.R., Lorenz, G.M., Felts, S.G., Plummer, W.A., Taillon, N.M., McPherson, M.C., Floyd, C.A., and Rice, C.

Grape colaspis (*Colaspis brunnea*) and rice water weevil (*Lissorhoptrus oryzophilus*) are the two most important pest of rice in Arkansas. Grape colaspis larvae damage rice plants at the seedling stage, whereas infestations of rice water weevil occur after the establishment of permanent flood in rice fields. Neonicotinoid seed treatments are the primary method of control for grape colaspis; however, these treatments can only protect rice seedlings for approximately 30 days after planting. Many growers are moving toward earlier planting dates of rice, extending the length of time between planting and establishment of permanent flood; often exceeding the length of time a neonicotinoid seed treatment protects rice seedlings from rice water weevil. Diamide seed treatments, such as, Dermacor and Fortenza provide excellent control of rice water weevil and last much longer than neonicotinoid seed treatments.

Combinations of neonicotinoid and diamide insecticide seed treatments were evaluated in order to determine whether they can improve control of rice water weevil over single products in these situations. Studies were conducted at the University of Arkansas Pine Tree Experiment Station and the RiceTec Experiment Station in 2019. Combinations of diamide and neonicotinoid insecticide seed treatments improved efficacy and provided season long control of rice water weevil. Greater yield was observed for several combinations of seed treatments compared to any single insecticide seed treatment product. Growers should consider using an insecticide seed treatment combination in areas where rice water weevils are a problem and the time between planting and permanent flood establishment will be over 30 days.

Field Sampling of Kernel Smut in Rice and its Effect on Yield and Quality

Espino, L.A., and Brim-DeForest, W.

Kernel smut, *Tilletia barclayana*, is a rice disease that has been present in the Sacramento Valley of California since the mid-1980s. In recent years, the disease has become prominent in warm areas of the Valley. The objective of this research was to develop a method to evaluate the disease level in the field and quantify losses due to kernel smut infection. In 2017 and 2018, affected rice fields of three common varieties were sampled at maturity. In each field, thirty, 1-square yard quadrant samples were hand harvested. From each sample, three sub-samples of ten tillers were randomly selected and inspected for kernel smut. Each quadrant sample was threshed, and number of smutted kernels, and grain, milling and head rice yield determined. To determine the number of smutted kernels in the grain, three 25 g rice sub-samples were soaked in a 0.27 M KOH solution for 24 hours to clear the hulls and make counting easier. The proportion of infected panicles predicted the number of smutted kernels per 25 g of grain. Number of smutted kernels did not affect grain yield. Milling yield was affected by number of smutted kernels in all varieties in both years, with percentage milling yield reduction rates ranging from 0.05 to 0.25. Head rice yield was only affected by number of smutted kernels in in 2018, with average reduction rates in percentage milling yield of 0.085. The results show that a method to evaluate kernel smut in the field may be viable, and that kernel smut can significantly affect the quality of rice.

Management of Stem Rot and Aggregate Sheath Spot with Fungicides in California Rice

Espino, L., and Brim-DeForest, W.

Stem rot (caused by *Sclerotium oryzae*) and aggregate sheath spot (caused by *Rhizoctonia oryzae-sativae*) are common diseases in the rice production area of California. Historically, both diseases were managed by burning the straw residue after harvest to reduce the levels of inoculum surviving in the field. After the year 2000, rice straw burning was regulated, reducing the acreage burned to approximately 10% of harvested acres. Since then, fungicides have been incorporated in the management of both diseases.

Fungicide trials were conducted in 2017, 2018 and 2019 with registered and experimental fungicides to evaluate their effect on the incidence and severity of stem rot and aggregate sheath spot, grain yield, and grain quality. In the trials, the standard product for comparing treatments was Quadris (azoxystrobin) applied at early heading, which is used in almost 50% of the rice acreage in California. This fungicide was registered in the late 1990s to control blast. Its efficacy against aggregate sheath spot had also been established, but positive results in controlling stem rot were not obtained until trials conducted in 2012 and 2013.

Results of the trials show that products containing the active ingredient azoxystrobin used at the maximum label rate are effective at reducing the incidence and severity of stem rot and aggregate sheath spot when applied at the mid boot or early heading stage. Applications at mid boot resulted in disease severity reductions that ranged from 35 to 96%. Applications made at the early heading stage reduced the severity of the diseases from 43 to 82%. Applications made earlier, between 35 and 45 days after seeding, coinciding with a cleanup herbicide application, rarely produced disease level reductions. An active ingredient soon to be registered in California, inpyrfluxam, was highly effective in reducing the severity of aggregate sheath spot when applied at the boot or early heading stage (more than 90% severity reduction). In some trials, benefits in grain yield and grain quality were observed.

Evaluation of Insecticides for Management of the Rice Water Weevil in California

Grettenberger, I., Espino, L., and Goding, K.

Rice water weevil has historically been one of the primary arthropod pests in CA, although its status as a “main” pest has been reduced in recent years. Insecticides have been the primary management tactic, although management of levees and field edges can also reduce populations. Many years of insecticide trials have been done in California, covering a range of products/active ingredients and treatment timings. However, these results have not thus far been summarized across trials/years. The objective of this work was to examine the efficacy of selected insecticides for rice water weevil in California rice by examining historical data and using past data with relevant insecticides, treating each treatment-trial combination as a data point. We used data from 2009-2017 for trials conducted at the CA Rice Experiment Station. Treatment timings were pre-flood (typically immediately before flood), early post-flood (2-3 leaf), and late post-flood/rescue (5-6 leaf), applied with a CO_2 pressurized sprayer. We focused on a standardized measure of rice water weevil control across years. We calculated percent control for each treatment (material + timing) relative to the untreated control rings for each trial. Each treatment was not necessarily used for each timing. The 2-3 leaf stage treatments tended to be more effective than the pre-flood treatments. For some materials (e.g., Belay SC) there was a noticeable rate effect (even with 3.5 vs. 4.5 oz/acre). There was variation among treatments, with the caveat that some have much greater replication than others. Some treatments appear to be more influenced by application timing. In addition, variability across trials is also evident for some treatments, indicating possible inconsistencies with efficacy (e.g., Mustang Max, 4 oz, pre-flood). Overall, our results help summarize years of trial data and provide a more robust summary of insecticide efficacy for rice water weevil management under California conditions.

Impact of Planting Date on Infestations of Stem Borers and Rice Water Weevils in Louisiana

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

The rice water weevil (*Lissorhoptrus oryzophilus*) is the most widely distributed and destructive early-season pest of rice in the United States. Injury caused by feeding of weevil larvae on rice roots results in significant yield losses when fields are left untreated. Moreover, a complex of stem boring lepidopteran pests has long been reported to attack Louisiana rice but infestations have been increasing in recent years. The sugarcane borer (*Diatraea saccharalis*) and the rice stalk borer (*Chilo plejadellus*) have been occasional pests of rice in Louisiana for decades, whereas, the Mexican rice borer (*Eoreuma loftini*) has recently invaded Louisiana and may pose a bigger threat to rice production. This study was conducted to examine the effects of planting date on rice water weevil density, stem borer damage (whiteheads) and corresponding impact on rice yields. Field experiments were established at the H. Rouse Caffey Rice Research Station, Crowley, Louisiana in 2018 and 2019. Six rice cultivars (CL151 [2018], CL152 [2019], Cheniere, Cocodrie, Jazzman 2, Jupiter, and PVL01) were drill-planted in small plots on six planting dates between March 15-May 29 in 2018 and March 22-May 17 in 2019. Plots were left untreated and laid out following a randomized block design with four blocks and one replicate per block. Densities of immature rice water weevils were evaluated at three and four weeks after permanent flood was established using a metal core sampler following an established method for weevil sampling. Damage caused by stemborer infestations was assessed by recording the total number of whiteheads in each plot at 100 percent heading. At grain maturity, entire plots were harvested with a small plot combine and yields were adjusted to 12 percent moisture. Densities of immature weevils were higher at later planting dates in 2018, whereas a decrease of weevil density at the latest planting date were observed in 2019. For both years, 'Jupiter' consistently supported the highest density of weevils. Whitehead densities increased at later plating dates in 2018 and 2019 and 'PVL01' consistently had the highest number of whiteheads for both years. In contrast, yield decreased at later planting dates for both years. Results suggest substantial yield loss due to insect pests in rice planted after late-April.

Use of Genetic Resistance and Biocontrol Agents for Management of Sheath Blight in Organic Rice

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

Sheath blight, caused by *Rhizoctonia solani* AG1-IA, is one of the most important diseases affecting organic rice production in the southern US. Management of this disease is a challenge because no synthetic fungicides are allowed to be used under organic production systems. In this study, field trials were conducted under organic management at Beaumont, Texas over 3 years to evaluate the resistance of 27 cultivars and the efficacy of eight biocontrol agents for management of sheath blight.

Plots were inoculated with *R. solani* inoculum at panicle differentiation. For biocontrol trials, plots were sprayed with biocontrol agents at 2 weeks after inoculation and unsprayed plots served as the controls. Sheath blight severity was rated on a scale of 0 to 9 where 0 represents no symptoms and 9 represents the most severe in damage (plants collapsed) at 1 week before harvest. Plots were harvested using a plot combine and yield was determined.

No cultivars had immune reactions or extremely high levels of resistance to sheath blight. CLXL729, Diamond, Rondo, Roy J, XL753, and XP760 showed moderate resistance with the ratings below 5.0. Cocodrie, CL111, CL151, CL153, Della-2 and Jazzman 2 had the highest levels of disease with the ratings higher than 7.0. Applications of Neo-Boost (peroxyacetic acid), Serenade Max (*Bacillus subtilis*) and MBI-600 (*B. subtilis*) significantly reduced sheath blight severity and numerically increased yield. Use of the resistant cultivars and biocontrol agents can reduce the damage caused by sheath blight in organic rice.

A New Haplotype of Rice Blast Resistance Gene *Ptr* in Weedy Rice Confers Resistance to the Most Virulent Race of *M. oryzae*

Zhao, H., Jia, Y., and Liu, Y.

Blast disease of rice caused by the filamentous fungus *Magnaporthe oryzae* (syn. *Maganporthe grisea*) and weedy rice (*Oryza sativa indica*) are two of the most significant constraints of rice production worldwide. Major resistance (*R*) genes are the primary means of preventing infections by *M. oryzae* strains carrying the cognate avirulence (*AVR*) genes. However, the instability of *M. oryzae AVR* genes often challenges the stability of deployed *R* genes. Searching for more effective blast *R* genes from different genetic resources is essential to manage rice blast disease. In our previous evaluation of germplasm, we determined that rice blast *R* gene *Ptr* confers resistance to several US blast races resistance except for the most virulent blast race, IB33. *Ptr* is a new class of blast resistance gene. In the present study we show that the Ptr protein with minor amino acid variation encoded by the *Ptr* allele, Ptr^{BHA} in a late-flowering black hull weedy rice, MS-1996-9 (PI 653419), here referred to as RR20, from Mississippi is responsible for resistance to IB33. The resistance gene to IB33 was mapped between single nucleotide polymorphic markers (SNP) 10.633,942bp and 10.820,033 bp with the closest SNP at 10.724,430 bp, excluding *Pi-ta* which is also near this region. A gene specific marker for *Ptr* was developed to examine the existence of Ptr^{BHA} in each individual of a mapping population derived from RR20 x (DGWG) through disease reactions using IB33. The presence of the gene specific marker of Ptr^{BHA} was correlated with the resistant reaction to IB33 suggesting that Ptr^{BHA} in RR20 is responsible for resistance against IB33. These findings suggest that a natural allele of *Ptr* in RR20 is a novel and effective blast *R* gene for breeders to deploy for resistance to this race of blast that currently does not exist in any U.S. cultivar.

Seed Dressing to Manage Seed Rots and Seedling Diseases of Rice Caused by *Rhizoctonia* sp.

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

Pre-mixed seed treatment fungicides containing (1) Apron XL+ Maxim 4FS; (2) Metalaxyl + Maxim 4FS; and (3) Dynasty +Apron XL +Maxim 4FS +Vibrance (Vibrance RST) were tested in the field in 2019 to evaluate their efficacy against soilborne seedling disease caused by *Rhizoctonia solani* AG9. Diamond, a conventional rice variety, tested all fungicide combinations. Hybrid rice, RT Gimini 214 CL, tested the latter two combination fungicides. The fungicide treatments also contained Cruiser 5FS and Fortenza to suppress insect damages such as Grape colaspis and Epivio Zn to alleviate zinc deficiency. Stand count and seedling height were recorded 27 days after planting; grain yield was determined at harvest. From both varieties, inoculated seeds that were not treated with fungicide were planted as a control. Results showed plant stand count to be a better parameter than seedling height with a consistent chemical response. In the presence of the disease, there were significant differences in seedling count per a row of 457 cm (15 ft). The seedling count of Diamond ranged from 6.5 to 158.2. The former was the mean from inoculated and fungicide untreated plots and the latter from inoculated and Vibrance RST treated plots. Likewise, in RT Gimini 214 CL, seedling stand ranged from 8.5 in fungicide untreated control to 73.7 plants in Vibrance RST treated plots. Stand count in non-inoculated seeds of Diamond and RT Gimini 214 CL were 119 and 61, respectively, clearly demonstrating how important the disease was to reduce seed germination and seedling stand. Overall, grain yields were directly proportional to seedling stands. When stand counts of insecticide treated and untreated plots were compared in RT Gimini 214 CL, there was about 34% advantage in using insecticides in non-inoculated plots. This study clearly showed the benefit of using seed dressing fungicides with insecticides to improve seedling stand and ultimately increase grain yield.

Impact of Rice Water Weevil and Stem Borer Infestations on Rice Yields

Wilson, B.E., Villegas, J.M., Landry, K.J., Mulcahy, M.M., and Stout, M.J.

The rice water weevil (*Lissorhoptrus oryzophilus*) and a complex of stem borers are economic pests of rice in Louisiana and Texas. The impact of weevil infestations on rice yields is well documented, but effects of stem borer infestations are poorly understood. Stem borer injury results in a blanked panicle, or "whitehead." Whiteheads are thought to represent a 100% yield loss for individual panicles, but the relationship between whitehead density and rice yield on a per hectacre basis is not well understood. This study aims to determine the relative yield loss from naturally occurring rice water weevil and stem borer infestations.

Two separate trials (early- and late-planted) were conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station in Crowley, LA during 2019. Four insecticide treatments were used to establish differing pest complexes: weevils + borers (non-treated), stem borers only (thiamethoxam + cyantraniliprole seed treatment), weevils only (mid-season foliar-applied chlorantraniliprole) and protected (chlorantraniliprole seed treatment).

Insecticide treatments effectively established the intended pest complexes in both trials. Weevil densities were reduced in stem borer only and protected plots relative to non-treated and weevil only plots. Whitehead densities were reduced in weevil only and protected plots relative to non-treated and stem borer only plots. Whitehead density was more than 4-fold greater in the late-planted trial (8-10 whiteheads/m^2) than in the early-planted trial (1.5-2.5). In the early-planted trial, rice yield was reduced by 4.0%, 23.9%, and 26.4% for the borer only, weevil only, and non-treated, respectively, relative to protected plots. In the late-planted trial, rice yield was reduced by 13.7%, 11.6%, and 18.4% for the borer only, weevil only, and non-treated treatments, respectively, relative to protected plots. Results demonstrate the substantial yield losses which occur from naturally occurring infestations of rice water weevil in south Louisiana and highlight the continued need for effective management strategies for this pest. Yield losses resulting from high densities of stem borers are comparable to that from weevils. A loss of approximately 1.5% resulted from each whitehead/m^2. Effective stem borer management will be required to maintain rice yields in late-planted rice in south Louisiana.

Recent Advances in USDA's Wildlife Repellents Research: Visual Cues for Avian Repellency and Rodent Repellents Progress

Werner, S.J., DeLiberto, S.T., Allen, B.B., and Olson, C.S.

The discovery phase of the United States Department of Agriculture's wildlife repellents research has been on-going since 1950. In the last decade, the progress of the National Wildlife Research Center's Repellents Research Project includes the development of repellent formulations for wild birds and the discovery of a repellent active ingredient in wild rodents associated with rice crop damage. Repellents are notoriously difficult to apply at concentrations that effectively protect the commodity while remaining safe for human consumption. Our research regarding avian repellents and visual cues has resulted in novel formulations that are based upon repellent efficacy and species-specific visual ecology. These formulations provide increased repellency at lower concentrations of the active ingredient plus specific combinations of visual cues. While evaluating bird-repellent rodenticide baits for the protection of non-target birds, we discovered the efficacy of anthraquinone-based repellents (Arkion Life Sciences, New Castle, DE, USA) in rodents. Further concentration-response testing demonstrated varied repellency (from 30-85% decreased consumption of treated food) in rodents. Anthraquinone-based rodent repellents applied to structural barriers reduced barrier defeat by 50-80% relative to untreated barriers. These discoveries are now being developed with commercial and small business cooperators for the non-lethal management of human-wildlife conflicts and the cost-effective protection of newly planted and ripening rice.

Efficacy of Foliar Applied Chlorantraniliprole for Control of Rice Stem Borers in Louisiana

Landry, K.L., Wilson, B.E., Villegas, J.M., and Mulcahy, M.M.

A complex of Crambid stem borers made up of the Mexican rice borer (*Eoreuma loftini*), sugarcane borer (*Diatraea saccharalis*), and rice stalk borer (*Chilo plejadellus*) are increasing in economic importance as insect pests in rice production in southwest Louisiana. The borer larvae gain entry into the rice culm (stem) of the plant by feeding on the leaf sheath of the plant. The larvae tunnel inside the hallow culm of the plant where feeding diminishes the nutrient supply to the growing portions of the plant. Rice plants in the vegetative or early reproductive stage display injury through withering and death of the youngest leaf which resulting in a condition called "deadhearts". Rice plants in the mid to late reproductive stage cause partial or complete sterility of seeds. The white, empty seed heads are easy to recognize due to the upright nature of the panicle. These partially or fully blanked panicles are called "whiteheads" and represent a nearly 100% yield losses for individual tillers. While chlorantraniliprole seed treatments effectively control stem borers, options to control active infestations during the growing season are limited. Currently, only pyrethroid insecticides are labeled foliar applications against stem borers. These products are highly toxic to crawfish which limits their utility in many regions, and stem borer infestations frequently go unmanaged.

A series of three field trials was conducted to evaluate the efficacy of foliar applied insecticides against stem borer infestations at the LSU AgCenter H. Rouse Caffey Rice Research Station in Crowley, Louisiana in 2018 and 2019. Seed was drill-planted in small plots (152 cm × 457 cm with 7 rows at 18 cm spacing) and insecticide treatments and an untreated check were assigned to plots following a randomized complete block design with 4 blocks and 1 replicate per block. Insecticide treatments were applied using a CO_2-pressurized backpack sprayer at 35 days after permanent flood in 2018 and in 22 and 33 days after permanent flood in 2019. Stem borer damage was assessed by recording the total number of whiteheads in each plot at 100 percent heading. Whitehead data were analyzed using a generalized linear mixed model with insecticide treatment as a fixed effect and block as a random effect. Means were separated using Tukey's HSD ($\alpha = 0.05$). Results show that Prevathon (chlorantraniliprole) provided superior efficacy over currently labeled pyrethroids (zeta-cypermethrin and lambda-cyhalothrin). Prevathon application reduced whitehead incidence up to 96.5% in 2018 and 87.5% in 2019 compared to untreated controls. Registration of Prevathon for foliar application in rice would provide a new tool for control of damaging stem borer infestations in Louisiana.

Disease Loss Estimates from the Rice Producing States in the United States: 2018 and 2019

Allen, T.W., Groth, D.E., Wamishe, Y.A., Espino, L., Gordon, J., and Zhou, X.G.

Disease loss estimates are an important aspect when considering the production losses associated with important plant diseases in any major row crop production system. Even though rice occupies a limited number of hectares in only a few states within the United States, the losses associated with major plant diseases remain a significant concern and continue to significantly reduce rice production on an annual basis. In 2018 and 2019, the plant pathologists representing the rice producing states began compiling disease 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 as a result of 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 and 2019 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 2018, rice diseases accounted for an estimated total of 4.7% loss in rice production. The greatest losses were observed as a result of sheath blight, caused by *Rhizoctonia solani*, and the disease with the least impact on the rice production area was bakanae with no losses observed. The top four yield-reducing diseases based on percent yield suppression across the entire rice producing area during the 2018 season were: sheath blight, neck blast, stem rot, and the seedling diseases which are caused by multiple organisms. On a state basis, 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 Arkansas (5.2%), followed by Texas (4.7%) and California (4.5%), with the lowest estimates of loss in Missouri (2.7%).

In 2019, rice diseases accounted for an estimated total of 4.9% loss of the total U.S. rice production. Similar to 2018, the greatest losses were observed as a result of sheath blight, and the disease with the least impact on the rice production area was bakanae with no losses observed. The top four yield-reducing diseases based on percent yield suppression across the entire rice producing area during the 2019 season were: sheath blight, neck blast, seedling diseases which are caused by multiple organisms, and stem rot. 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%).

Total rice hectares in the United States accounted for 1.18 million hectares of rice production, regardless of whether the rice grown was long, medium or short grain. In 2019, the total number of hectares devoted to rice accounted for 1.00 million hectares. Between the two years, a reduction of 15.2% in the total number of hectares occurred. Total rice production, averaged across the six rice producing states, accounted for 8,625 kg/ha in 2018 as compared to 8,377 kg/ha in 2019. Between 2018 and 2019, a 3% reduction in average rice production across the entire rice producing area was observed.

Development and Evaluation of Rice Lines Possessing Resistance to the Rice Water Weevil, *Lissorhoptrus oryzophilus*

Stout, M.J.

The rice water weevil, *Lissorhoptrus oryzophilus*, is the major early season insect pest of rice in the United States. Management of this insect over the past six decades has relied almost exclusively on insecticides, and alternative management tactics are needed. Evaluations of thousands of rice genotypes have failed to identify any genotypes of rice possessing high levels of resistance to this insect. However, multiple experiments have shown that levels of weevil infestation in the cultivar ‘Jefferson’ are typically lower than in other commercial cultivars. In 2009, crosses were made by Dr. Xueyan Sha using the cultivars ‘Jefferson’ (moderately resistant) and 'Cocodrie', a weevil-susceptible, high-yielding, high-quality cultivar. Over the next several years, progeny from these crosses were evaluated and selected for weevil resistance. From 2017 to 2019, three lines resulting from this selection process were evaluated in small plots for resistance to weevils, agronomic characteristics, and grain yield and quality. The putatively resistant lines showed resistance to weevils comparable to that seen in ‘Jefferson’, and yields and quality in these lines were no lower than in ‘Cocodrie’. Results of these evaluations will be presented.

Field Efficacy of Trichoderma (TM17) Against Sheath Blight of Rice

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

Rice sheath blight, caused by the soil-borne fungal pathogen *Rhizoctonia solani*, is an economically important disease in rice. Depending upon the severity of the disease, it may cause 25-100% yield losses. Chemical control of disease leads to increase environmental toxicity hence the biological control is one of the best methods to manage rice diseases. *Trichoderma* is a very effective biological mean for plant disease management. It is highly interactive in root, soil and foliar environments. It reduces growth, survival or infections caused by pathogens by different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme secretion. Due to its efficient broad-spectrum antimicrobial activity, *Trichoderma* has been established as an internationally recognized biocontrol fungus. *Trichoderma* have been found effective in controlling rice blast and sheath blight of rice. In this study, we found and identified a novel strain of *Trichoderma atroviride*, named TM17. The mycelium of *T. atroviride-TM17* exhibits a high growth rate, high sporulation capacity, and strong inhibitory effects against *Rhizoctonia solani* AG1-1A pathogens that cause rice sheath blight. *T. atroviride-TM17* foliar applications at 1×10^9 conidia mL^{-1} were performed at 56 and 71 days after sowing (DAS), in 2019, as pre and post application treatment, respectively. In addition, rice seed treatment with the same concentration of liquid TM17 and untreated control were treatments used for this experiment setting. Pre- and post-treatments were used as foliar spray application seven days before and after the artificial inoculation of *Rhizoctonia solani* AG1-1A inoculum, respectively. Disease data revealed, it was evident that the level of disease was lower as compared to the control and seed treatment application of the biocontrol agent.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Ben Lawrence

Rice Response to Sub-lethal Concentrations of Non-target Herbicides

Lawrence, B.H., Bond, J.A., Golden, B.R., Allen, T.W., Edwards, H.M., and McCoy, J.M.

Rice production in Mississippi occurs in the northwestern portion of Mississippi within the floodplain of the Mississippi and Yazoo rivers due to the region's clay-textured soils, environment, and water availability. In 2018, rice producers harvested 56,275 ha, with production in Bolivar, Sunflower, Tunica, Quitman, and Washington counties accounting for approximately 73% of Mississippi rice ha. In these primary rice-producing counties, land area devoted to rice production makes up 6.25% of row crop hectarage. Often rice is produced within proximity of corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean [*Glycine max* (L.) Merr]. Depending on planting date, rice can be at various growth stages when preplant herbicide applications containing paraquat are be being applied to land devoted to corn, cotton, and soybean production. Research was conducted at the Mississippi State University Delta Research and Extension Center from 2015 to 2018 to (1) determine the effects of sub-lethal concentrations of paraquat, metribuzin, fomesafen, and cloransulam-methyl applied at different rice growth stages and (2) characterize rice response to a sub-lethal concentration of paraquat in combination with common POST and residual herbicide.

Three studies were conducted from 2015 to 2018 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to characterize rice performance following exposure to a sub-lethal rate of paraquat, metribuzin, fomesafen, and chloransulam-methyl applied at different growth stages and to evaluate rice response to a sub-lethal rate of paraquat applied alone or in mixtures with sub-lethal rates of metribuzin or fomesafen. Experimental design for both studies was a randomized block with four replications. In the timing studies, paraquat, metribuzin, fomesafen, and chloransulam-methyl were applied at 84, 42, 39 and 3.5 g ai ha^{-1}, respectively, to spiking to one-leaf rice (VEPOST), two- to three-leaf rice (EPOST), three- to four-leaf rice (MPOST), 7 days postflood (7 DPFLD), and to rice at panicle differentiation (PD). In the Herbicide Mixture Study, treatments were arranged as a two-factor factorial with Factor A consisting of paraquat applied at 0 and 84 g ha^{-1} and Factor B being herbicide mixture and including no herbicide mixture, metribuzin at 42 g ha^{-1}, and fomesafen at 39 g ha^{-1}. Additionally, in the Residual Herbicide Study paraquat was applied alone or in mixture with Authority MTZ, Boundary, Canopy, Corvus, Cotoran, Envive, Fierce, Lexar EZ, Prefix, or Sonic at 10% the recommended use rate in Mississippi to rice in the EPSOT growth stage. Injury data in all timing studies were regressed against DAT allowing for both linear and quadratic terms with coefficients depending on DAT and non-significant model terms were removed sequentially until a satisfactory model was obtained. All other data in the timing studies were regressed against d after emergence (DAE) allowing for both linear and quadratic terms with coefficients depending on DAE, and non-significant model terms were removed sequentially until a satisfactory model was obtained. All data that did not exhibit a regression trend in the timing studies and in mixture studies were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$. Data collected in the timing studies consisted of injury 3 DAT and at weekly intervals to 28 DAT, and d to 50% heading as an indication of rice maturity, and rough rice yield. In both the Herbicide Mixture Study and Residual Herbicide Study data collection was similar to that in the timing studies.

Rice yield was negatively affected following exposure to paraquat applied any time after rice emergence. Paraquat applications to rice in early reproductive growth reduced rough rice yield and delayed maturity the greatest. Paraquat plus metribuzin injured rice 69% 28 d after treatment (DAT), which was 10 to 13% greater than following paraquat alone or paraquat plus fomesafen. Paraquat alone reduced rough rice yield 23% and was no different than paraquat plus fomesafen. However, when paraquat was applied in mixture with metribuzin rough rice yield decreased an additional 11%. Paraquat plus 10 different residual herbicides injured rice ≥51% 28 DAT and reduced rough rice yields ≥21%. These data indicate that paraquat can have negative impact on rice growth and development. Therefore, it is crucial that if environmental conditions are conducive for off-target herbicide movement extreme caution should be exercised when applying paraquat adjacent to fields devoted to rice production.

Rice Response to Late-season Off-target Herbicide Movement at Multiple Application Timing

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

The proximity of rice to other crops in Mississippi such as cotton (*Gossypium hirsutum* L.), corn (*Zea mays*), and soybean [*Glycine max* (L.) Merr.], creates a great potential for herbicide exposure onto rice fields. In Mississippi, rice reproduction and ripening often overlaps with soybean maturation creating potential for herbicide exposure during these growth stages. The growing adoption of harvest-aid use across upwards of 2 million soybean acres throughout Mississippi only furthers the risk of late-season exposure. Therefore, research was conducted evaluating rice response following desiccant exposure across multiple application timing.

Research was established from 2016 to 2018 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to determine the response of rice to sub-lethal concentrations of soybean desiccants during reproductive and ripening growth stages. Objectives of this research were to identify differences in visual injury response across multiple desiccants, identify differences in yield and yield component response, and to identify differences in rice response across multiple application timing. To achieve these objectives treatments were arranged as a split-plot design consisting of desiccant as the whole plot and application timing as the sub-plot. Studies included the desiccants paraquat, glyphosate, saflufenacil, sodium chlorate, paraquat and saflufenacil, and paraquat and sodium chlorate. Treatments were applied at five differing rice growth stages beginning at 50% heading, 0 d after heading (DAH), with subsequent applications at 1-week intervals (0, 7, 14, 21, and 28 DAH) up to harvest. Rates were based on 0.10 of the labeled harvest-aid rate in Mississippi. Herbicides were applied at a constant carrier volume of 140 L/ha with a CO_2 pressurized backpack sprayer. Visible estimates of rice injury were recorded 3, 7, 14, 21, and 28 day after treatment. At maturity, whole aboveground portions of rice plants were collected from a random 1-m section from rows 2 or 7 in each plot to determine rice dry weight, yield components, and harvest index. Plots were then mechanically harvested with a small-plot combine to obtain rough rice yield. Total milled (consisting of whole and broken kernels) and head rice (consisting of whole kernels) yields were then determined from cleaned 120-g subsamples of rough rice. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

Injury was observed with five of six desiccants at all application timings. No injury was observed with glyphosate application across all rating intervals. In the studies evaluating paraquat, injury was >5% at all evaluations regardless of application timing.

Rough rice grain yield was reduced in four of the six studies. In studies evaluating saflufenacil and sodium chlorate rough rice grain yield was >95% across all application timings. In contrast, rough rice grain yield following all glyphosate applications was reduced by >6%. Rough rice grain yield was reduced >12% 0 to 21 DAH, following paraquat application. Similar trends were observed with paraquat and saflufenacil and paraquat and sodium chlorate, with rice exhibiting yield decreases >6% following an application 0 to 14 and 0 to 21 DAH, respectively. Yield component trends closely resembled reductions observed in rough rice grain yield. Reductions in head rice yield were >5% following applications of paraquat or paraquat and saflufenacil 0 to 14 and 0 to 21 DAH respectively. Late-season exposure to sub-lethal concentrations of desiccant from 50% heading (0 DAH) to 28 DAH has an impact on rough rice grain yield, yield components, and head rice yield.

This research evaluating rice grain yield, yield component, and milling quality response to sub-lethal concentration of common desiccants applied late in the season suggests that rice sensitivity varies across desiccants and application timing. Rough rice grain yield reductions coupled with milling quality reductions and driven by the proximity of rice to corn, cotton, soybean, and sorghum in Mississippi creates the need to exercise caution when applying desiccants.

Arkansas Benzobicyclon E.U.P. Results and Technical Profile

Sandoski, C.A., Dyer, C.D., and Takahashi, A.

Benzobicyclon is a novel herbicide that is currently under development by Gowan for use on rice in the Mid-South USA. The molecule is characterized by excellent safety to both *japonica* and *indica* rice varieties, a favorable toxicological and eco-toxicological profile and offers broad spectrum control of grasses, sedges and broadleaves at rates of 250 – 370 g ai/ha. Benzobicyclon is a slow releaser of the active triketone metabolite that functions as an inhibitor of *p*-hydroxyphenylpyruvate dioxygenase (HPPD). The molecule is currently registered in California and the Mid-South registration is expected in 2021.

A State EUP was obtained in Arkansas in 2019 for application of Rogue® (a 35.4% SC formulation of benzobicyclon) to no more than 480 acres of water-seeded rice. Fields were selected based on histories of severe infestations of weeds or weed spectrums that have been historically difficult to control. Rogue SC Herbicide provided improved control of weedy rice in a Provisia® system when compared with Provisia applied alone. This was the first time this was demonstrated in commercial fields. 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), eclipta, arrowhead, gooseweed, and weedy rice in the EUP fields. The State EUP programs confirmed the fit of benzobicyclon in water-seeded rice and allowed for practical experience with growers and consultants under actual field conditions. These commercial applications proved that Rogue SC Herbicide could be safely applied to rice via aerial application.

Assessment of Weed Suppression and Straighthead Occurrence in Plastic Mulched and High Seed Rate Water Seeded Rice under Organic Condition

Huang, B., Mahato, G.R., McClung, A., and Zhou, X.G.

Weeds are a major yield limiting factor in organic rice farming and are more problematic than in conventional production system. The lack of effective weed management methods for organic rice growers is the main barrier for expansion of organic rice production in the US. Weed competitive rice varieties were selected for measuring the effectiveness of weed suppress using water seeding, plastic mulching, cover cropping and crop rotation in organic production system, as the potential weed management methods for organic rice farming. Water seeding experiment 2016: A mixture of crimson clover and winter wheat was planted in fall 2015 and terminated in spring 2016. Fifteen rice varieties were water seeded one month after termination of the cover crop to observe the weed competitiveness of rice varieties. Rice varieties were planted in RCBD design with four replications. Cover crop planting 2017: In fall 2016, mixture of crimson clover + ryegrass and crimson clover + oat was planted in separate section of the field and terminated in the spring 2017. Plastic mulch trial 2017: After termination of crimson clover + ryegrass in spring 2017, plastic mulch trial was conducted using six rice varieties mapped in CRD with four replications and were planted at 15cm x 30cm distance. High seed rate water seeding trial 2017: After termination of mixture of crimson clover and oat in spring 2017, another separate experiment was conducted where 10 rice varieties were water seeded at two high seed rate of 224 kg/ha and 448 kg/ha. Five rice varieties were selected for separate study which were also used in plastic mulch trial. Plastic mulch trial 2018: In spring 2018, plastic mulch trial was conducted using six varieties used in previous year 2017 after the termination of ryegrass planted in fall 2017. Rice varieties were planted at 15 cm x 25 cm using RCBD with five replications. After data analysis, high seed rate water seeding was effective in suppressing the weeds. However, no yield benefit was obtained because high seed rate resulted high intraspecific competition between rice plants leading to high straighthead score and low yield. Water seeding is effective and current popular method of weed suppression in rice. Plastic mulch was very effective suppressing the weeds during whole growing season of rice.

Effect of AWD Irrigation on Yield Components and Biological Responses of Recurrent Inbred Lines from a Weed-Suppressive *indica x tropical japonica* Mapping Population

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

Alternating-wetting-drying (AWD) is a conservation irrigation management system that is being implemented in commercial rice production in the USA. Among its potential advantages are the ability to reduce irrigation costs and increase water use efficiency, thus extending the viability of underground aquifers while maintaining economical productivity of the rice industry. Currently, our understanding of yield losses under AWD stress is limited. For this field study, 14 recombinant inbred lines (RILs; F10) were chosen from a collection of 330 RILs from a PI 312777 x Katy mapping population based on their diverse and unique plant traits. PI 312777 is naturally high-yielding, weed-suppressive, and AWD stress-tolerant compared with Katy. The selected RILs were evaluated for two years under AWD and conventional flooded (FLD) irrigation systems for yield components and AWD-stress tolerance. The experiment was conducted in 2017 and 2018 as a split plot design with four replications, main plots of conventionally flooded (FLD) or AWD irrigation, and subplots of the parents, RILs, and five standard cultivars as checks. Rice was drill-seeded 2-cm deep in Dewitt silt loam soil into plots 4-m long with six, 18-cm-wide rows on May 9 of 2017 and 2018 at Stuttgart, AR. Pre-flood nitrogen fertilizer was broadcast-applied as urea at 110 kg ha-1 N, followed by the initial 'permanent' flood application to all plots on June 20, 2017 and June 7-8, 2018. All other cultural and weed control practices were performed generally as in conventional rice production. Drain/reflood cycles in AWD plots were implemented July 14/July 21-24 and July 28/Aug. 25, 2017; and July 5/July 17-18, 2018 (a 2nd AWD cycle could not be implemented in 2018 due to extended periods of rainfall). The first and 2nd AWD cycles reached minimum percent soil volumetric water content (VWC) at approximately 10 and 13 weeks after emergence, respectively, and were intended to establish 'severe AWD' conditions in plots (VWC ~15-20%; except when rain sometimes prevented adequate drying). To determine relative levels of plant stress, leaf temperature and C assimilation rate data were recorded in all plots when ~minimum VWC was reached in AWD plots. Yield components were determined from 1-m of row several days before bulk harvesting the whole plot for final yield, which was done Oct. 4-17, 2017 and Sept 14 to Oct. 12, 2018 depending on the maturity of the RILs.

The parents and several RILs differed in their relative AWD stress tolerance. RILs #12, 144, 327, and 76, and the PI 312777 parent had generally 'higher tolerance' compared with 'lower tolerance' for RILs #15, 416, and the Katy parent in both years (and #250 and 90 in 2017 only). The 'higher tolerant' RILs usually had less sterility of the main panicle than the 'lower tolerant' RILs. In a separate analysis of 10 cultivar standards in 2017, early-heading in AWD was associated with low panicle sterility (e.g. in Jupiter), which might signify an AWD-stress-avoidance mechanism. Interestingly, Katy tended to withdraw less water from plots, but was more inhibited by AWD stress compared with PI 312777. Principal components analysis (PCA) revealed that yield in the AWD treatment was most positively associated with total biomass, 1000 seed weight, productive tillers /m row, % seed set of the main panicle, and final plant height, and was negatively associated with % seed sterility of the main panicle (noticed more prominently in 2017 when VWC 'low' levels averaged ~5% points lower than in 2018). Principal components #1 and #2 explained 50.7% of the total phenotypic variability in AWD treatments. Average kernel length and soil VWC were (slightly) positively correlated at both dates and years. This correlation could have arisen if plots with Katy-like RILs (i.e. having 'long grains' and relatively low root mass) remained wetter during the AWD cycle, or if PI 312777-like RILs (i.e. having shorter grains and greater root mass and tiller production) extracted more water compared with other RILs. AWD drying caused canopy temperatures to rise and carbon assimilation rates to fall, and these effects were lessened when rain events interfered with the soil drying phase. Seedling root traits studied in agar plates that tended to be associated with high yields under AWD stress in the field included greater total length and a wider spread pattern of roots. Several RILs clearly performed better than others under the AWD stress conditions in our study and will be investigated further to better understand the mechanisms involved in the AWD stress tolerance. About 275 of the 330 RILs have been genotyped using a '6K' SNP chip and are in process of being evaluated for productivity and growth and development traits that should identify novel alleles for higher yield under AWD irrigation management.

Louisiana Benzobicyclon EUP Results

Bergeron, E.A., Dyer, C.D., and Takahashi, A.

Benzobicyclon is a novel herbicide that is currently under development by Gowan for use on rice in the Mid-South USA. A State EUP (Experimental Use Permit) was obtained in Louisiana in 2018 for application of Rogue® Plus (a 76.5% WDG formulation of benzobicyclon (67%) and halosulfuron-methyl (9.5%)) to no more than 480 acres. A State EUP was also obtained in 2019 for the application of Rogue® SC Herbicide (a 35.4% SC formulation of benzobicyclon) to the same amount of acres. All applications were only applied on water-seeded rice. Fields were selected based on histories of severe infestations of weeds or weed spectrums that have been historically difficult to control. This was the first time that this was demonstrated in commercial rice fields that were not crop destruct. Benzobicyclon provided excellent control of ducksalad, sprangletop, annual sedges (to include ALS herbicide-resistant species such as rice flatsedge and smallflower umbrella sedge), eclipta, arrowhead, and gooseweed. The State EUP's confirmed the fit of benzobicyclon in water-seeded rice and allowed for practical experience with growers and consultants under actual field conditions. These commercial applications proved that benzobicyclon could safely and effectively be applied to rice via aerial application.

How Much is that Airplane Really Putting Out? Questions and Issues with Modern Aerial Application

Carey, V.F.

Aerial application is a necessary evil for application of pesticides and fertilizer in flooded rice culture. As aircraft have developed from small planes traveling less than 80 miles per hour (128 kilometers per hour) to modern turbine driven aircraft traveling in excess of 150 miles per hour (240 kilometers per hour), application accuracy issues have continued to develop. Many rice pesticide labels state a minimum application volume of 187 liters per hectare (10 gallons per acre) is required. This may have been a practical requirement in years past, but today's aircraft have difficulty in achieving that output because of their operating speed and the altitude required for safe operation. There is data generated for several products that show decreased efficacy when a lower than optimal application volume is used, due primarily to reduced coverage. This contrast between practical application volume and efficacy presents a challenge for growers, applicators and pesticide manufacturers. There needs to be a balance between coverage, efficient (and safe) application volume and drift for optimal application. This balance point may be different for each aircraft/boom configuration and pesticide combination. The purpose of this presentation is to bring some of these questions and issues to the forefront for consideration and conversation. The desired outcome of this presentation and discussion would be increased awareness and communication between all parties involved.

Comparison of Preplant Incorporated and Preemergence Residual Herbicides in Rice

Piveta, L.B., Norsworthy, J.K., Patterson, J.A., and Zacarro, M.L.

Residual herbicides are recommended as part of a total weed management program to avoid herbicide resistance. The evolution of resistance is slowed by reducing the number of weeds that need to be controlled postemergence. Thus, the longevity of residual herbicides needs to be evaluated when applied as a preplant incorporated (PPI) or preemergence herbicide (PRE). Applying as a PPI may increase the likelihood of activation before planting, but it can also increase the risk of crop injury due to the herbicide being readily available for plant uptake.

A field experiment was conducted in 2019, at the Pine Tree Research Station near Colt, Arkansas. This experiment was implemented as a randomized complete block design with four replications, where herbicide efficacy was evaluated for control of barnyardgrass and yellow nutsedge. Factor A was timing of application, being PPI or PRE, and factor B was the herbicide treatments: clomazone (Command®) at 336 g ai ha^{-1}, quinclorac (Facet L®) at 280 and 560 g ai ha^{-1}, imazethapyr (Newpath®) at 70 and 106 g ai ha^{-1}, clomazone + quinclorac (Obey®) at 334 + 334 g ai ha^{-1}, quinclorac + imazethapyr (Clearpath®) at 336 + 70 g ai ha^{-1}, imazosulfuron (League®) at 340 g ai ha^{-1}, and halosulfuron + prosulfuron (Gambit®) at 52 + 30 g ai ha^{-1}. A nontreated check was also included in the experiment. Crop injury and weed control were evaluated at 14, 21, and 28 days after planting (DAP). Data were analyzed using JMP Pro 14 and were subjected to ANOVA, and effects were considered significant when $P<0.05$ under Fisher's protected LSD.

Injury ratings were low across all rating dates, with up to 16% injury observed at 14 DAP following the application of clomazone. In general, higher levels of injury were found with PPI-applied clomazone. Injury from all herbicides diminished over time, with no injury observed at 28 DAP. At 14 DAP, all treatments, except Gambit, provided greater than 90% barnyardgrass control, regardless of application type. However, at 14 DAP, yellow nutsedge control was better (> 90%) in treatments containing acetolactate synthase (ALS) inhibitors (Newpath®, Clearpath®, League®, and Gambit®) in PPI applications.

Programs for Effective Weed Control in Furrow-Irrigated Rice

Barber, L.T., Butts, T.R., Hill, Z., Collie, L.M., and Ross, A.

Furrow-irrigated rice has gained popularity over the last two years in Arkansas. With the widespread increase in furrow-irrigated rice acres, weed control programs and their effectiveness in this system have come under question. The purpose of this research was to determine the most effective herbicide programs for season-long weed control in furrow-irrigated rice. Experiments were conducted from 2017-2019 at Marianna, Arkansas on a Calloway silt loam soil in a randomized complete block design. Individual plots were 3.7 meters wide and 9 meters in length. Rice cultivar XP745 CL was planted at 28 kg ha^{-1}. Several herbicide programs were evaluated, all of which contained clomazone 461g ai ha^{-1} PRE alone and in combination with other herbicide modes of action, followed by two POST applications of various herbicide combinations. All herbicide applications were made with a spray volume of 112 L ha^{-1} and visual ratings for weed control were taken at 28 days after planting (DAP) and 14 days after the final late post application (LPOST). Palmer amaranth control was highest 28 DAP when saflufenacil (Sharpen) 144g ai ha^{-1} was applied with clomazone PRE. Palmer amaranth control POST was only achieved 14 days after LPOST with multiple applications or combinations of florpyrauxifen-benzyl applied at 15 to 30g ai ha^{-1} or with a tankmix combination of propanil 3.46 kg ai ha^{-1} plus triclopyr 217 g ai ha^{-1}. Results indicate, two applications of one of the previous two herbicide mixtures will be needed for season-long Palmer amaranth control in furrow-irrigated rice. Barnyardgrass control was similar to management in a flooded rice environment, however, residuals become more important in a furrow-irrigated rice system. Applications of imazethapyr early POST followed by either cyhalofop, fenoxaprop or bispyribac LPOST provided the highest control of barnyardgrass by 14 days LPOST. If POST applications were not made timely then barnyardgrass control was significantly reduced. Goosegrass has proven to be difficult to control in furrow-irrigated rice fields. Goosegrass control was highest (87%) when cyhalofop was applied in a program LPOST. The weed spectrum appeared to shift more towards broadleaves and difficult to control grasses in the furrow-irrigated rice system. Producers should budget at least one extra herbicide application in furrow-irrigated rice production for difficult to control weeds and increased weed germination late season without presence of the flood. Additionally, multiple residual herbicide applications should be overlapped to prevent continuous flushes of grass weed species.

Inheritance of Resistance and Response of Provisia™ Rice to Quizalofop-P-Ethyl under U.S. Field Conditions

Camacho, J.R., Linscombe, S.D., Webster, E.P., and Oard, J.H.

Provisia™ rice was developed recently by the BASF Corporation for control of grass weeds and is complementary to existing Clearfield® technology. Our previous research showed that resistance of Provisia™ rice to the ACCase herbicide quizalofop-p-ethyl (QPE) in laboratory and greenhouse environments is governed by a single dominant Mendelian gene. However, these results may not be consistent in different populations or field environments. Therefore, the first objective of the current research is to determine the inheritance of resistance to QPE in rice using different segregating populations evaluated under U.S. field environments. The second objective is to evaluate response of QPE resistant breeding lines to various herbicide concentrations at two U.S. (Louisiana) locations. Chi-square tests of 12 F_2 populations evaluated in Louisiana environments during 2014 and 2015 indicated that QPE seedling resistance at 240 g ai ha−1 was governed by a single dominant Mendelian gene with no observable maternal effects. Similar results were obtained in 5 F_3 populations derived from the aforementioned F_2 populations. Allele-specific SNP markers for QPE resistance also followed Mendelian segregation in the five F_2 populations. For the second objective, six QPE resistant inbred lines showed transient leaf injury at 1X (120 g ai ha−1) or 2X (240 g ai ha−1) field rates, 7 and 21 d after treatment (DAT). However, a trend of reduced injury (recovery) from 7 through 33 DAT was observed for all breeding material. No differences in grain yield were found between untreated QPE resistant lines and those treated with 1X or 2X QPE field rate. Single gene inheritance and good levels of QPE herbicide field resistance in different genetic populations suggest feasibility for rapid and effective development of new QPE resistant varieties and effective stewardship of the Provisia™ technology.

Seedbank Longevity of Cultivated and Weedy Rice in Till and No-Till Cropping Systems

Gu, X.-Y., Mispan, M.S., and Turnipseed, B.E.

Dormant seeds from weedy and feral plants may survive in croplands for years, depending on genotypes (G) and environments (E, including agronomic practices). A series of research on the ecological genetics of weedy rice (*Oryza sativa*) has been conducted to provide fundamental knowledge for improving weed management strategies and mitigating the risk of gene/transgene flow from cultivars. The first objective of this project was to identify genetic and developmental mechanisms shared between seed dormancy (SD) and soil seedbank longevity (SL). A set of 16 isogenic lines for four SD genes isolated from weedy "red" rice were evaluated for germination capability in a controlled environment and SL in the soil of a rice field. Germinability was correlated positively with seed decay rate and negatively with seed survivability in the soil. The four SD loci, including the red pericarp color gene *Rc/SD7-1,* were all involved in regulation of SL through main or epistatic effects, with *Rc* contributing most to the SL variation when it combines with the other SD gene(s). The other objective of this research was to model G-by-E interactions in genetic backgrounds of conventional or Clearfield™ (CL) rice in till and no-till cropping systems. A subpopulation of 150 recombinant inbred lines (RILs) from a cross of weedy/conventional lines were evaluated for SL on the soil surface or in burial to mimic a no-till or a tillage practice. Seed survival under the surface and burial conditions was positively correlated, and the burial enhanced the survivability by about 20%. Five SL QTLs, including one collocated with *Rc/SD7-1*, were mapped, and they all interacted with the till and no-till environments. On-going research includes: 1) confirming the SL QTLs using the whole population of >400 RILs; and 2) modelling G-by-E interactions for the mapped SD/SL genes in populations segregating for the CL gene *Acetolactate Synthase*. This research provided information on the magnitude of SD's effects on SL, new SL genes functionally deafferented between weedy and cultivated rice, and survivability profiles of seeds buried in different soil layers for varying periods. This information could help improve tillage practices to better manage weed problems and infer the likelihood for survivability or fertility of genetically engineered crops in soil seedbanks.

Notable Insights from Arkansas Rice Weed Control and Tolerance Research

Norsworthy, J.K., Butts, T., and Barber, L.T.

More than 100 field and greenhouse trials were conducted in 2019 to develop solutions to existing weed management challenges in Arkansas rice and to evaluate new and emerging technologies. Some of the major takeaways or observations are highlighted. First, benzobicyclon continues to show tremendous promise for removing weedy rice from traited and non-traited rice. Benzobicyclon when applied as part of an overall weed management program was highly effective in controlling weedy rice. Control of weedy rice does appear to be a function of presence or absence of the HIS1 gene, weedy rice size at application, and flood depth. An application of florpyrauxifen-benzyl preflood closely followed by benzobicyclon postflood tended to improve weedy rice control over benzobicyclon alone. However, on hybrid rice, florpyrauxifen-benzyl often injured the crop and subsequently applying benzobicyclon further stressed the rice, resulting in increased auxin-line symptoms. Another notable observation was that when quinclorac preceded florpyrauxifen-benzyl, the later herbicide caused greater injury to rice. Additionally, injury to PVL01 (Provisia rice) was observed in some commercial rice fields in 2019 following application of quizalofop. Injury appeared greatest in low lying areas of some fields and there was an apparent pattern associated with the aerial application of quizalofop. Two late season trials were conducted to better understand the cause of this injury. In one trial, there was substantial injury to PVL01, and the injury was magnified when moist conditions occurred immediately prior to or following a 2X rate of quizalofop to 2-leaf rice that was subsequently sprayed again with a 2X rate of the herbicide preflood. At the other test site, this response was not observed. Future efforts will focus on better understanding to what extent low rates of glyphosate and imazethapyr, moist soils, and nitrogen interact with quizalofop applications to Provisia rice.

Remote Sensing of Weedy Rice in California Rice: Challenges and Opportunities

Brim-DeForest, W., Hogan, S., and Espino, L.

In July 2018, a preliminary study was conducted to determine if it was possible to identify weedy rice in the field using red-green-blue (RGB) and multispectral (blue-green-red-red edge, and near infrared) cameras attached to a multi-rotor drone. Plants were groundtruthed in the field using a handheld GPS device. The data was analyzed to determine if there were any differences between the rice variety and weedy rice. Unfortunately, after analysis, the data collected in the field in 2018 did not reveal any detectable differences.

In 2019, two additional drone flights were conducted, this time angling the cameras at a 90-degree oblique angle, instead of straight down on the fields from above. An analysis using an Analytical Spectral Devices (ASD) hyperspectral electrospectrometer to collect spectral signatures from all of the plants was also conducted in the greenhouse (weedy rice, rice, and all major grass weed species). Unfortunately, once again, the results from the flights did not show discernable differences between the weedy rice and rice. The results from the ASD showed small differences between the weedy rice, the rice variety, and the weed species. However, the spectra the multispectral camera sees are currently not the ones where there are spectral differences between the plants. That said, tilting the RGB imagery seemed to bring out more contrast in the imagery, and maybe with different view angles relative to the sun, the weedy rice might stand out. Given our current technology, it is suspected that only architectural differences (e.g. high variability relative to the sun and sensor angle), or seasonally dependent differences in senescence, might reveal a distinction between the plants.

Abstracts of Posters on Weed Control and Growth Regulation
Panel Chair: Ben Lawrence

Cyperus difformis Cross-Resistance to ALS Inhibitors in California Rice Fields

Ceseski, A.R., and Al-Khatib, K.

Populations of *Cyperus difformis* L. (smallflower umbrella sedge) resistant to the ALS inhibitor bensulfuron-methyl were discovered in California rice fields in 1994, four years after its release. Since then, *C. difformis* populations resistant to each ALS inhibitor registered for California rice have been identified. To adequately inform growers of their *C. difformis* management options and inform the rice industry of the magnitude of the ALS resistance issue, a comprehensive characterization of the scale, distribution, and mechanisms of ALS inhibitor cross-resistance is required.

Sixty-two populations of *C. difformis* suspected to be ALS inhibitor resistant were collected from throughout the region and screened for cross-resistance. Herbicides administered were bensulfuron-methyl, halosulfuron-methyl, bispyribac-sodium, and penoxsulam, applied at discriminating rates of 70.1 & 210.3g ai ha^{-1}, 70.1 & 210.3g ai ha^{-1}, 37.4 & 112.2g ai ha^{-1}, and 42 & 126g ai ha^{-1}, respectively. Six populations of *C. difformis* confirmed ALS cross-resistant were self-pollinated, and S-1 seed were tested for resistance levels via dose-response with the abovementioned herbicides, with rates ranging from 13.3-852g ai ha^{-1}, 13.3-852g ai ha^{-1}, 7.1-455, and 8-510g ai ha^{-1}, respectively. All herbicide treatments were administered with required adjuvants in a compressed-air singletrack spray booth fitted with one 8002EVS tip, delivering 187L ha^{-1}.

Screening revealed six major patterns of ALS inhibitor cross-resistance, with no apparent geographic distribution pattern. Each population tested was resistant to bensulfuron-methyl, with average survival of 75% at the lower rate. Twenty-one populations were susceptible to halosulfuron-methyl, even though it and bensulfuron-methyl are sulfonylureas. Only three populations showed resistance to penoxsulam; two were resistant to all four herbicides. Dose-response confirmed that the majority of resistance in the tested populations was dose-dependent, suggesting nontarget-site resistance mechanisms. Two populations showed high survival at the highest herbicide rates, with RI's >200, and therefore may possess insensitive ALS enzymes. Studies to elucidate target- and nontarget mechanisms of resistance are underway.

Do Barnyardgrass Accessions Differ in Sensitivity to Loyant?

Priess, G.L, Norsworthy, J.K., and Brabham, C.B.

The commercialization and widespread use of Loyant (florpyrauxifen-benzyl) on rice in Arkansas was observed in 2018. However, barnyardgrass accessions appeared to have differing sensitivity levels to Loyant. Barnyardgrass seed from fields where plants survived Loyant applied the previous year were sent to the University of Arkansas for accessions to be screened for sensitivity to the herbicide. A dose response greenhouse experiment was designed to evaluate the effectiveness of Loyant on barnyardgrass at 1/16x, 1/8x, 1/4x, 1/2x, 1x, 2x, and 4X the labeled rate of 30 g ai ha^{-1}. The 1/4x rate of Loyant controlled the susceptible standard (100%). Eight out of twelve barnyardgrass accessions were controlled less than 50% when a 2x rate of Loyant was applied. Additionally, three rice cultivars were evaluated for sensitivity to Loyant. Several of the barnyardgrass populations evaluated were comparable to rice in degree of tolerance to Loyant. Based on comparison to the susceptible standard, some accessions of barnyardgrass in Arkansas display a high level of resistance to Loyant. Future efforts should try to identify the mechanism for resistance and determine if measures can be taken to effectively control this weed in fields where few chemical options remain.

Effect of Rice Growth Stage at Application on Varietal Tolerance to Benzobicyclon

Patterson, J.A., Norsworthy, J.K., Sandoski, C., Lancaster, Z.D., Beesinger, J.W., and Piveta, L.B.

Benzobicyclon is a new herbicide that is currently being evaluated for use in Midsouth rice production. Benzobicyclon must be applied post-flood for its phytotoxic form, benzobicyclon hydrolysate, to be formed. Little to no herbicidal activity has been observed from benzobicyclon when there is no continuous flood present. Benzobicyclon will be the first Group 27 (HPPD) herbicide available for Midsouth rice production. In 2018 and 2019, field experiments were conducted at the Rice Research and Extension Center near Stuttgart, Arkansas. The objectives of these experiments were to assess levels of injury across five rice cultivars when receiving an application of benzobicyclon, and to evaluate the impact of growth stage at the time of application on injury caused by benzobicyclon. The experiments were implemented as split plot designs with four replications. The herbicides used in the trial were Rogue (benzobicyclon) and Rogue Plus (benzobicyclon + halosulfuron) with the benzobicyclon and halosulfuron rates being 741 and 116 g ai ha^{-1}, respectively, which are twice the anticipated labeled rate. The rice varieties used were CL153, PVL01, Rondo, Diamond, and CLXL745. Herbicide treatments were applied post-flood at three crop stages: 1- to 2-leaf, 3- to 4-leaf, and tillering. In 2018, three weeks after the post-flood application, Rondo was severely injured (>95% injury) at all growth stages likely because of its indica background. For the four other japonica-type rice cultivars, tolerance to both benzobicyclon treatments generally increased with rice size at application. Generally, rice was more tolerant to benzobicyclon plus halosulfuron (Rogue Plus) than benzobicyclon alone (Rogue) possibly because of differences in formulation of these two herbicides (SC vs DF). For tillering rice, no more than 18% injury was observed, and this injury was transient, indicating rice has adequate tolerance to this herbicide. In 2019, three weeks after the post-flood application, Rondo was severely injured (>96% injury) at all growth stages, and the four other japonica-type rice cultivars were injured by less than 6% across all treatments.

Can Loyant Followed by Rogue Safely be used on Hybrid and Medium-Grain Rice?

Beesinger, J., Norsworthy, J., Sandoski, C., Patterson, J., Lancaster, Z., and France, O.

Florpyrauxifen-benzyl (Loyant) is a synthetic auxin (Group 4) herbicide intended to be a broad-spectrum herbicide as a pre-flood treatment. Benzobicyclon (Rogue), the first HPPD inhibitor (Group 27) to be used in rice, has yet to be labeled in the midsouthern United States but is used as a post-flood treatment in rice maintained with a continuous flood in other countries. Loyant has been found to control many broadleaf weeds, barnyardgrass (*Echinochloa crus-galli*), and sedges (*Cyperus* ssp.), while Rogue boasts control of weedy rice (*Oryza sativa*) and sprangletops (*Leptochloa* spp.), making the combination of both herbicides an effective means of controlling the four most significant weeds in Arkansas rice production. Loyant, however, has been shown to induce auxin injury on some varieties of rice. Rogue has also been shown to cause phytotoxicity on certain varieties, mainly those with an *indica* background. An experiment was conducted at the Rice Research and Extension Center near Stuttgart, Arkansas in 2019 to test the tolerance of certain medium-grain and hybrid cultivars to Loyant, Rogue, and a combination of the two. Varieties planted included the hybrids XP753, CLXL745, and Gemini 214CL and the medium grain in-bred Titan. Herbicide treatments included no Loyant or Loyant applied pre-flood at 30 g ae ha^{-1} and no Rogue or applied at 371 g ai ha^{-1} in a post flood application. There was minimal injury to all cultivars in this trial, with no more than 15% injury observed. In a separate large-plot demonstration planted to Gemini later in the growing season, Loyant at 30 g ae ha^{-1} was severely injurious to the rice (>40% injury) and this auxin like injury increased when followed by Rogue. Based on these results, there does appear to be increased risk for injury to rice when Loyant is followed by Rogue, but this risk is likely variety specific and may be dependent upon environmental conditions following application of both herbicides.

Do Group 15 Herbicides Have a Fit in Louisiana Rice Production?

Webster, L.C., Webster, E.P., McKnight, B.M., Rustom, S.Y., Greer, W.B., Walker, D.C.

Over the past three decades, barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] has been confirmed throughout the Mid-South to be resistant to several herbicides with differing sites of action. Beginning in 1989, barnyardgrass resistant biotypes were discovered to be resistant to propanil and since then barnyardgrass biotypes have been found to be resistant to quinclorac, imazamox, imazethapyr, penoxsulam, and bispyribac. In addition to barnyardgrass, red rice (*Oryza sativa* L.) has been found to be resistant to imazethapyr and imazamox in the Clearfield rice production system. In order to combat herbicide resistance, growers are exploring non-labelled herbicides such as very-long-chain fatty acid inhibiting herbicides, also known as group 15 herbicides.

A study was conducted in 2019 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the crop safety and potential weed control of group 15 herbicides in Louisiana rice production. Plot size was 3-m by 11.3-m with 16-19.5 cm drill-seeded rows of 'CL-111' at 78.4 kg ha^{-1}. The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of acetochlor at 1,050 g ai ha^{-1}, dimethenamid at 940 g ai ha^{-1}, S-metolachlor at 1064 g ai ha^{-1}, pyroxasulfone at 119 g ai ha^{-1}, and pethoxamid at 661 g ai ha^{-1}. Factor B consisted of herbicides applied preemergence (PRE), delayed preemergence (DPRE) and early postemergence (EPOST). All DPRE and EPOST applications were applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations for the study were recorded at 14 and 28 days after (DA) each timing for crop injury in addition to barnyardgrass and red rice control.

Crop injury was observed at 55 and 32% when treated with acetochlor at 14 and 28 DA PRE, respectively. All other herbicides resulted in crop injury of 87 to 97% at 14 DA PRE and 75 to 95% at 28 DA PRE. Rice treated with all herbicides evaluated exceeded 41 and 36% injury at 14 and 28 DA DPRE, respectively. Crop injury of 20 and 21% was observed at 14 DA EPOST when treated with acetochlor or pethoxamid, respectively. At 28 DA EPOST, crop injury was 5 and 10% when treated with pethoxamid or acetochlor, respectively. Rice treated with all other herbicides resulted in 37 to 60% and 23 to 57% crop injury at 14 and 28 DA EPOST, respectively. These results indicate crop injury is reduced as the rice becomes more developed before application; however, a reduction in control of barnyardgrass and red rice was observed at the DPRE and EPOST timings compared with the herbicides applied PRE.

Does Soil Moisture at Application Influence Weed Control with Loyant?

Zaccaro, M.L., Norsworthy, J.K., and Beesinger, J.W.

The release of the Loyant™ technology by Corteva Agriscience™ occurred in the 2018 growing season. This technology is based on a novel active ingredient - florpyrauxifen-benzyl, which provides broad-spectrum weed control. Previous research reported that Loyant has a high efficacy to control troublesome weeds in rice production, such as barnyardgrass (*Echinochloa crus-galli*) and hemp sesbania (*Sesbania herbacea*). It is recommended that Loyant applications are made pre-flood, and then a permanent flood is established soon after application. In addition, the herbicide has been verified to be useful to control Palmer amaranth (*Amaranthus palmeri*) in dryland conditions. Therefore, due to the flexibility of the Loyant herbicide, and the good efficacy to control weeds, we hypothesized that at a higher soil moisture will promote better weed control in the rice. The objective of this study was to evaluate the effect of soil moisture and herbicide applications that included florpyrauxifen-benzyl on weed control and crop safety.

An experiment was conducted in 2019 at the Rice Research and Extension Center (RREC) near Stuttgart, Arkansas. A long-grain hybrid rice variety (XP 753) was planted on April 25 at the rate of 36 seeds/m row, and then plots were established measuring 2 by 5-m. Herbicide treatments were made on May 30th, when barnyardgrass was at the 4-leaf growth stage. The trial was set up as a split-plot design with four replications, where the main-plot factor was the soil moisture at application (wet or dry), and sub-plot factor was the herbicide treatments. Herbicide treatments were Loyant 30 g ai/ha, Loyant plus methylated seed oil (MSO) at 0.6 L/ha, and a premixture of cyhalofop + florpyrauxifen-benzyl (16.9% + 1.26%) at 2.05 L/ha plus MSO. A nontreated check was included in this experiment. The plots with different soil moisture treatments were kept in separate bays. One bay was kept dry and the wet bay was flushed prior to herbicide application to increase soil moisture. The herbicide treatments were applied using a CO_2-pressurized backpack sprayer coupled with AIXR 110015 nozzles, calibrated to deliver 140 L/ha. Crop injury and weed control were evaluated at 14, 28, and 48 days after treatment (DAT), also grain yield was estimated at maturity. Data were analyzed using JMP Pro 14, where ANOVA test was performed, and appropriate means were separated with using the LSMeans procedure with a significance level of 0.05.

None of the treatments resulted in significant injury to the rice. Only herbicide treatment influenced weed control. At 28 DAT, Loyant alone had slightly lower barnyardgrass control than the cyhalofop + florpyrauxifen-benzyl premix. By 48 DAT, the treatments were no longer statistically different, but barnyardgrass control was still high, ranging from 94 to 97%. All treatments had excellent control of hemp sesbania at 14 and 28 DAT. Even though not statically different, control of barnyardgrass and sprangletop (*Leptochloa fusca* ssp. *fascicularis*) was numerically lower in treatments applied to dry soil. The treatment combinations did not statistically influence yield results. Therefore, we rejected our hypothesis because treatments using Loyant were not statistically influenced by soil moisture at application.

Efficacy of Benzobicyclon on Weedy Rice at Different Growth Stages

Castner, M.C., Norsworthy, J.K., Brabham, C.B., Sandoski, C., Patterson, J.A., and Zaccaro, M.L.

Weedy rice (*Oryza sativa*) is one of the most threatening weeds to Midsouth rice production due to a lack of chemical control options as well as its adverse influence on grain quality. Not only are chemical control options limited, the effective window for controlling weedy rice is likely a function of size. In order to evaluate the extent of herbicidal activity of benzobicyclon, experiments were conducted near Stuttgart, Arkansas, and Colt, Arkansas in 2019. A total of 15 weedy rice accessions and 6 known rice cultivars were planted at two separate timings and flooded when the initial planting reached 4 to 5 leaves at Colt and 1 to 2 tillers at Stuttgart to determine the efficacy of benzobicyclon at multiple growth stages. Treatments were arranged as a two-factor split-plot with three replications, with the whole-plot factor being size at application (3-4 leaves or 1-2 tillers at Stuttgart; 1-2 or 4-5 leaves at Colt) and sub-plot factor being accession. An interaction of accession and application timing was observed for injury at both 14 and 28 days after treatment (DAT). Overall, smaller, later planted accessions saw greater injury in comparison to earlier planted accessions. However, highly sensitive accessions or rice cultivars were effectively controlled or severely injured at both application timings. Injury from a cross between Purple Marker, a sensitive cultivar, and RoyJ, a tolerant cultivar, showed partial tolerance when applications exceeded the 3-4 leaf stage. Ultimately, benzobicyclon is most effective when applied to weedy rice prior to the 3-leaf growth stages or when weedy rice plants do not express a functional HIS-1 gene.

Carryover of Preface and Postscript to Non-imidazolinone-resistant Rice on a High pH Soil

France, O.W., Norsworthy, J.K., Lancaster, Z.D., Patterson, J.A., and Beesinger, J.W.

The recently released FullPage™ technology utilizes imidazolinone herbicides, imazamox (Postscript™) and imazethapyr (Preface™), to control problematic weeds such as: barnyardgrass (*Echinochloa crus-galli*), broadleaf signalgrass (*Urochloa platyphylla*), and red rice (*Oryza sativa* spp.). Both herbicides can be applied preemergence and postemergence in FullPage™ rice production systems; however, the effect of these residuals may carry-over and cause injury in non-FullPage™ rice for the next growing season. To test this hypothesis a study was conducted at the Pine Tree research station in Pine Tree, AR over the years of 2018 and 2019 on a high pH soil (8.0 – 8.3). The trial was designed as a single factor factorial with herbicide combination as the main factor. In 2018, FullPage™ rice was planted and applied with: imazethapyr and imazamox at either 105.4 g ha^{-1} plus 43.7 g ha^{-1}, respectively, or 210 g ha^{-1} plus 87.4 g ha^{-1}, respectively, or imazamox alone at 43.7 g ha^{-1} or 87.4 g ha^{-1}. There was a total of five treatments including the nontreated check which received neither imazethapyr nor imazamox. All treatments also received applications of clomazone (Command), quinclorac (Facet and Zurax™) at two timings, and propanil (SuperWham) at recommended rates to better simulate an integrated weed management approach in a commercial rice production system. In 2019, a non-FullPage™ rice variety (Diamond) was planted in plots applied with treatments the previous season and used to collect residual injury data. Data collected during the 2019 season includes ratings of visible injury, stand reduction, stunting and chlorosis taken weekly following rice emergence as well as yield data at harvest. Plots receiving the high rate of both imazethapyr and imazamox had significantly greater injury than any other treatment and was followed by the treatment receiving the low rate of both herbicides, indicating that imazethapyr did carryover but imazamox did not. Yield data parallels injury data findings with plots receiving the high rate of both herbicides averaging 67% yield and plots receiving the low rate of both averaging 80% yield versus the nontreated. All other treatments yielded within 10% of the nontreated. Data collected from other ratings will be discussed.

Evaluation of Fullpage Rice Systems Containing Preface and Postscript

Farr, R.B., Norsworthy, J.K., and Piveta, L.B.

The use of imazamox and imazethapyr in rice production to control troublesome weeds such as barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) increased with the introduction of Clearfield rice cultivars. As barnyardgrass developed resistance to propanil and quinclorac, heavy selection pressure was placed on imidazolinone chemistries. This has brought forth the need for effective rice weed control programs that utilize multiple modes of action as well as rice cultivars with improved tolerance to imazamox and imazethapyr. Adama and RiceTec have collectively launched Postscript (imazamox) and Preface (imazethapyr) for use in Fullpage rice. The purpose of this study was to evaluate different rice weed control programs that include these new formulations of imazamox and imazethapyr. This study was conducted at the Rice Research and Extension Center near Stuttgart, AR. The study contained 13 experimental treatments arranged in a randomized complete block design plus a nontreated check for comparison. Herbicide programs consisted of treatments with and without preemergence applications of clomazone, 1- to 2-leaf rice applications utilizing different combinations of Postscript or Preface alone or with clomazone, pendimethalin, or quinclorac, 4- to 5-leaf rice applications utilizing different combinations of Preface or Postscript alone or with florpyrauxifen-benzyl or halosulfuron, and treatments with or without post-flood treatments of Postscript. Visual estimates of weed control were taken every 7 days after each application until 56 days after final application. No injury to the Fullpage rice from Postscript or Preface was observed. The results from this study showed significant difference in control of individual weed species among treatments, but no differences in yield. Treatments that included a preemergence application of clomazone plus saflufenacil had significantly better control of rice flatsedge and hemp sesbania (*Sesbania herbacea* (Mill.) McVaugh) than treatments that did not, even at 56 days after the final application. An application of florpyrauxifen-benzyl at the 4- to 5-leaf stage of rice provided less barnyardgrass control than any other treatment. Applications of Postscript and Preface when used as part of a postemergence application were found to be similar statistically. The findings from this study are aimed to aid rice producers in determining how to better implement new formulations of imazamox and imazethapyr as tools in effective weed management programs.

Does Planting Date Affect Sensitivity of Rice Cultivars to Loyant?

Avent, T.H., Norsworthy, J.K., Beesinger, J.W., Piveta, L.B., and Lancaster, Z.D.

Loyant (floryprauxifen-benzyl) released in 2018 by Corteva provided effective control of weeds in rice, including some grasses; however, occurrence of unacceptable levels of rice injury have been reported across the Midsouth rice region. To date, there has been no definitive answer as to what causes the injury. Field trials were conducted near Stuttgart, Arkansas at the Rice Research and Extension Center in 2019 to determine if planting date or environmental conditions at or near application affected the severity of rice injury caused by florpyrauxifen-benzyl. The experiment was designed as a complete randomized block design with three factors: cultivar, florpyrauxifen-benzyl rate 15, 30, and 60 g ha^{-1}, and three planting dates of early April, early May, and late May. Injury was influenced by the main effects of planting date and rate of florpyrauxifen-benzyl at 10 and 28 days after treatment (DAT), with the early May planting being the least injurious across rate and cultivar. Cultivar also had no significant effect on rice injury. At 20 days after treatment (DAT), a two-way interaction was observed of both planting date and florpyrauxifen-benzyl rate, indicating that early April and early May plantings had less injury than when planted in late May. Warmer conditions during application and rapid rice growth associated with the later planting are believed to have contributed to the increased injury. Averaged across planting dates, rice injury increased as florpyrauxifen-benzyl rate increased. This research suggests that as planting dates shift to later in the growing season and as rates of florpyrauxifen-benzyl increase, there is a higher risk for rice injury. This research should help growers better understand the risks of applying florpyrauxifen at higher than labeled rates, especially under warm conditions conducive for rapid growth of the crop.

Evaluation of Pyraclonil, a New Broad-Spectrum Herbicide, in California Water-Seeded Rice

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

California rice production has limited amount of herbicide tools for weed management. There have been many cases of herbicide resistant weeds uprising that further reduce the tools available for growers. Pyraclonil is a new broad-spectrum herbicide available for California in the future. It is a PPO inhibitor and so far no resistance has been observed in California rice weeds for this mode of action. Pyraclonil efficacy and rice crop injury were evaluated in a field trial for the 2019 season. A randomized complete block design (RCBD) with four replications study was conducted at the Rice Experiment Station in Biggs, California. Weed control with seven pyraclonil herbicide programs was evaluated in M206 rice. Pyraclonil was applied at day of seeding at 300 g a.i./ha (14.9 lb/ac). Partner herbicides included propanil, benzobicyclon plus halosulfuron, clomazone, thiobencarb, bispyribac-sodium, penoxsulam and florpyrauxinfen-benzyl applied at their respective timing and rate stated on the label. Weed control was determined at 14, 28, and 42 days after seeding (DAS). Grain yield was obtained. ANOVA was used to analyze data and means were separated using LSD (p=0.05). Pyraclonil gave excellent control of watergrass (*Echinochloa spp.*), sprangletop (*Leptochloa fascicularis*), ricefield bulrush (*Schoenoplectus mucronatus*), smallflower sedge (*Cyperus difformis)* and ducksalad (*Heteranthera limosa)*. Acceptable yields were recorded for all seven pyraclonil herbicide programs. No significant crop response injury was recorded from pyraclonil treatments. This study showed that pyraclonil is a promising herbicide for weed control in California water-seeded rice cropping systems.

Herbicide Activity on Common Louisiana Aquatic Weeds

McKnight, B.M., Webster, E.P., Rustom Jr., S.Y., Webster, L.C., Greer, W.B., and Walker, D.C.

Rice production systems in Southern Louisiana are commonly rotated with crawfish aquaculture production systems. In these production systems immediately following rice harvest, the area is flooded to allow for crawfish growth and reproduction. Typical rice crawfish production areas may remain flooded for 11 months or longer. Several species of common Louisiana aquatic weeds can become troublesome in this rotational system due to the duration of flood water impoundment. Many of these weed species are not specifically mentioned on rice herbicide labels. The objective of this study was to evaluate the activity of several herbicides labeled for use in Louisiana rice production on these troublesome aquatic weeds.

A field study was conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the activity of seven different herbicides, applied alone or in combination, on grassy arrowhead (*Sagittaria graminea* Michx.), pickerelweed (*Pontedaria cordata* L.), ladysthumb (*Polygonum persicaria* L.), ducksalad (*Heteranthera limosa* (Sw.) Willd.), yellow nutsedge (*Cyperus esculentus* L.) and alligatorweed (*Alternanthera philoxeroides* (Mart.) Grisb.). Plot size was 1.5 m by 5.2 m and a 91-cm diameter galvanized metal ring was installed within each plot to provide a defined area for transplanting aquatic weeds and to also contain herbicide treatments. Grassy arrowhead, pickerelweed and ladysthumb were transplated inside the metal rings 3 weeks prior to treatment to allow time for plant establishment. Since the study area was infested with a naturally occurring stand of ducksalad, yellow nutsedge and alligatorweed, transplanting of these species was not necessary. No rice was planted in this study to prevent competition between rice and weeds. All herbicides were applied with crop oil concentrate at 1% v $^{-1}$. Application consisted of treating the entire plot area with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} spray solution and a hand-held spray boom with five flat-fan 110015 nozzles at 38-cm spacing. Visual injury ratings were collected at 14, 28, 42 and 56 DAT. At the conclusion of the study, 56 DAT, plants were hand-harvested, grouped by species and fresh weight biomass was determined.

By the conclusion of the study, 56 DAT, pickerelweed was controlled 96% with any rate of the pre-package mix of halosulfuron + prosulfuron. No pickerelweed biomass was present in rings treated with this mix, indicating complete control of this weed by 56 DAT. Florpyrauxifen-benzyl applied at 15 g ai ha^{-1}controlled pickerelweed 96% and no pickerelweed biomass was detected in plots receiving this treatment at 56 DAT. Grassy arrowhead treated with halosulfuron + prosulfuron at 83 and 111 g ai ha^{-1} was controlled 96% and biomass was not present in treated rings at 56 DAT. Penoxsulam, florpyrauxifen-benzyl, and penoxsulam + triclopyr controlled grassy arrowhead 97%, 96%, and 97%, respectively. These treatments also provided complete control and no grassy arrowhead biomass was present in treated rings at 56 DAT. At 56 DAT alligatorweed biomass was reduced, compared with the nontreated, following treatment with halosulfuron + prosulfuron, florpyrauxifen-benzyl, penoxsulam, and penoxsulam + triclopyr. Visual control of yellow nutsedge was 96% to 97% at 56 DAT when treated with any rate of halosulfuron + prosulfuron or florpyrauxifen-benzyl. No yellow nutsedge biomass was present in rings treated with these herbicides at the conclusion of the study. Benzobicyclon + halosulfuron + prosulfuron controlled yellow nutsedge 98% and no yellow nutsedge biomass was observed in rings treated with this mix, 56 DAT. All herbicides and herbicide mixtures evaluated in this study, with the exception of saflufenacil applied at 50 g ai ha^{-1}, reduced ladysthumb biomass, compared with the nontreated.

Salvage Options for Northern jointvetch (*Aeschynomene virginica*) and Hemp Sesbania (*Sesbania herbacea*) Using ALS-inhibiting Herbicides and Benzobicyclon in Drill-Seeded Rice

Davis, B.M., Sandoski, C., and Butts, T.R.

Hemp sesbania (*Sesbania herbacea*) and northern jointvetch (*Aeschynomene virginica*) are among the top ten problematic rice weeds in Arkansas according to a crop consultant survey. Both weeds produce "black seed" that is difficult to separate from rice during harvest, leading to weed seed in grain samples at the mill. Several options are available for early-season control, but in the event of a failure or escape there are few options for a post-flood salvage treatment that will provide adequate control. The objective of this research was to determine a viable herbicide option to control hemp sesbania and northern jointvetch in a post-flood salvage situation.

Two studies were conducted in the summer of 2019 at the University of Arkansas at Pine Bluff Small Farm Outreach Center near Lonoke, AR. The first study evaluated efficacy of several ALS-inhibiting herbicides [halosulfuron (Permit), halosulfuron + thifensulfuron (Permit Plus), and halosulfuron + prosulfuron (Gambit)] applied alone at multiple rates on hemp sesbania and northern jointvetch. Treatments consisted of halosulfuron at 17, 35, 53, and 70 g $aiha^{-1}$, halosulfuron + thifensulfuron at 18 + 2 and 36 + 4 g $aiha^{-1}$, respectively, and halosulfuron + prosulfuron at 18 + 11, 36 + 22, 54 + 33, and 72 + 44 g $aiha^{-1}$, respectively. The second study evaluated tank-mixture options of ALS-inhibiting herbicides [halosulfuron (Permit) and halosulfuron + prosulfuron (Gambit)] at multiple rates with benzobicyclonfor the control of hemp sesbania and northern jointvetch. Treatments consisted of benzobicyclon at 247 g $aiha^{-1}$ applied alone and in combination with halosulfuron at 53 and 70 g ai ha^{-1}, and in combination with halosulfuron + prosulfuron at 18 + 11, 27 + 17, and 36 + 22g ai ha^{-1}, respectively. Both experimental designs were randomized complete block designs with four replications in the first study and three replications in the second study. Treatments were applied post-flood with a CO_2 backpack sprayer equipped withDG 110015 tips calibrated to deliver 94 L ha^{-1}. Visual weed control ratings were taken weekly and were estimated using a scale of 0% to 100% where: 0% is no control and 100% is complete plant death. Data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference test at a 5% level of significance.

In the first study, all treatments provided 98% or greater control of both weedspecies at 3 weeks after treatment (WAT). At pre-harvest, all treatments still provided excellent control of greater than 94%. In the second study, all treatments provided 85% or greater control of hemp sesbania and northern jointvetch at 4 WAT with the exception of benzobicyclon alone providing less than 10% control of both weed species. At pre-harvest, hemp sesbania control remained above 85% for all treatments excluding the benzobicyclon alone treatment which was less than 30%. Northern jointvetch control with benzobicyclon plus halosulfuron at 53 and 70 g ai ha^{-1}, and benzobicyclon plus halosulfuron + prosulfuron at 36 + 22g ai ha^{-1}, respectively, provided greater than 80% control while the remainder of the treatments provided less than 70% control. Benzobicyclon alone showed no control of northern jointvetch at pre-harvest.

Hemp sesbania and northern jointvetch were controlled in a post-flood salvage situation using ALS-inhibiting herbicides alone or in combination with benzobicyclon. Control of these weeds prior to seed set is key to reducing or eliminating "black seed" in samples at the mill and in return, reducing dockage to the grower to increase potential profit. Weed size and timing of application are critical in the control of these problematic rice weeds in Arkansas. Any of the three ALS-inhibiting herbicides evaluated in this research applied at label rates either alone or in combination with benzobicyclon can control these problematic weeds as a salvage option in flooded rice.

Is Florpyrauxifen-benzyl Volatile when Applied to Rice Foliage, Bare Soil or Open Water?

Greer, W.B., Webster, E.P., McKnight, B.M., Walker, D.C., Rustom, S.Y., and Webster, L.C.

Florpyrauxifen-benzyl is a new synthetic auxin herbicide that has activity on select broadleaf, grass, sedge, and aquatic weeds in rice (*Oryza sativa* L.). With the introduction of a new synthetic auxin also comes an increased risk for off-target movement of this herbicide.

Similar herbicides of the synthetic auxin group such as dicamba and 2,4-D have shown to volatilize and be subject to vapor drift under the right environmental conditions. Furthermore, this herbicide is often applied to rice fields that neighbor susceptible vegetation like soybean [*Glycine max* (L.) Merr.] and poses an increased risk of off-target damage. Therefore, the volatility of florpyrauxifen was evaluated when applied to rice foliage, bare soil, and open water using soybean as a bioindicator to measure distance moved.

To induce high humidity and steady wind speeds, wind tunnels were placed in the middle of two, 15.24 m rows of soybean spaced at 0.97 m. Treatments consisted of florpyrauxifen applied alone at 29.4 g ai ha^{-1}, florpyrauxifen 29.4 g ai ha^{-1} + ammonium sulfate (AMS) 2.24 kg ai ha^{-1}, and dicamba applied alone at 1115 g ai ha^{-1}. Treated flats of either rice foliage, bare soil, or open water were placed in the center of the wind tunnel for 48 hours after application. Flats were then removed, and soybean visual injury and plant height were recorded in 0.3 m increments from the center of the plot. At crop maturity, individual soybean yield components were recorded to determine how vapor drift of florpyrauxifen affected vegetative and reproductive growth of soybean.

Results indicate that florpyrauxifen applied alone or with AMS, unlike other synthetic auxins, is not susceptible to volatilization after application and moved no more than two feet regardless of the substrate it was applied to. Furthermore, florpyrauxifen treatments showed no difference in individual yield components from the non-treated check. This suggests that while there have been instances of off-target movement of florpyrauxifen to soybeans, it is likely due to physical spray droplet movement as opposed to vapor drift.

Using Reduced Rates of Quizalofop for the Control of Weedy Rice

Walker, D.C., Webster, E.P., McKnight, B.M., Rustom, S.Y., Webster, L.C., and Greer, W.B.

A current weed management issue in rice-producing areas throughout the world is the management of weedy rice (*Oryza sativa* L.), more particularly, imidazolinone-resistant (IR) weedy rice. With concerns around IR weedy rice resistance, BASF developed a new herbicide-resistant rice sold under the trade name Provisia®. The herbicide targeted for use is quizalofop, which will also be sold under the trade name Provisia®. Quizalofop is a Group 1 herbicide, which inhibits the acetyl-coA carboxylase (ACCase) enzyme. The targeted single quizalofop application rate in ACCase-resistant rice production is 92 to 155 g ha^{-1}, not to exceed 240 g ha^{-1} yr^{-1}. Research was conducted at the Rice Research Station near Crowley, Louisiana to evaluate the activity of quizalofop at different rates for management of weedy rice.

Quizalofop was applied at 23.2, 46.2, 69.2, 92.4, and 116 g ha^{-1} to weedy rice at the two- to three-leaf stage and at panicle initiation to determine the rate needed for control. Quizalofop was applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Plot size was 3 m by 11.3 m with 16, 19.5 cm drill-seeded rows of weedy rice planted at 67 kg ha^{-1}. The study was a randomized complete block with three replications. In order to have an accurate representation of a weedy rice population, four separate studies were conducted using four different types of weedy rice: a conventional line, an imidazolinone-resistant hybrid line, an inbred imidazolinone-resistant hybrid line, and red rice.

Weedy rice control and plant heights were recorded at 7, 14 and 28 days after treatment and immediately prior to biomass collection. At 14 d after the two- to three-leaf timing, 46.2, 69.2, 92.4, and 116 g ha^{-1} of quizalofop controlled weedy rice 91 to 98%. At 28 days after treatment (DAT), regrowth occurred on weedy rice treated with 46.2, 69.2, and 92.4 g ha^{-1} with observed control of 74 to 79%; however, quizalofop applied at 116 g ha^{-1} controlled weedy rice 90%. At 28 days after the panicle initiation timing, quizalofop applied at 69.2, 92.4, and 116 g ha^{-1} controlled weedy rice 83, 95, and 99%, respectively. Therefore, reduced rates can be used to manage weedy rice and minimize the amount of applied product throughout the growing season.

Inbred and Hybrid Rice Cultivar Response to Florpyrauxifen-benzyl

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

Florpyrauxifen-benzyl is a postemergence (POST) herbicide developed by Corteva Agrisciences for control of broadleaf, grass, and sedge weeds, and it is a member of the synthetic auxin herbicide family, the arylpicolinates. The arylpicolinates have a unique site of action within susceptible broadleaf, grass, and sedge weed species. Postemergence applications may be made from the two- to three-leaf rice stage up to 60 d before harvest, and flooding within 5 d of application improves weed control. Variability in cultivar tolerance has been documented based on differences in cultivar growth rate, growth stage, morphology, and physiology. Previous research in Mississippi has demonstrated that rice cultivars respond differently to florpyrauxifen-benzyl; however, that work only evaluated a limited number of cultivars. Therefore, research was initiated to evaluate the response of commercial rice cultivars to sequential POST applications of florpyrauxifen-benzyl applied at different rates.

The study was conducted in 2019 at the Mississippi State University Delta Research and Extension Center in Stoneville. Individual plots measured 1.4 m in width and 3.8 m in length. Treatments were arranged as a two-factor factorial within a randomized complete block experimental design with four replications. Factor A was rice cultivar and included 'Diamond', 'RTXL753', 'CL153', and 'RT7321-FP'. Factor B was florpyrauxifen-benzyl treatment and consisted of no florpyrauxifen-benzyl treatment, single applications of florpyrauxifen-benzyl at 0.029 and 0.059 kg ai/ha, and a split application of florpyrauxifen-benzyl at 0.029 followed by (fb) 0.029 kg ai/ha. Single applications were applied to rice in the two- to three-leaf growth stage. Split applications were applied to rice at the EPOST stage fb the sequential treatment 14 d after EPOST application timing (LPOST). Visible estimates of rice injury on a scale of 0 to 100% (0 = no injury and 100 = total plant death) were recorded at 7, 14, and 28 d after the LPOST treatment by comparing treated plots with control plots for the respective cultivar in each replication. Plant heights were recorded 14 d after LPOST treatment. The number of days to 50% heading was recorded as an estimate of rice maturity and was converted to delay in days to 50% heading by subtracting data from the nontreated plot from that in the treated plot for the respective cultivar in each replication. Rice height and rough rice yield were collected at maturity, and these data were converted to a percent of the control for the respective cultivar in each replication by dividing data from the treated plot by that in the nontreated plot and multiplying by 100. All data were subjected to ANOVA, and estimates of the least square means were utilized for mean separation with $p \leq 0.05$.

Rice injury from florpyrauxifen-benzyl was rolling of leaves, minor discoloration, and less dense canopy in treated plots compared with the nontreated control for the same cultivar. Injury 14 and 28 d after LPOST treatment was similar among all florpyrauxifen-benzyl treatments for each cultivar. Although injury 14 d after LPOST for Diamond was less with split applications of florpyrauxifen-benzyl compared with either rate applied as a single application, injury was ≤ 5% for all florpyrauxifen-benzyl treatments. Diamond was injured less than other cultivars 14 and 28 d after LPOST following florpyrauxifen-benzyl in a single application at 0.059 kg/ha and with the split application. Pooled over florpyrauxifen-benzyl treatments, rice height 14 d after LPOST was lower for Diamond compared with CL153 and RT7321-FP. Additionally, RTXL753 height was less than that for Diamond. Florpyrauxifen-benzyl treatment did not influence rice maturity or rough rice yield. Delay in days to 50% heading was ≤ 2 d, and rough rice yields were ≥ 94% of the nontreated for all cultivars and florpyrauxifen-benzyl treatments.

Current labeling only allows florpyrauxifen-benzyl application at 0.029 kg/ha. Furthermore, it is unlikely that multiple applications of florpyrauxifen-benzyl will be applied at a single site. However, in commercial fields, variability in growth stages and irregularities in florpyrauxifen-benzyl application may occur that would make application rates exceed that specified on the label under some commercial field situations. In the current research, Diamond was injured less than other cultivars with florpyrauxifen-benzyl 14 d after LPOST treatment. Despite observed differences in injury, rice maturity and rough rice yield were not affected for any cultivar. This demonstrates that florpyrauxifen-benzyl can safely be applied to Diamond, RTXL753, CL153, and RT7321-FP.

Nitrogen Fertilizer Programs Following Rice Exposure to a Sub-lethal Concentration of Paraquat

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

Due to Mississippi's diverse cropping mix and production of rice (*Oryza sativa* L.) near corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean [*Glycine max* (L.) Merr.], off-target paraquat movement to rice has become a major issue in recent years for Mississippi rice producers. Nitrogen (N) fertilizer is applied to rice in greater quantity and frequency than all other nutrients to optimize rice yield. A common N fertilizer management practice is to apply starter N fertilizer as ammonium sulfate (AMS) at 24 kg N ha^{-1} to support rice that encounters early-season stress. Therefore, research was conducted to evaluate (1) whether starter N fertilizer can aid rice recovery from exposure to a sub-lethal concentration of paraquat and (2) rice response to different N fertilizer management strategies following exposure to a sub-lethal concentration of paraquat.

Two studies (Starter N Fertilizer Study and Nitrogen Fertilizer Timing Study) were conducted from 2015 to 2018 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate N fertilizer management following exposure to a sub-lethal concentration of paraquat. Treatments in the Starter N Fertilizer Study were arranged as a two-factor factorial within a randomized complete block design and four replications. Factor A was paraquat treatment and consisted of paraquat at 0 and 84 g ai ha^{-1} applied to rice in the two- to three-leaf (EPOST) stage. Factor B was starter N fertilizer timing and consisted of no starter N fertilizer and starter N fertilizer at 24 kg ha^{-1} as AMS (21-00-00) applied to rice in the spiking to one-leaf rice (VEPOST), EPOST, and three- to four-leaf (MPOST) stages. The Nitrogen Fertilizer Timing Study utilized a two-factor factorial treatment arrangement in a randomized complete block design with four replications. Factor A was paraquat treatment and consisted of paraquat at 0 and 84 g ha^{-1} EPOST. Factor B was N fertilizer application timings and consisted of N fertilizer at 168 kg N ha^{-1} as urea (46-00-00) applied in a single application at four-leaf to one-tiller rice (LPOST); in two sequential applications of 112 and 56 kg N ha^{-1} applied LPOST followed by (fb) panicle differentiation (PD); in three sequential application of 84, 42, and 42 kg N ha^{-1} applied LPOST fb 14 d postflood (14 DPF) fb PD; in four sequential applications of 42, 42, 42, and 42 kg N ha^{-1} applied MPOST fb LPOST fb 14 DPF fb PD; and in four sequential applications of 42, 42, 42, and 42 kg N ha^{-1} applied LPOST fb 14 DPF fb PD fb 5% heading (5% HD). In both studies, data collected included visible estimates of rice injury 3, 7, 14, 21, and 28 d after paraquat treatment (DAPT), rice height 14 DAPT, days to 50% heading, rice aboveground biomass, and rough rice yields. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

In the Starter N Fertilizer Study, rice injury following exposure to a sub-lethal concentration of paraquat ranged from 41 to 55% at all evaluations. Rice dry weight prior to flooding was reduced from 106 to 24 g m^{-2} following exposure to paraquat. Rice height was 16 cm following exposure to paraquat compared with 28 cm with no exposure to paraquat. Averaged across six site years and four starter N fertilizer application timings, rice dry weight at maturity was reduced from 1,731 to 1,157 g m^{-2}, rough rice yield was reduced from 8,400 to 5,490 kg ha^{-1}, and total milled rice yield was reduced from 71 to 70% following exposure to paraquat EPOST. Starter N fertilizer treatment had no influence on rice growth, development, or yield following exposure to paraquat.

In the Nitrogen Fertilizer Timing Study, rice was injured 45 to 62% 3, 14, and 21 DAPT regardless of N fertilizer timing. For all N fertilizer timings, rice injury 28 DAPT was ≥60%; however, greatest rice injury (67%) was recorded in plots exposed to paraquat when 100% of N fertilizer was applied in a single LPOST application. Paraquat reduced rice height from 108 to 93 cm, increased d to 50% heading 10 d, reduced dry weight at maturity from 1,800 to 1,000 g m^{-2}, total milled rice yield from 70 to 69 g, and rough rice yield from 7,930 to 4,430 kg ha^{-1}. Rice maturity was 86 to 88 d regardless of N fertilizer timing; however, a timing with 100% of N fertilizer applied LPOST increased d to 50% heading more than when a split application was utilized. Rough rice yield was 6,300 kg ha^{-1} when data were averaged across paraquat treatments and N fertilizer was applied at 42 kg N ha^{-1} in four equal doses at MPOST:LPOST:14 DPF:PD; however, this N fertilizer management strategy produced rough rice yield comparable to all single, two-, and three-way split applications of N fertilizer.

Data from these studies indicate severe rice growth and development issues can occur from rice exposure to a sub-lethal concentration of paraquat. Additionally, rice was unable to overcome early-season exposure to paraquat. In both studies, manipulation of N fertilizer management did not facilitate rice recovery from early-season exposure to paraquat.

Off-target Movement of Rogue plus Permit: Should There be a Concern?

Piveta, L.B., Norsworthy, J.K., Sandoski, C., and Houston, M.M.

Gowan Company is developing Rogue (benzobicyclon), a new rice herbicide for post-flood control of problematic weeds. Rogue and Permit (halosulfuron) premixed (Rogue Plus), can control a broad-spectrum of aquatics, grasses, broadleaves, and sedges. However, soybean are often grown in close proximity to rice and could be injured through off-target movement of these herbicides. Therefore, the objective of this research was to evaluate the effect of drift application of benzobicyclon + halosulfuron to sulfonylurea-tolerant (STS) and non-STS soybean at different growth stages.

An aerial application study was conducted in 2019, at the Rice Research and Extension Center (RREC) near Stuttgart, AR. The application timings were at V3 and R1 soybean growth stages to both STS and non-STS varieties. Applications were made across soybean rows with a 15.2 m (50 ft) swath, at 46.8 L ha^{-1} (5 GPA). Visible soybean injury was assessed on three 91.4 m (300 ft) transects, divided into 7.6 m (25 ft) sections, each downwind from the outside edge of the sprayer swath. Visible injury ratings at 21 and 28 days after treatment (DAT) were recorded from each transect in 7.6 m (25 ft) sections from both varieties and application timings.

In the V3 timing, visible injury ratings at 21 DAT show that substantial injury, 5% or greater, was present for at least the first 45.7 m (150 ft) in the non-STS variety. However, in the R1 timing, 5% injury was observed no less than 68.6 m (225 ft) downwind of the application in the non-STS variety. At 28 DAT, visible injury at each application timing in the non-STS variety substantially decreased, with 5% injury notable only until 30.5 m (100 ft) at V3, and 45.7 m (150 ft) at R1. In conclusion. In the STS variety, 5% injury was recorded in the first 15.2 m (50) and 7.6 m (25 ft) at the V3 timing at 21 and 28 DAT, respectively. No visible injury was observed in the STS soybean variety at the R1 application timing. In conclusion, benzobicyclon is not a major contributor to soybean injury for both V3 and R1 application timings and show only relevance in near-direct applications.

Rice Cultivar Response to Glyphosate or Paraquat During Reproductive Growth Stages

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

In 2018 4.2 million acres of principal crops were planted in the state of Mississippi. Of this acreage, 110,000 acres were devoted to rice production in 2018. The close proximity to other crops such as cotton (*Gossypium hirsutum* L.), corn (*Zea mays*), and soybean [*Glycine max* (L.) Merr.], creates a great potential for off-target herbicide movement onto rice fields. The growing adoption of harvest-aid use across upwards of 2 million soybean acres throughout Mississippi only furthers the risk of late season exposure to off-target herbicide movement. Therefore, research was conducted evaluating rice response across multiple cultivars to late-season exposure of glyphosate or paraquat.

Research was established from 2016 to 2018 at the Mississippi State University Delta Research and Extension Center in Stoneville, MS, to evaluate rice grain yield and yield component response to exposure of sub-lethal concentrations of common desiccants across multiple rice cultivars. Secondary objectives of this research were to identify differences in visual injury response across multiple rice cultivars and to identify differences in visual injury response across multiple desiccants. To achieve these objectives, treatments were arranged in a randomized complete block with a five (rice cultivars) × three (desiccant) factorial. The rice cultivars evaluated were CLXL745, XL753, CL163, Rex and Jupiter. Desiccants evaluated were none (0 lb ai/A), glyphosate (0.1125 lb ae/A) and paraquat (0.025 lb ai/A). Applications were initiated at the 50% heading growth stage of each respective cultivar. Rates were based on 0.10 of the labeled harvest-aid rate in Mississippi. Desiccants were applied at a constant carrier volume of 140 L/ha with a CO_2 pressurized backpack sprayer. Visible estimates of rice injury were recorded 3, 7, 14, 21, and 28 day after treatment. At maturity a small plot combine was utilized to harvest each plot and collect rough rice yields. Total milled (consisting of whole and broken kernels) and head rice (consisting of whole kernels) yields were then determined from cleaned 120-g subsamples of rough rice. Percentage of nontreated control data were calculated by dividing the data from the treated plot by that in the nontreated control plot in the same replication and multiplying by 100. All data were subjected to ANOVA and estimates of the least square means were used for mean separation with $\alpha = 0.05$.

Differential injury estimates among cultivars and herbicide treatments was observed when glyphosate or paraquat was applied at 50% heading. Injury from glyphosate at 50% heading was non-detectable across all cultivars. However, injury following paraquat applications was >7% across all rating intervals and cultivars. Hybrid cultivars exhibited less injury with paraquat applications than the inbred cultivars in the study.

Rice following exposure to glyphosate or paraquat at 50% heading growth stage produced rough rice grain yield decreases ranging from 0 to 20 and 9 to 21 %, respectively. Rough rice grain yield decreases were observed across all cultivars following paraquat exposure, and all inbred cultivars following glyphosate exposure. Across herbicide treatment, head rice yield was reduced in three of five cultivars in the study. When pooled across cultivar paraquat applications cause a head rice yield reduction of 10%, while rice following glyphosate application remained >95%. While differential tolerance among cultivars to paraquat or glyphosate exposure was observed, impacts on grain quality coupled with yield reductions suggests extreme rice sensitivity to exposure to sub-lethal concentrations of these herbicides at the 50% heading growth stage.

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

Potential for New Rice Herbicides Applied in a Salvage Situation

Rustom, S.Y., Webster, E.P., Mcknight, B.M., Webster, L.C., Greer, W.B., and Walker, D.C.

Early season weed management is typical in rice production; however, situations arise where early weed management fails prior to flooding. Postemergence weed management after the flood is established is often referred to as a salvage situation. Salvage treatments can be problematic due to the advanced growth stage of weeds and inadequate herbicide coverage.

Research was conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, LA to evaluate the potential of new rice herbicides applied in a salvage situation. Herbicides evaluated were: florpyrauxifen-benzyl at 14.5 and 29 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, halosulfuron plus prosulfuron at 55 and 83 g ai ha^{-1}, halosulfuron plus thifensulfuron at 53 g ai ha^{-1}, Orthosulfamuron at 94 g ai ha^{-1}, and orthosulfamuron plus quinclorac at 490 g ai ha^{-1}. Treatments were applied after flooding when rice was at the 2- to 3-tiller growth stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} with five flat-fan 110015 nozzles spaced 35 cm apart.

At 28 DAT, each rate of florpyrauxifen-benzyl, the 83 g ha^{-1} rate of halosulfuron plus prosulfuron, and orthosulfamuron plus quinclorac controlled alligatorweed [Alternanthera philoxeroides (Mart.) Griseb.] 89 to 98%. Control for alligatorweed was reduced when treated with all other herbicides and rates evaluated. At 42 DAT, All halosulfuron-containing products and the 29 g ha^{-1} rate of florpyrauxifen-benzyl controlled yellow nutsedge (Cyperus esculentus L.) 92 to 99%. Control was reduced when yellow nutsedge was treated with all other products and rates. Rice treated with halosulfuron plus prosulfuron at 83 g ha^{-1} resulted in a rough rice yield of 5110 kg ha^{-1}. Yield was reduced to 4106 kg ha^{-1} when treated with the 53 g ha^{-1} rate of florpyrauxifen-benzyl.

Droplet Size Deposition, Spray Pattern Uniformity, and Coverage from Aerial Applications

Butts, T.R., Fritz, B.K., Jank, P.C., Gill, M., and Bretthauer, S.M.

Aerial pesticide applications are used on a majority of the rice hectares in Arkansas, including the more than 60% of pre-flood rice hectares that receive a herbicide application from aerial spray equipment. It is important to understand spray dynamics from agricultural aircraft to maximize their coverage, reduce spray drift, and increase their effectiveness. Therefore, the objectives of this research were to: 1) evaluate spray pattern uniformity and effective swath width from several agricultural aircraft setups, (2) determine spray coverage from these setups, and 3) investigate droplet size deposition during an in-wind and cross-wind application.

Research was conducted using an Air Tractor AT-802A agricultural aircraft (Air Tractor, Inc., Olney, TX 76374) with its inherent spray equipment setup and a research-oriented setup. The agricultural aircraft was initially equipped with CP-09-3E Poly Straight Stream nozzles with 3-way stainless steel deflectors (Transland, LLC., Wichita Falls, TX 76302) to determine spray uniformity and coverage. This initial inherent setup was evaluated at a 0° and 30° deflection and at a 47 and 94 L ha^{-1} spray output (four total treatments) to assist the pilot with personal decisions on maintaining an optimal spray swath across typical setups used throughout the growing season. Additionally, a research-oriented spray equipment setup at 28 L ha^{-1} was evaluated for spray pattern uniformity and droplet size deposition comparing CP-11TT poly nozzles (Transland, LLC., Wichita Falls, TX 76302) equipped with 0010 (straight stream) versus 4010 (40° flat fan) tips and in an in-wind versus cross-wind spray environment (four total treatments). Each treatment consisted of water tank-mixed with pink Rhodamine dye and was replicated three times which consisted of three independent fly-overs. Data collection comprised water sensitive cards placed every 2 m across the entire potential swath width and a cotton filament string hung across the entirety of the spray swath. The water sensitive cards were analyzed for coverage and droplet size using a proprietary program in LabVIEW (USDA-ARS, Aerial Application Technology Unit, College Station, TX 77845) and the strings were analyzed using fluorimetry to generate relative fluorescence values across the swath distance. Coverage, droplet size, and relative fluorescence data were then further analyzed for effective swath width and plotted using Python software (Python Software Foundation, Wolfeboro, NH 03894).

Results illustrated that the agricultural aircraft's inherent setup provided a uniform pattern across the spray swath, and had an effective swath of approximately 24 m, regardless of the deflection used or spray volume. This was likely due to the use of the large number of nozzles across the boom (96 total) which allowed for spray setups to be manipulated with little effect on the spray pattern uniformity. Spray coverage increased with increasing the spray volume and when using the 30° deflection (smaller droplet size). The research-oriented setup revealed no necessary changes were required for spray pattern uniformity when switching between the straight stream tip (0010) and 40° flat fan tip (4010). Additionally, coverage increased with the use of the flat fan tip due to the smaller droplet size generated. Droplet size deposition was unique when sprayed in the in-wind versus cross-wind environment. In an in-wind spray environment, droplets of differing sizes were heterogeneously mixed throughout the spray swath, and the typical bell curve spray pattern was present. However, in a cross-wind environment, droplets were deposited with the coarsest droplets deposited on the up-wind side of the swath and the finest droplets deposited on the downwind side in a skewed spray pattern. This could severely impact coverage during an application as improper overlap would likely occur; therefore, it is recommended to make aerial applications in-wind if possible to heterogeneously distribute droplets across the swath and to maintain the standard bell-shape curve spray pattern necessary for proper overlap.

Loyant Herbicide Injury and Weed Control on Rice in Texas

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

Weeds are among the most important factors limiting rice production in Texas and other rice-producing United states. Herbicides are an essential tool to the control of numerous weeds, including grasses, broadleaves and sedges. Loyant is among the new herbicides available for weed control in rice. Loyant provides the broadest weed control spectrum of any new rice herbicide in recent years. It can control grasses, broadleaves, sedges and even aquatic weeds such as ducksalad. Loyant received Section 3 from EPA in 2017 and has been available for commercial use since 2018. Provisia® Rice, a complement to Clearfield® Rice, provides a new tool for the control of weeds that are troublesome in Clearfield® Rice. However, various herbicides have different modes of action, target weeds, and timings and methods of application. Improper selection and use of herbicides may result in crop injury, causing rice grain yield and quality loss. The objective of this study was to evaluate the impact of Loyant and its combined use with other herbicides on crop injury, weed control, and yield in hybrid, Clearfield® rice, and Provisia® Rice under Texas environments.

A field trial was conducted as split plot design with variety as main plots and herbicide program as subplots at Eagle Lake, Texas in 2018 and 2019. The 2018 trial evaluated eight herbicide application programs plus an untreated control on four rice varieties, PVL01 (Provisia), XL760 (hybrid), CL153 (Clearfield) and CLRT7311 (Clearfield). The 2019 trial evaluated eight herbicide application programs on four varieties, PVL02, XL753, CL153 and CLXL745. Loyant was applied 1.2 kg/ha (16 oz/A) at mid-postemergence, preflood, or post-flood in combinations with other herbicides. The other herbicides included Aim, Beyond, Bolero, Clincher, Command, Gambit, Grasp, League, Newpath, Permit, Quinstar, RiceOne, Sharpen, Stam, Strada, and Strada XT2 applied at labeled rates. The treatments were arranged in a randomized complete block design with four replications. Plots consisted of seven 4.9-m rows, spaced 19 cm 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, northern jointvech, yellow nutsedge, morningglory and palmer amaranth were planted into each plot. Percent plant injury caused by herbicides and weed control were visually rated. Rice was harvested using a plot combine at variety maturity. Grain yield and moisture were determined, and rice yields were adjusted to 12% moisture content. Milling quality (% head rice and % total milled rice) also was determined.

In each year, Loyant-containing herbicide programs provided excellent control of weeds, including broadleaf signalgrass, barnyardgrass, northern jointvech, yellow nutsedge, morningglory, hemp sesbania, and palmer amaranth, on each of the four rice varieties evaluated. Loyant caused varying degrees of crop injury, especially at the early cropping season in 2018. Injury symptoms included stunting and leaf rolling. However, rice plants affected could recover in the late season. No or little crop injury caused by Loyant and other herbicides was observed in 2019. The response of rice variety to Loyant crop injury differed among the varieties tested. PVL01 and PVL02 tended to be more susceptible to crop injury caused by Loyant than other varieties evaluated. The hybrids XL753 and XL760 had no or minor crop injury, resulting in a 2- to- 4% yield increase.

Comparison of Loyant and Graminicides Applied Alone and in Tank-Mixture in Arkansas Rice

Hill, Z.T., Barber, L.T., Doherty, R.C., Collie, L.M., and Ross, A.

In Arkansas rice production, multiple herbicides are used either alone or in combination to combat problematic weeds. Typically, producers utilize graminicides, such as Clincher (cyhalofop) or Ricestar (fenoxaprop) to control grass species commonly found in rice; however, it is more common to include multiple herbicides in a tank mixture to achieve a broad spectrum of weed species. Loyant™ (florpyrauxifen), a new herbicide that contains the Rinskor™ active has been shown to have broad-spectrum POST activity on most broadleaf and some grass, and sedge species.

In this experiment, multiple rates of Loyant were applied alone and in tank-mixture with graminicides to determine the most effective combination for the weeds present. This experiment was conducted on a silty-clay loam soil in Tillar, Arkansas. The study was designed as a randomized complete block with four replications, where herbicide efficacy was evaluated for the control of barnyardgrass (*Echinochloa crus-galli* L.), hemp sesbania (*Sesbania herbacea* (Mill.) McVaugh), and rice flatsedge (*Cyperus iria* L.). Treatments in this experiment consisted of Loyant applied at 10.9, 14.6 and 29 g ai/ha; Clincher at 323 and 646 g ai/ha; Ricestar at 122 g ai/ha; Provisia at 120 g ai/ha; as well as each of the graminicides at their respective rates in tank-mixture with the three rates of Loyant. These treatments were applied to XP 153 hybrid rice cultivar at the three to four leaf stage and barnyardgrass was four to five leaf.

Regardless of the evaluation timing, a positive trend was observed as the rate of Loyant increased when applied alone or in tank-mixture with the graminicides. At 20 days after treatment (DAT), >90% control of barnyardgrass was observed from several treatments, with Loyant 28 g ai/ha + Clincher at 646 g ai/ha providing the most effective control at this timing. All treatments containing Loyant provided effective control of hemp sesbania throughout the season regardless of rate. Greater than 95% control of rice flatsedge was observed from most treatments, except where lower rates of Loyant were tank-mixed with Provisia and Clincher. It was evident that in the treatments containing Provisia, greater rates of Loyant were required to control the increased population of rice flatsedge where the crop stand had been killed. Although a reduction in barnyardgrass control was observed from all treatments at 42 DAT, the same positive trend was observed as the Loyant rate increased. The combinations of Loyant at 14.6 and 29 g ai/ha with both rates of Clincher, Ricestar at 122 g ai/ha, and Provisia at 120 g ai/ha provided comparable control of barnyardgrass (≥80%). Greater than 95% control of rice flatsedge was continued to be observed at this evaluation timing, except from the Loyant at 10.9 g ai/ha + Provisia at 120 g ai/ha treatment.

Based on these data, it can be determined that the most effective combination to control large barnyardgrass and other weeds present was Loyant at 29 g ai/ha + Clincher at 646 g ai/ha. Additionally, Loyant at 29 g ai/ha + Ricestar at 122 g ai/ha provided comparable control of both species throughout the growing season. Regardless of the graminicide applied, these data suggest that applying the higher rate of Loyant was necessary to increase control of barnyardgrass and large annual sedge.

Abstracts of Papers on Rice Culture
Panel Chair: Bobby Golden

Evaluating the Effect of Nanoagrichemicals on the Fate and Uptake of Arsenic in Rice

Wang, X., Ma, X., and Dou, F.

Arsenic (As) accumulation in rice grains is a global food safety concern that is substantially affected by the As redox chemistry in rice rhizosphere. The use of nanoagrichemicals such as nanofertilizers and nanopesticides has grown rapidly and some of them displayed strong capability to alter plant uptake of co-existing heavy metal ions including redox sensitive As by altering their speciation and bioavailability to plants. Silicon-based materials are common amendments for rice paddies and silicon oxide nanoparticles (SiO_2NPs) have been recently suggested as an effective silicon source for rice growth. However, how these nanoparticles may affect the fate and availability of coexisting As has not been examined. We quantified the total arsenic in different rice tissues grown in arsenic tainted soils in the presence and absence of different concentrations of SiO_2NPs (150, 500 and 2000 mg/kg) at both continuously flooded and alternate wetting and drying conditions. Our results suggested that the accumulation of As in rice tissues is significantly affected by the addition of SiO_2NPs, but the net effect depended upon the dose of SiO_2NPs and water irrigation schemes. For examples, SiO_2NPs up to 2000 mg/Kg lowered As concentration in rice shoots in fully flooded rice seedlings, but SiO_2NPs at 2000 mg/Kg markedly increased total As concentration in rice shoots growing in alternate wetting and drying irrigation condition. Our results demonstrate that applications of nanoagrichemicals may unexpectedly affect the fate and bioavailability of co-existing environmental chemicals in rice tissues, and the net effect depends on the composition and concentrations of agrichemicals as well as the growing conditions of rice.

A Sensor-Based Response Index to Guide Mid-Season N Fertilization

Linquist, B.A. and Rehman, T.H.

The current nitrogen (N) recommendation for California rice (Oryza sativa) is that growers apply the amount of N required for an average yielding year at the beginning of the season. Most commonly, this is applied as aqua-ammonia injected into the soil before the crop is planted (the preplant N rate may also include some starter N fertilizer that is mixed with P and K). At panicle initiation (PI - about 45 to 55 days after planting) it is recommended that growers assess the crop to determine if additional top-dress N fertilizer is required. An accurate assessment is important because not applying N when needed can lead to a reduction in yield; however, applying N fertilizer when it is not needed can lead to lodging, delayed maturity, increased incidence of disease and reduced yields/quality.

Some tools are available to assess crop N status at PI such as the leaf color chart and SPAD chlorophyll meter, but these tools are not readily adopted as they are time consuming and limited to a relatively small sampling area. The development of new sensor-based technologies, such as the handheld Greenseeker and drones; however, have provided a promising alternative to assess N status quickly over a large area and develop N management recommendations. The potential of these technologies to guide N management has been studied extensively in wheat (*Triticum aestivum*) and maize (*Zea mays*), but there have been relatively few such studies in rice. The objective of this study is to develop a sensor-based tool to guide mid-season N management in rice systems.

Twelve N response trials were established from 2016 to 2019 at various on-farm and on-station sites throughout the Sacramento Valley rice growing region. Experiments were arranged in a split-plot randomized complete block design. Main plot treatments were varying rates of preplant N fertilizer ranging from 0 to 275 kg N ha^{-1} broadcast by hand as urea (2016-17) or injected into the soil as aqua ammonia (2018-19). Subplot treatments were top-dressed N rates of 0 or 34 kg N ha^{-1} broadcast by hand as ammonium sulfate at PI. At PI, NDVI (Normalized Difference Vegetative Index) was measured using a Greenseeker handheld crop sensor and NDRE (Normalized Difference Red Edge) was measured with a Matrice 100 drone equipped with a MicaSense Red-Edge multispectral camera. After index measurements, plots were split into subplots receiving their respective top-dress N treatment. At physiological maturity, plants were harvested from each subplot to calculate final grain yield. A Response-Index (RI) was developed from the PI NDVI and NDRE values in each plot. The RI is the ratio of the NDVI and NDRE value in the enriched N treatment (representing a crop with unlimited N –in this case the highest N rate at each site) divided by the NDVI or NDRE value from the other N rate treatments at a site. The yield response to a top-dress N application in each plot was compared to the RI for that plot. Based on preliminary data, we have found that for both NDVI and NDRE, if the RI was 1.10 or greater a top-dress N application leads to higher yields. If the RI was less than 1.10, there was no yield response or yields decreased. The NDVI (r^2 = 0.74) and NDRE (r^2=0.64) response-indices were both positively correlated with the likelihood (%) of a positive yield response to top-dress N. Although this research is still ongoing, these results provide promise that a sensor-based response index can guide mid-season N fertilization in California rice.

Using a Response Index and Greenseeker Handheld to Predict Rice Response to Midseason Nitrogen

Roberts, T.L., Hardke, J., Hoegenauer, K., Shafer, J., Williamson, S., Scott, C., and Bolton, D.

Midseason nitrogen (N) applications in direct-seeded, delayed-flood rice (*Oryza sativa* L.) require aerial application, which adds additional costs of production. Modern pureline rice cultivars do not respond to midseason N applications to the extent that older longer season cultivars did. This lack of response to mid-season N can be attributed to better preflood N management and the reduction in days to maturity of many modern pureline rice cultivars. Additionally, previous research has shown that properly managed optimum preflood N applications can maximize both rice grain and milling yields for modern pureline cultivars. Midseason N applications in rice may not be needed in many cases where the proper preflood N rate was applied and managed properly. However, there is currently no means to predict when and where rice will respond to midseason N applications so producers tend to continue applying midseason N to eliminate the potential for yield loss due to N deficiency. Work has been on-going to develop a response index (RI) for rice using a Greenseeker handheld to provide producers with the ability to predict midseason N needs for pureline rice cultivars. Field trials have been conducted for the past six years to develop and refine a RI that will work across multiple rice cultivars and environments. Current results suggest that a RI of 1.2 will result in a 90%+ chance of a significant yield increase from midseason N applications, whereas a RI of 1.1 indicates a less than 15% chance of a statistically significant yield increase. Based on this research, current recommendations are to apply midseason N to rice when the RI is greater than 1.15. Validation of these RI values have been on-going and support the previous research where responses to the application of midseason N might be expected (RI>1.15). Future research will focus on the application of NDVI to other platforms for ease of use.

Boot Nitrogen Applications for Hybrid Rice in Direct-Seeded, Delayed-Flood System

Hardke, J.T., Roberts, T.L., Norman, R.J., Frizzell, D.L., Smartt, A.D., Castaneda-Gonzalez, E., Frizzell, T.D., Clayton, T.L., and Hale, K.F.

Hybrid rice cultivars now account for over 50% of Arkansas rice acres annually. Applying 34 kg nitrogen (N)/ha at the late boot growth stage is a standard production practice for hybrid cultivars. Previous research has shown a reduction in lodging potential while enhancing grain yield and milling yield. Newer hybrid cultivars have not been evaluated for their response to late boot N applications; therefore, a study was initiated in 2017 with current hybrid cultivars to evaluate the benefits of this practice.

The RiceTec hybrids RT CLXL745 and RT XP753 were drill-seeded at three locations each year from 2017 to 2019. These locations included the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center (NEREC) near Keiser, AR, the Pine Tree Research Station (PTRS) near Colt, AR, and the Rice Research and Extension Center (RREC) near Stuttgart, AR. Three preflood-N rates were used at each location: at NEREC, 146, 179, and 213 kg N/ha; at PTRS, 112, 146, and 179 kg N/ha; and at RREC, 101, 134, and 168 kg N/ha. At each location all plots received either an additional N application of 34 kg N/ha or zero kg N/ha at the late boot growth stage (complete exsertion of the flag leaf with leaf collar visible). The study was conducted in a randomized complete block design with four replications at each location.

Averaged across cultivar, location, and preflood N rate, plots receiving a boot-N application had significant increases in grain yield, head rice yield, and total rice yield compared to plots that did not receive a boot-N application. Lodging was recorded only for CLXL745, where the boot-N application resulted in a significant reduction in lodging compared to where no boot N was applied. The addition of boot-N did not result in a significant difference in harvest moisture or plant height compared to plots receiving no boot-N.

Predicting Potassium Deficiency of Rice during Reproductive Growth using Y-leaf Potassium Concentration

Slaton, N.A., Gruener, C.E., Roberts, T.L., Hardke, J.T., and Smartt, A.D.

Potassium (K) deficiency can limit rice (*Oryza sativa* L.) grain yield on soils with low exchangeable K. Symptoms of K deficiency are not always easy to visually diagnose during early reproductive growth and diagnostic tissue-K concentrations are often growth-stage specific. Our primary objective was to i) characterize Y-leaf-K concentration response to K fertilization across time and ii) develop critical Y-leaf-K concentrations between the R1 and R4 growth stages for flood-irrigated rice. Ten Y-leaves were collected weekly during reproductive growth from selected fertilizer-K rates (0 to 149 kg K ha^{-1}) in 13 trials with Mehlich-3 extractable soil-test K ranging from 32 to 164 mg K kg $soil^{-1}$ that were seeded with either a pure line (8) or hybrid (5) rice cultivar. The Y-leaves were dried, digested, and analyzed using traditional laboratory methods. The R1 growth stage was predicted using the DD10 program and rice development at each sample date expressed as growing degree days after R1 (GDDR1). The critical-K concentration across time was defined as the leaf-K concentration predicted to produce 95% of the maximum yield. A grain yield increase from K fertilization was measured at five of the 13 trials. The five K-responsive trials were all seeded with a pure-line cultivar with three of the responsive trials being long-term K fertilization trials where a yield response was expected based on soil-test K. The remaining 10 trials were located at five sites where trials with a hybrid and pure-line cultivar were planted in adjacent areas. No yield response to fertilizer K was measured in either cultivar at three of the sites that included both a hybrid and pure-line cultivar. At the remaining two sites, grain yield was increased by K fertilization in only the pure-line cultivar. In the five K-responsive trials, rice receiving no fertilizer K produced 67 to 90% of the maximum yield produced by rice receiving fertilizer K. In general, Y-leaf K concentration in K-sufficient rice was greatest at the R1 stage and declined linearly or quadratically with rice development suggesting that the critical Y-leaf K concentration may also change across time. For rice grown on soils with low available K and receiving no or a low fertilizer-K rate, Y-leaf K concentration was relatively stable until the R2 stage (flag leaf emergence) at which time Y-leaf-K concentration started to decrease. A multiple regression model that included GDDR1 and Y-leaf K concentration to predict relative yield from all of the trials (n=813) was significant and accounted for 44% of the relative yield variation. When the multiple regression was performed using data from the five trials seeded with a hybrid cultivar (n =300), the model was not significant and explained only 3% of the variability in relative yield. The same model with only the pure-line cultivar data was significant with an r^2 value of 0.55 (n =513). The results suggest that the Y-leaf-K concentration can be used to assess the K nutritional status of pure-line cultivars during reproductive growth and that hybrid cultivars may be less responsive to K fertilization and may produce maximal yield without fertilization on soils with lower K availability than pure-line cultivars.

Use of Sodium chlorate as a Harvest Aid on Rice Cultivars Grown in Arkansas

Frizzell, D.L., Hardke, J.T., Castaneda-Gonzalez, E., Frizzell, T.D., Clayton, T.L., Lytle, M.J., and Hale, K.F.

Sodium chlorate is used as a harvest aid or desiccant on approximately 40% of rice acres in Arkansas. Currently, the University of Arkansas System Division of Agriculture (UADA) recommendation for application of a desiccant to rice is to apply sodium chlorate when average grain moisture is within the range of 18–25%. This is based on work using conventional, pure-line varieties in studies conducted during 1999 and 2000. However, little is known about the effect of sodium chlorate applications on hybrid rice cultivars regarding impact on harvest moisture, grain yield, or milling yield. Therefore, a study was initiated in 2018 to evaluate the influence of sodium chlorate on hybrid rice within the current recommended application timing for grain moisture.

During 2018, there was a general trend of reduced grain moisture, grain yield, and percent head rice (%HR) compared to non-treated plots at all harvest timings, and a trend toward reduced total white rice at higher grain moisture. Grain moisture reductions were significant compared to untreated plots at 8 of 10 harvest timings. Significant grain yield reductions only occurred when harvest was delayed 6 or more days following sodium chlorate application. Significant reduction in %HR was noted 7 days after application at 25% grain moisture, 3 and 7 days after application at 23% moisture and 3 and 6 days after application at 15% grain moisture during this initial study year. The initial results of this study suggest that recommended harvest timing following sodium chlorate application should remain the same for hybrids and pure-line varieties (3–4 days after application). However, while pure-line varieties may be treated safely with sodium chlorate from 18% to 25% grain moisture, hybrids may need to be below 23% grain moisture for safe application of sodium chlorate.

During 2019, the study was initiated at a lower grain moisture than 2018, and only included a single harvest timing of 3-4 days after application. The initial application was made at 20% grain moisture and subsequent weekly applications were made until Timing 4 was applied to plots that measured 11.9% grain moisture. Sodium chlorate application did not impact harvest moisture or percent total rice at any timing during this study year. Grain yield was positively affected by sodium chlorate, but only at 20% grain moisture. There was a slight trend toward reduced percent head rice yield with the application of sodium chlorate at all four application timings.

Cultivating Flooded Rice as a Treatment Technology to Mitigate Phosphorus Loads from Agricultural Watersheds

Bhadha, J.H., Rabbany, A., Tootoonchi, M., Gonzalez, L., and VanWeelden, M.

During summer more than 202 km^2 of fallow sugarcane land is available for rice production in South Florida. The net value of growing flooded rice in the region as a rotational crop with sugarcane far exceeds its monetary return. Soil conservation, pest control, and phosphorus (P) load reduction are only some of the benefits. With no P fertilizer applied, rice cultivation in Florida can potentially function as a sink for P as a result of particulate settling and plant P uptake, while harvested whole grain rice can effectively remove P from a rice field per growing season. As part of the George Barley Water Prize, we proposed utilizing flooded rice cultivation as a treatment technology to mitigate P loads from farmlands. A controlled experimental plot (9.75 × 2.44 m) was designed to quantify reduction in P concentration and loads between inflow and outflow over a 110-day rice cultivation cycle. Daily water samples were collected from inflow and outflow over a six-week period once a steady flood was established. Inflow water P concentration was manipulated weekly, from 0, 0.075, 0.22, 0.50, 0.22, and 0.075 mg/L P concentrations. Approximately 160 L of water were treated daily. On average, 28% reduction in TP concentration and 51% reduction in SRP was observed between inflow and outflow, corresponding to significant P load reductions using this treatment technology. Future research work includes (i) evaluating P use efficiency in crop management by identifying and selecting rice varieties tolerant to low P inputs; and (ii) effect of varying flood depth on P loads from rice fields.

Effect of Urease Inhibitor and Soil Moisture on Ammonia Volatilization: A Laboratory Trial

Dou, F., Tu, Q., Li, X., Jiang, J., and Tan, A.

Ammonia volatilization is an important source of N loss in direct-seeded, delay-flooded rice production. Urease inhibitors have been used to mitigate ammonia volatilization loss. However, the effectiveness of such application is affected by management practices and environmental conditions. Factors involved in the process includes but not limited to types of urease inhibitors used, N application rate, soil moisture and soil texture.

A laboratory incubation experiment with four replications was conducted to determine the effect of urease inhibitors [Agrotain Ultra, Factor, N-Fixx PF, NitroGain, N-Veil, Nitrain, and the control] on NH_3 loss through under aerobic and waterlogged conditions on a Hockley silt loam soil at 20°C. Ammonia volatilization and soil inorganic N were measured in day 1, 3, 7, 14, and 21. Urease inhibitor significantly affected ammonia volatilization under different soil moisture conditions. Agortain Ultra, NitroGain, and Nitrain could effectively reduce ammonia volatilization of surfaced applied urea. However, under anaerobic condition, urease inhibitors were not so effective in reducing ammonia volatilization as being observed under aerobic condition. Given anaerobic condition, hydrolyzed N existed mainly as ammonium instead of nitrate. Our study indicated that mitigation of ammonia volatilization loss in rice production varied with urease inhibitors and environmental conditions.

Effects of Deep Seeding on Weed Management and Crop Response in California Rice Systems

Ceseski, A.R., Godar, A., Al-Khatib, K.

California rice (*Oryza sativa* L.) is grown as a monoculture, seeded by air into permanently-flooded basins. Decades of overreliance on a small number of herbicides have led to widespread herbicide resistance. The objectives of this study were to evaluate the weed management and crop physiology feasibilities of deep-drilled rice. Seeding deep should delay stand emergence and allow use of broad-spectrum herbicides on emerged weeds, without injuring the rice. This would make additional modes of action available for the mitigation of herbicide resistance.

Seed of *cv.* M-206 and M-209 were dry-drilled to 3 cm and 6 cm in a split-split-plot design with four herbicide programs over 2018-2019. Herbicide programs centered on using glyphosate as a burndown treatment prior to rice emergence. Irrigation was by flushing every seven days until 28DAP, whereupon a 10-cm flood was established for the remainder of the season. Herbicides and required adjuvants were applied by CO_2-pressurized backpack sprayer with 8003VS flat-fan nozzles at 187 L ha^{-1}. Glyphosate was applied at 870 g ae ha^{-1} just as rice was spiking.

Glyphosate alone was able to control >60% of grasses and >80% of sedges. Treated plots were weed-free. Rice first-leaf tips died back after glyphosate application but stands developed normally. Stands at 6-cm planting decreased by 15.5% and 5.3% in 2018 but increased by 3.8% or were unchanged in 2019 for M-206 and M-209, respectively. Stand reductions were largely compensated for by increased tillering. Yields were not affected by 6-cm depth for either *cv.* in 2018, while in 2019, they increased by 5% or decreased by 3.4% for M-206 and M-209, respectively. Yields compared to nearby water-seeded fields were 2-22% and 3-11% higher in 2018 and 2019, respectively. We found that excellent weed control and competitive yields are achievable with this program, given good scouting and field management.

Monitoring Spatial Variability and Yield in Air-seeded Rice Fields using Unmanned Aircraft Systems

Hashem, A.A., Runkle, B., Massey, J.H., Green, S., Shew, A., Burns, B., and Reba, M.L.

Weekly multispectral and thermal imagery were collected during the rice-growing season using two unmanned aircraft systems on four zero-grade fields in east Arkansas. Vegetation indices were used to find spatio-temporal patterns in growth dynamics. Yield data were analyzed and correlated to the vegetation growth in three phenological stages.

Physiological Response of Rice to Aminoethoxyvinylglycine (AVG) under High Night Temperature

Mohammed, A.R. and Tarpley, L.

High night temperature (HNT) is known to decrease rice yield and quality. The impacts of aminoethoxyvinylglycine (AVG), an ethylene synthesis inhibitor, on higher plants have been the subject of many studies. However, little or no work has been carried out on rice responses to AVG under HNT-stress conditions. This study determined if ethylene-triggered responses are a major component of rice response to HNT and if application of AVG negates ethylene-triggered responses under HNT.

Plants were grown under ambient night temperature (ANT) (25ºC) and HNT (30ºC) in the greenhouse. They were subjected to HNT in open zones of the greenhouse through use of continuously controlled infrared heaters, starting from boot stage of the rice plants until harvest. Night temperatures were imposed from 2000 h until 0600 h. Plants were treated with AVG at boot stage of the rice plant. Net photosynthesis (P_N) of the penultimate leaves was measured between 1000 h and 1200 h using a LI-6400 portable photosynthetic system (LI-COR Inc., Lincoln, Nebraska, USA), 5 days after treatment (DAT). Respiration rates were measured on the penultimate leaves between 2300 h and 0200 h using a LI-6400, 5 DAT. Spikelet fertility was defined as the ratio of the number of filled grains to total grains in the panicle and was measured at harvest.

High night temperature decreased P_N, spikelet fertility and yield and increased respiration rate, membrane damage and grain chalkiness. The AVG application increased SF and brought rice yields under HNT up to levels observed under ANT as a result of increased P_N and decreased respiration and membrane damage; so indicating that ethylene-triggered responses are a major component of rice response to HNT.

Soil Amendments to Reduce Heavy Metal Concentrations in Rice Grain

Roberts, T.L., Hardke, J., Hoegenauer, K., Bolton, D., and Shafer, J.

Arsenic (As) is a heavy metal that is ubiquitous in nature and has been shown to have carcinogenic effects if consumed at high levels over a significant period of time. Recent research in Southeast Asia has shown As bioavailability increases in flooded or paddy conditions and As concentration in paddy rice can reach dangerous levels if consumed regularly. The current crisis in Southeast Asia has garnered worldwide attention and many collaborative efforts have been aimed at lowering As levels in rice. Arsenic can occur in the plant and soil as either an organic compound or an inorganic compound. Previous studies have shown that organic forms of As are often less toxic or less bioavailable than the inorganic form. On average, there are 500,000 hectares of rice in Arkansas each year and the rice production industry is a huge portion of the agricultural and economic sector within the state of Arkansas. Previous research has indicated that water management is often the simplest way to lower As levels in rice grain, but often times comes at the cost of rice milling quality or yield potential. By growing rice in an upland or non-flooded environment similar to furrow-irrigated rice or rice that implements strict alternate wetting and drying protocols you can successfully lower rice grain As concentrations. More recent research has focused on the use of soil amendments to potentially reduce the As bioavailability in the soil and ultimately lower the As uptake by the rice plant therefore lowering the potential As accumulation in the rice grain. This research focuses on the use of several soil amendments including potassium sulfate, rice hulls and other silica containing amendments to reduce As accumulation in the rice grain in a direct-seeded, delayed-flood production system. Significant reductions in grain As accumulation were seen when rice hulls were incorporated into the soil preplant and the level of As reduction was closely related to the bioavailability of As in the soil. In areas where As was highly bioavailable in the soil, there were two- and three-fold reductions in grain As concentration. However, in soils with low bioavailability of As the reductions, although statistically significant, were much lower. Research findings will focus on the rates and soil amendments that can be implemented to successfully reduce grain As concentrations in soils where rice is grown under direct-seeded, delayed-flood conditions and the flood is maintained with no alternative water management techniques.

Arkansas Irrigation Yield Contest

Henry, C.G., Simpson, G., Rix, J., Pickelmann, D., and Mane, M.R.

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 user efficiency 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 novel crop contest was developed to document water use efficiency and practices that farmers utilize to conserve water. This integrated research and Extension program is a novel program that worked 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 1.2 hectares (3 acres) is done to document water use efficiency (WUE) for each entrant. The irrigator with the "Most Crop per Drop" awarded. 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. This provides a unique research opportunity. The contest is supported by the industry, in the two years of the program, Ricetec, Mars corporation, McCrometer, Seametrics, Irrometer, Delta Plastics, Agsense (Valmont Industries), Trellis, the Arkansas Soybean Promotion Board, the Arkansas Corn and Grain Sorghum Board, P and R Surge, provide cash or product prizes for the winners upwards of around $20,000 for the first place winner.

Each contestant is provided a report card anonymously 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 12-hectare (30-acre) or larger field and request for a meter to be installed before any irrigation. Portable tube, propeller style meter is 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 1.65 tons/ha (200 bushels per acre) is required for winners to ensure realistic yield goals are being entered into the contest. Thus, both a high yield and high water use efficiency must be obtained to win the contest.

Average water use efficiency for all rice contestants in 2018 and 2019 was (5.16 bushel/inch) for both years, while average rice yield within the contest was 1.72 tons/ha (209 bpa) in 2018 and 1.57 tons/ha (190 bpa) in 2019. Both first place winners used the flooded rice production system. The two-year average water use efficiency for flooded rice was 14.5 ha-cm/ha (5.7 bushels/ac-inch) and the average water use efficiency for furrow irrigated rice was 12.5 cm-ha/ha (4.9 bushels/ac-inch). The lowest water use efficiency for any individual rice field was a furrow irrigated field with 7.1 tons/ha (2.8 bushels/ac-inch). The highest yields for all rice was recorded in furrow irrigated rice was 2.2 tons/ha (266 bpa) and the lowest yield for any rice entry came from a furrow irrigated rice field with a yield of 1.1 tons/ac (132 bpa). Support from and participation by extension agents as well as NRCS Conservationists and Technicians has caused the contest to develop in Arkansas. Many contestants indicate that the motivation for entering the contest is not the prizes, but the learning that comes with implementing new irrigation management tools Contestants commonly use the measurements obtained through the contest as a measure of their own continuous improvement in irrigation efficiency whether they win prizes or not.

Determination of Rice Grain Yield Response to Nitrogen Fertilization

Coker, A., Adotey, N., Gentimis, T., Harrell, D.L., Kongchum, M., Shiratsuchi, L., and Tubana, B.

Nitrogen (N) is the most essential nutrient to rice due to the heavy impact this nutrient has on rice grain yield. Nitrogen is the most abundantly applied fertilizer and makes up a bulk of the fertilizer budget of the rice crop. Current N fertilizer recommendations are based on N fertilizer response trials conducted each year by state experiment scientists across multiple locations. These studies result in optimum N rate ranges on an individual cultivar basis. Among the range of recommended N rates, the higher N fertilization rates might increase yield greatly, but a producer might not be able to cover the additional expenses of added N fertilizer applications. The economical optimum N rate (EONR) of fertilization is used to estimate where the N fertilization rate impacts rice grain yield but is still economically efficient. The optimum N rate is determined by fitting certain statistical models to rice grain yield data. Three popular models include: 1) linear-plateau, 2) quadratic-plateau, and 3) quadratic. The estimated EONR of fertilization can vary between each of the statistical models even when using the same data set. The objectives of this study were to: 1) evaluate rice grain yield response to N fertilization using three regression models (linear-plateau, quadratic-plateau, and quadratic models) and 2) determine the EONR for each model by assessing the coefficients of determination (R^2), maximum rice grain yield each model produced, and the estimated EONRs of fertilization.

This study used data that was taken from field trials which were conducted at two locations in 2017 and four locations in 2018. A total of seventeen different rice cultivars were evaluated for their response to N fertilization. Not all seventeen varieties were included at each location for each year. The rice varieties were treated with eight N rates, each replicated four times (0, 34, 67, 101, 135, 168, 202, and 235 kg ha^{-1}). The rice hybrids were treated with six N rates, each replicated four times (0, 67, 101, 135, 168, and 202 kg ha^{-1}). Nitrogen rates were surface broadcasted on the rice plots at pre-flood, the 4- to 5-leaf physiological growth stage. The rice was managed according to state recommendations during the growing season. Data were collected from each individual variety- site-year trial for the use in the fertilizer response analyses. A small plot combine equipped with a HarvestMaster H2 high capacity graingage was used to determine the weight and moisture of the harvested rice plots. The linear- plateau, quadratic-plateau, and quadratic response models were fit to the fertilizer response data from each variety- site-year trial. The study evaluated the models by assessing the coefficients of determination (R^2), maximum rice grain yields each model produced, and the estimated EONRs of fertilization. Statistical analysis was performed on all data collected for each variety-site-year using R-Studio 1.1.456.

The mean R^2 value for the linear-plateau, quadratic-plateau, and quadratic response models across all cultivars were: 0.80, 082, and 0.81, respectively. The high and similar R^2 values indicates how each response model fit the data set equally well and each should be able to estimate useful EONR of fertilization for the individual variety-site-years.

However, the estimated EONR of fertilization for a given variety-site-year were drastically different between the three response models despite the similar R^2 values. The quadratic model predicted the highest EONR 86% of the time, the linear-plateau model predicted the highest EONR 76% of the time, and the quadratic-plateau model predicted the highest EONR 2% of the time. The quadratic model also predicted the highest grain yield at EONR of fertilization more than the linear-plateau and quadratic-plateau models. Economic estimates were determined to give a more logical look into the response models to determine which model is the most economically efficient. Based on the response model with the greatest net returns, the quadratic model was the best model to determine the EONR of fertilization 71% of the time. However, the R^2 data showed the quadratic-plateau model to be the best response model to determine the EONR of fertilization. The variation between which response model is the best to determine the EONR of fertilization highlights why other factors besides the R^2 data should be considered. The response models are purely empirical, and justification should be given when choosing between the different response models.

Expansion of Invasive Apple Snails (*Pomacea maculata*) into Rice Production Regions in Southwest Louisiana

Lucero, J.M. and Wilson, B.E.

The apple snail, *Pomacea maculata*, is an invasive rice pest in Asia, Europe, Central America, and now the United States. Their modes of introduction have varied from being transported through attachment to boats to being released intentionally to establish a food market or through the aquarium fish trade. The apple snail's fast-reproductive rate and voracious appetite have made it a damaging economic pest in the rice production systems it has invaded including Spain, the Philippines, and Central America. Apple snail damage to rice, *Oryza sativa*, occurs primarily through the reduction of plant populations by consuming seedling rice. Thus, the introduction of the snails into Louisiana represents a major threat to the state's rice industry.

Over the last decade, the apple snail has established itself in Louisiana, but has only recently begun infesting rice farms. Observations suggest rapid expansion from river systems into rice production systems occurred as a result of the 2016 flooding event in south Louisiana. However, the snails' current distribution, rates of expansion, and impacts to rice in Louisiana are unknown. In order to determine current apple snail distribution and abundance, we set up 46 sites consisting of five-foot PVC pipe among three separate grids surrounding the Mermentau River and Bayou Lacassine. PVC pipes were used as structures for egg masses to be laid on to provide targeted-monitoring sites. The three grids of sampling sites were established surrounding unconnected sites where apple snails were initially detected in rice fields. Grids 1, 2, and 3 were composed of 36 sites, 6 sites, and 4 sites, respectively. Each site is monitored monthly for the presence of snails and egg masses, and the number of egg masses at each site is recorded. Environmental factors, such as temperature, vegetation, and water availability, are also recorded. Spatial analysis with ArcGIS software was used to map current data and help map potential future apple snail expansion. After two months of monitoring this fall, apple snail presence has been confirmed in four parishes located on both sides of the Vermilion River. No new areas of expansion have been detected thus far, and no major impacts on rice have been observed. However, crawfish trap capture has been significantly reduced to the point that producers are draining their crawfish ponds. Ongoing research efforts aim to determine how rapidly populations are expanding and factors that are suitable for their establishment.

Differential Response of Rice Varieties to Flooded and Aerobic Rice Systems

Mohammed, A.R, Harper, C., Tabien, R., and Tarpley L.

Declining availability of water and lack of rainfall is threatening the traditional way of growing rice under flooded conditions. Efficiency in the use of water is critical to safeguard food security, especially of rice—the stable food for more than half of the world's population. A study was conducted at Texas A&M AgriLife Research Center at Beaumont, Texas, to evaluate the response of diverse rice types to different water management systems for rice production. The rice cultivars were grown under aerobic or flooded soil conditions. Plant height, numbers of tillers, yield and milling qualities were determined. Our results indicated differential responses among the varieties to water management systems. Sensitive varieties showed decreased plant height, number of tillers and yield. Depending upon the availability of water, rice can be grown under aerobic or flooded condition, however selection of variety is critical.

Response of Pure-line Rice Cultivars to Midseason Nitrogen Fertilizer Application Timing

Smartt, A.D., Norman, R.J., Roberts, T.L., Slaton, N.A., Hardke, J.T., Frizzell, D.L.,
Castaneda-Gonzalez, E., Coffin, M.D., and Gruener, C.E

Beginning in 2010, research trials have been conducted at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center (NEREC), Pine Tree Research Station (PTRS), and Rice Research and Extension Center (RREC) to examine the influence of midseason nitrogen (N) application timing on the grain yield of conventional, pure-line rice (*Oryza sativa* L.) cultivars. Previous research suggested that the midseason N application was most effective when applied from beginning internode elongation (BIE) to 12.7-mm (0.5-inch) IE, but was conducted over 20 years ago, so it is necessary to examine the impact of midseason N application timing on current rice cultivars. Each trial in this study included a semi-dwarf cultivar from Louisiana (Cheniere in 2010, 2011, and 2012, CL152 in 2013, Mermentau in 2015 and 2016, and CL153 in 2017 and 2018) and a short-stature cultivar from Arkansas (Taggart in 2010, 2011, and 2012, Roy J in 2013, 2015, and 2016, and Diamond in 2017 and 2018). There were two preflood N rates at each location and up to five midseason N application timings, which were at BIE, BIE+7 days, BIE+14 days, BIE+21 days, and BIE+28 days. Beginning in 2012, there was also a control, where no midseason N was applied, and an optimum single preflood (SPF) N application treatment was added in 2013. In 2010 and 2011, the study indicated a positive influence on rice grain yield when midseason N wa applied from BIE to BIE+14, while BIE+21 days was not tested. The 2012 study indicated midseason N applied from BIE to BIE+21 days significantly increased rice grain yield at two locations, while none of the midseason N application timings resulted in a yield increase at the third location. Similarly, the 2013 study showed midseason N applications from BIE to BIE+21 days generally increased grain yield for both preflood N rates at the NEREC and RREC, while no midseason N application timings produced a yield response at the PTRS with the greater preflood N rate. In 2015 at the RREC, midseason N applications made at BIE+14 and BIE+21 days resulted in grain yields that did not differ from the SPF application, while earlier applications resulted in lower grain yields. Consequently, application timings were expanded to include BIE+28 days in 2016 and at the RREC the latest midseason N application timing produced lower grain yields than the SPF treatment, while none of the earlier timings differed from the SPF treatment. Similarly, in 2017 at the RREC, midseason N applications made at BIE+28 days did not impact yields relative to the control. In 2018, midseason N applied at BIE+28 days only improved yields, relative to the control, at the lower preflood N rate at the NEREC, while other midseason N application timings consistently increased grain yields. When a greater preflood N rate was used, several midseason N application timings resulted in greater grain yields than the SPF N application. The midseason N application window appeared to span multiple weeks over the course of this study. Although midseason N applied at BIE+28 days generally seemed too late to impact grain yields, applications from BIE to BIE+21 days oftentimes improved yields relative to a control with no midseason N. Results from these studies have led to the new recommendation that the midseason N application should be applied no earlier than BIE and at least 3 weeks and at times 4 weeks after the preflood N application; both of these conditions must be met to obtain the full grain-yield benefit from the midseason N application.

Effects of Late Season Nitrogen Application on Yield in Hybrid Rice

Scott, C.L., Bolton, D.T., Roberts, T.L., Hardke, J.T., Hoegenauer, K.A.

Over 500,000 hectares of rice (*Oryza sativa* L.) are planted in Arkansas annually which accounts for as much as half the U.S. total rice production. Due to lower seeding rate, larger numbers of tillers and higher yield compared to pureline cultivars, more and more of these hectares are being planted in hybrid rice. To fully realize the yield potential and other benefits of choosing a hybrid rice cultivar, a departure from traditional nitrogen (N) application timing could be necessary. Common practice has been to fertilize rice with a single preflood (SPF) application, but a late season application could have a positive effect on yield as well as milling quality. To compare the effects of N application timing and rate on hybrid rice grain yield, trials were established at two locations within the state. One location on a silt loam soil and one on a clay soil. Hybrid cultivars selected for this study were RT XP 753 and RT Gemini 214 CL. Six preflood N rates of 0, 33, 67, 100, 134, and 168 kg N ha^{-1} as well as two late season N rates of 0 and 33 kg N ha^{-1} were implemented. The late season applications were made during the R3 growth stage which is the recommended timing for what is commonly referred to as the “boot” application. Results indicate significant differences in grain yield across locations and in most cases there were no interactions between PF N rate and late season N application. These results suggest that the late season application significantly increases rice grain yield across all PF N rates. Further work will focus on the translocation and metabolism of late season N applications to identify the mechanism or metabolic function that this late season application alters that ultimately results in increased grain yields.

Influence of Planting Date on Seeding Rate Decisions for Diamond Rice Variety

Castaneda-Gonzalez, E., Hardke, J.T., Norman, R.J., Frizzell, D.L., Frizzell, T.D., Hale, K.F., and Clayton, T.L.

The establishment of a uniform and adequate rice (*Oryza sativa* L.) stand is critical to achieve high yields. Selecting the appropriate seeding rate is the first step in achieving optimal yields. Traditional methods for seeding rate studies are utilized to determine adequate seeding rates for new cultivars and applied to a wide range of production/growing conditions in Arkansas. The seeding date window in Arkansas extends from late March through June exposing the crop to a range of environmental conditions that may affect crop performance in relation to the seeding rate used.

Diamond, a mid-season, high yielding, long-grain cultivar released in 2016 treated with fungicides and an insecticide was planted at two locations: the Rice Research and Extension Center (RREC) near Stuttgart, AR, and the Pine Tree Research Station (PTRS) near Colt, AR at seeding rates of 108, 215, 323, 431, and 538 seed/m^2 (10, 20, 30, 40, and 50 seed/ft^2). Trials were planted at five to six planting dates at each location during the 2018 and 2019 growing seasons corresponding to late March, early April, mid-April, early May, mid-May, and early June. Stand density prior to tillering and grain yield were evaluated.

A general trend of stand density increase as seeding rate increased was observed for all seeding dates, whereas grain yield decreases when planted outside the optimum window at any given rate. Environmental conditions at RREC supported good growing conditions even when planted outside the optimum planting date window resulting in similar yields across seeding rates. Seeding rates lower than the baseline recommended for silt loam soils of 323 seed/m^2 resulted in inadequate stand density required to achieved maximum yield potential, and seeding rates greater than the recommended baseline resulted in stands greater than the recommended 108-215 plants/m^2 when favorable environmental factors were present.

At RREC, significant grain yield responses were not observed with increased seeding rates when planted outside the optimum recommended seeding date range. However, at PTRS at times there was a significant grain yield increase when planted outside the optimum recommended seeding date range. Overall results at RREC disagree with current recommended increases to seeding rate when planted early or late, while results at PTRS agreed with current recommendations. The results of this study emphasize the need to consider prevalent environmental conditions when determining seeding rates for a particular location at a particular planting timing in order to achieve the minimum stand density needed to maximize grain yield potential.

Potential Use of Nitrapyrin as a Nitrification Inhibitor for Delayed Flood ice

Mansour, W.J., Golden, B.R., Bond, J.A., Gore, J., Dodds, D., Slaton, N.A., Pieralisi, B., and McCoy, J.M.

In the southern United States, urea is the predominant ammonium-forming nitrogen (N) source implemented in a delayed-flood rice production system because of its high N content (46% N) and relatively low cost. Establishing a permanent flood within a few days' post urea application is essential due to potential losses of N through ammonia volatilization and/or nitrification/denitrification. Ammonia volatilization occurs when urea is hydrolyzed to ammonium carbonate [$(NH_4)_2CO_3$] by the urease enzyme and ammonium carbonate decomposes to produce ammonia (NH_3) and carbon dioxide (CO_2). Nitrification is a two-step microbial process in which ammonium (NH_4) is converted into nitrite (NO_2) and lastly into nitrate (NO_3). Denitrification is a microbial facilitated process where NO_3 in the soil is utilized as an electron acceptor under anaerobic conditions resulting in gaseous oxides that are lost to the atmosphere. In order to impede NH_4 losses the use of nitrification inhibitors (NI) allows producers a longer time frame in between fertilizer applications to permanent flood establishment in rice. Currently, there are several products labeled for use as NI's; however, the focus of this research will pertain to nitrapyrin (as Instinct II). The objectives of this research were to evaluate nitrapyrin in the field as broadcast versus impregnated applications on urea, as well as to examine the efficacy of dicyandiamide (NBPT) (as Agrotain) and nitrapyrin alone and in combination on various rates of N fertilizer.

Research to evaluate nitrapyrin efficacy in rice culture was established at the Delta Research and Extension Center in 2018 and 2019 near Stoneville, MS. All test sites were drilled using CL153 variety at a rate of 73 kg ha^{-1}. Broadcast applications were implemented via pressurized CO_2 back pack sprayer calibrated to deliver a spray volume of 140.31 L ha^{-1} at 262 kPa with Teejet XR 11002 spray tips. Test trials were established to evaluate impregnated nitrapyrin alone or in combination with NBPT. Nitrapyrin and NBPT were both impregnated on urea prills at labeled rates of 1.97 L ha^{-1} and 1.04 L metric $tons^{-1}$, respectively. Two soil textures were evaluated to simulate rice production and determine enhanced efficiency fertilizer additive efficacy. Site one was conducted on a Tunica clay (Clayey over loamy, superactive, nonacid, thermic Vertic Epiaquepts) with a pH of 6.7 and 2.1% organic matter. Site two was conducted on a Commerce silty clay loam (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with a pH of 6.8 and 1.0% organic matter. Urea was broadcast at 5-LF with N rates 112 and 168 kg N ha^{-1} for the Tunica clay and 112 and 146 kg N ha^{-1} for the Commerce silty clay loam. Each trial was arranged as a randomized complete block design with four replications. At physiological maturity trials were harvested with a small plot combine and grain yields were adjusted to 12% moisture content. Statistical analysis was conducted using PROC GLIMMIX procedures in SAS version 9.2 and means were subjected to analysis of variance implementing Fischer's protected LSD ($P > 0.05$) to compare grain yields among treatments within each trial.

Analyzing the Tunica clay soil textures data inferences revealed that regardless of application method no significant differences were observed among treatments when urea was applied at 122 kg N ha^{-1}. No significant differences were observed among treatments when urea was applied at 168 kg N ha^{-1}. Although not significantly different, broadcast or impregnated applications of nitrapyrin resulted in similar or numerically greater yields when compared to other treatments regardless of N rate. Analyzing the Commerce silty clay loam data inferences revealed that regardless of NBPT, nitrapyrin or their combination, no significant differences were observed with mean rice grain yield when 112 kg N ha^{-1} of urea was applied at 5-LF. When urea applications increased to 146 kg N ha^{-1}, significant differences were observed for mean rice grain yield. Additionally, the greatest numerical mean rice grain yield was achieved with broadcast applications of nitrapyrin when compared to other treatments. Yield increases with broadcast applications of nitrapyrin at 146 kg N ha^{-1} could be attributed to an increase in area coverage, which provided a greater level of efficacy as a nitrification inhibitor when urea was applied.

Currently, there is no label for nitrapyrin use in direct-seeded, delayed-flood rice culture. Although yields were not significantly different, numerical differences in grain yields were observed when broadcast applications of nitrapyrin were compared with NBPT impregnated applications. Data inferences can be made that nitrapyrin can be implemented as a potential enhanced efficiency fertilizer additive for N management.

Results of the 2019 Arkansas Rice Grower Research and Demonstration Experiment Program

Hale, K.F., Hardke, J.T., Baker, S., Freeze, D., Runsick, S.K., Baldridge, B., Beaty, K., Perkins, K., Simpson, A., and Gordon, B.

In 2019, the Rice Grower Research and Demonstration Experiment (GRADE) Program was conducted in commercial rice fields at nine locations across Arkansas. The University of Arkansas System Division of Agriculture and the Arkansas Rice Research and Promotion Board first initiated this program in 2017 to conduct large block replicated field trials on grower farms to bridge information between small plot research trials and grower field experiences. It is a collaborative effort between growers, consultants, county Extension agents, Extension specialists, and researchers using large block plots of approximately ½ acre or larger within a grower's field to achieve our goals.

The program has continued to grow since its limited start in the 2017 growing season. In 2019, all trials were prepared with a minimum of three replications in a randomized complete block design. Four of the locations were variety demonstrations utilizing the varieties Diamond, LaKast, and Roy J. Two demonstrations evaluated Nitrogen Soil Test for Rice (N-STaR) and GreenSeeker technology to gauge the effectiveness and profitability of the use of midseason nitrogen (N) fertilizer applications. There were also two seeding rate demonstrations that assessed multiple seeding rates using hybrid rice. Additionally, a furrow-irrigated demonstration was implemented using CL153, Diamond, and XP753.

The Clark Co. seeding rate demonstration compared seeding rates of 15, 20, 26, and 31 kg seed/ha (13, 18, 23, and 28 lb seed/acre). Only the lowest seeding rate of 15 kg/ha failed to maximize grain yield. The Lonoke Co. seeding rate demonstration compared seeding rates of 12, 18, 24, and 29 kg seed/ha (11, 16, 21, and 26 lb seed/acre). All seeding rates produced similar grain yields.

The Greene Co. GreenSeeker midseason N trial evaluated the use of GreenSeeker for determining midseason N needs. GreenSeeker readings were taken throughout the trial area prior to midseason N fertilization. Comparing plots receiving no midseason N to those receiving 112 kg urea/ha, GreenSeeker readings successfully predicted a significant grain yield response to midseason N fertilization.

Variety trials compared Diamond, LaKast, and Roy J planted at standard recommended seeding rates. At Jefferson Co., Diamond and Roy J produced the greatest grain yields while LaKast produced the greatest milling yields. At Lee Co., Diamond produced the highest grain yields while LaKast produced the highest milling yields. At Lawrence Co., all varieties produced similar grain yields, but LaKast again produced the highest milling yields. At Clay Co., Diamond and Roy J produced the highest grain yields and Roy J the highest milling yields. The results from these demonstrations will be used in conjunction with small plot research to improve recommendations for Arkansas rice growers for best production practices.

Influence of Nitrapyrin on Total Nitrogen Uptake and Yield in Direct-Seeded, Delayed Flood Rice System

Hoegenauer, K.A., Roberts, T.L., and Bolton, D.

The two primary nitrogen (N) loss pathways in mid-south rice (*Oryza Sativa L.*) production are ammonia volatilization and denitrification. Under the commonly used direct-seeded, delayed-flood production system, N losses due to denitrification are rare when preflood N is applied timely and managed properly. If the permanent flood is established shortly after the preflood N application and the flood is maintained until maturity, little to no N is expected to be lost from the system due to denitrification. However, it can be difficult to time the application of preflood N and the permanent flood properly especially when environmental conditions such as rainfall are not easily predicted. In cases where the flood cannot be established timely due to rainfall or muddy soil conditions, there is the potential for some of the preflood N to be nitrified prior to establishment of the permanent flood. This study was designed to investigate the use of nitrapyrin, a nitrification inhibitor, to help mitigate this issue. The study was conducted at two locations in the rice growing region of Arkansas. One site was established on a silt loam soil and the other site was established on a clay soil. A treatment scheme was used to evaluate soil applied nitrapyrin immediately preflood and applied 10 to 14 days preflood across three N rates (100, 75, and 50% of the recommended preflood N rate). Nitrogen rate had a significant effect on grain yield at both the silt loam ($P < 0.0001$) and clay ($P < 0.0001$) sites as expected. However, there was a significant N rate x Application Timing interaction ($P = 0.0017$) at the silt loam site. However, this interaction was non-significant ($P = 0.2217$) at the clay site. Neither site had a significant main effect of Application Timing ($P = 0.1686$ and $P = 0.4905$ for silt loam and clay respectively). From this data, we can conclude that the use of nitrapyrin may be useful under few and very specific circumstances. This study should be replicated in future years to further evaluate these findings.

Evaluation of Water Management Practices on Nitrogen Fertilizer Efficiency using ^{15}N Isotope Tracer

Kongchum, M., Harrell, D.L., Adotey, N., and Coker, A.

Nitrogen is a major element in rice fertilizers. A flooded rice production system generally recovers 20-40% of the nitrogen fertilizer application. Various studies on the nitrogen use efficiency in rice fields have been reported, such as the application of urease inhibitors, N application methods, and cultural practices. The objectives of this study were to evaluate nitrogen fertilizer efficiency in three water management practices, three N fertilizer application techniques, and two rice varieties using ^{15}N-labeled urea.

A field experiment was conducted to evaluate nitrogen fertilizer efficiency of three water management practices, three N application methods, and two rice varieties. Rice variety CL153 and hybrid CLXL745 were drill seeded with 20.3 cm row spacing. At the 2- to 3-leaf growth stage, 25.4 cm diameter PVC tubes were placed on the ground to cover two rows of rice. The plants inside the tubes were thinned to 4 and 6 plants for CLXL745 and CL153, respectively. The three water management practices used were delayed flood (DF), alternate wetting and drying AWD), and semi-aerobic (SA). Urea-^{15}N of 5 atom% was applied at the rate of 168 kg N/ha with three different application methods: 1) single preflood (PF); 2) a 2-split application at PF (112 kg N/ha) and PI (56 kg N/ha); and 3) a 3-split application at PF (90 kg N/ha), PI (39 kg N/ha), and boot (39 kg N/ha).

The fraction of nitrogen in the plant derived from the ^{15}N labelled fertilizer (%NDFF) was not different among the application methods. Delayed flood had the highest average %NDFF in all plant tissue samples (at 50% HD, rice straw, and grain) for CL153, but the highest %NDFF in grain for CLXL745 was detected in the AWD treatment. The highest %NDFF averaged across all water management treatments was found in 3-split N application method followed by 2-split, and single preflood application. Semi-aerobic water management practice had the lowest grain yield for both rice varieties.

A Five-Year Summary of the University of Arkansas Rice Research Verification Program

Mazzanti, R., Baker, R.P, Hardke, J.T., and Watkins, K.B.

Rice (*Oryza sativa, L.*) production is constantly changing as new cultivars are released and new production challenges arise. Producers continue to request the University of Arkansas System Division of Agriculture field-test existing technology to determine the profitability of rice production based on recommended practices. In 1983, the Arkansas Cooperative Extension Service and the Arkansas Rice Research and Promotion Board initiated the Rice Research Verification Program (RRVP). The RRVP is an interdisciplinary effort between growers, county Extension agents, Extension specialists, and researchers. The RRVP is an on-farm demonstration of all the research-based recommendations required to grow rice profitably in Arkansas. The trends in yields, management decisions, and impacts will be presented.

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.

Each RRVP field and cooperator was selected prior to planting. Cooperators agreed to pay production expenses, provide crop expense data for economic analysis, and implement Extension recommended production practices exclusively in a timely manner from seedbed preparation to harvest.

Since the program's inception 36 years ago, RRVP yields have averaged 0.9 ton/ha (18 bu/acre) above the state average. The most recent 5 year RRVP average stands at 0.96 ton/ha (19 bu/acre) above the state average. The consistently higher yield averages of the program in comparison to the state average can mainly be attributed to intensive cultural management and integrated pest management.

Poly-4™ as a Potassium Fertilizer Source in Rice

Williamson, S.M., Roberts, T.L., Hardke J.T., and Shafer, J.B.

Potassium (K), often seen as the most limiting nutrient behind nitrogen (N) in Arkansas rice (*Oryza sativa*) production systems, is vital to cell water regulation, photosynthesis and many enzymatic processes. Potassium fertilization, most commonly applied as muriate of potash (MOP; 0-0-60), is almost always required to reach maximum rice yield potential in Arkansas' silt loam soils. The objective of this study was to evaluate the effects of Poly-4™, a naturally occurring, multi-nutrient fertilizer, in comparison to other common K sources on whole-plant K uptake and rough rice grain yield. This study was arranged in a randomized complete block design with six replicates and consisted of ten treatments to evaluate the use of three K fertilizer sources (MOP, sulfate of potash-SOP and Poly-4™) alone or in combination to provide 134 kg K_2O/ha. Following preplant K fertilizer incorporation, drill-seeded rice was planted in 2017 and 2018 in plots measuring 2m x 5m on low soil-test K Calhoun silt loam sites at the Pine Tree Research Station (PTRS) near Colt, AR. Current recommendations for direct-seeded, delayed-flood rice production in Arkansas were followed for disease and pest control, and rice was flooded within 48 hr following the application of 150 kg N/ha as Agrotain® treated urea. Aboveground biomass samples from a 1 m section of a bordered row were collected at the 50% heading stage, dried at 60ºC, ground to pass a 1mm sieve, and analyzed for mineral content to determine total K uptake. Following maturity, plots were harvested with a plot combine and calculated yields were adjusted to 12.5% moisture and extrapolated. In both years, a positive response to K inputs was observed with treatments receiving K fertilization presenting a significantly ($P < 0.01$) higher total K uptake. No significant differences were observed in total K uptake amongst K sources. Likewise, rough rice grain yields were significantly higher ($P < 0.0005$) for plots that received K fertilization and no significant differences were observed amongst K sources. Based on the results of this study, Poly-4™, alone or in combination with MOP, proves to be an effective K fertilizer source for use in rice produced on silt loam soils in Arkansas.

Rice Grain Yield Response to Planting Date in Arkansas, 2017-2019

Clayton, T.L., Castaneda-Gonzalez, E., Hardke, J.T., Frizzell, D.L., Norman, R.J., Plummer, W.J., Hale, K.F., Frizzell, T.D., Moldenhauer, K.A.K., and Sha, X.

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 2017 to 2019, from late March through early June, five to six plantings were made in two locations, the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (RREC) near Stuttgart, AR, and the Pine Tree Research Station (PTRS) near Colt, AR. The cultivars grown were the pureline varieties CL153, CL272, Diamond, Jupiter, PVL01, and Titan, and the hybrids RT CLXL745, RT Gemini 214 CL, and RT XP753. For the PTRS location, the optimum planting window was late March through early May in 2017, but in 2018 and 2019, the optimum window was late April through early May. At RREC, the optimum planting window was late March through late April; however, in 2019, yields did not dramatically decline even through mid-May. 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.

Producer Rice Evaluation Program On-Farm Cultivar Testing

Frizzell T.D., Hardke J.T., Frizzell D.L., Hale K.F., Castaneda-Gonzalez E., Plummer W.J., and Clayton T.L.

On-farm cultivar testing provides the ability to evaluate performance in commercial fields with more unpredictable environments than those at traditional research stations. The Producer Rice Evaluation Program (PREP) utilizes commercial fields throughout the state of Arkansas to evaluate 25 different rice cultivars including experimental and commercial lines. These on-farm tests are used to analyze different agronomic aspects of cultivars such as disease, lodging, plant stand, plant height, grain yield, and milling yield in diverse environmental conditions, soil types, and growing practices. The most important decision for a producer can be the cultivar that will provide the maximum yield potential for each field. On-farm testing can indicate the cultivars that are best suited for a particular growing situation. Studies were located in grower fields in Craighead, Greene, Lee, Lonoke, Poinsett, Prairie, and Woodruff counties for the 2019 season. The average grain yield across all six locations was 199 bu/ac and the location with the highest average grain yield average was Woodruff County at 223 bu/ac. The cultivars with the highest average grain yield across all locations were RT XP753, RT Gemini 214 CL, RT 7301, RT 7521 FP, CLXAR19, RT 7501, Jupiter, RT 7321 FP, Titan, and Diamond. Cultivars with highest head rice yields were PVL02, CLM04, Jupiter, CLJ01, CL151, CL153, Jazzman-2, ARoma 17, Jewel, Lynx, and PVL01.

Optimize Nitrogen Rate and Planting Density to Improve Grain Yield of Different Rice Cultivars in Northeast China

Zhou, C.C., Huang, Y.C., Jia, B.Y., Wang, S., Dou, F.G., Samonte, S.O.PB., Chen, K., and Wang, Y.

Nitrogen fertilization and planting density are two key factors that can interactively affect the grain yield of rice. Three different types of rice cultivars, inbred Shendao 47, inbred Shendao 505, and hybrid Jingyou 586 were used to investigate the effects of nitrogen (N) rate and planting density (D) on the aboveground biomass, harvest index, leaf photosynthetic features, grain yield, and yield components using a split-split-plot design with four replications at two sites over two continuous years. The main plots were assigned to four nitrogen fertilizer rates: 0 (N0), 140 (N1), 180 (N2), and 220 (N3) kg ha^{-1} N; the subplots were assigned to three planting densities: 25×10^4 (D1), 16.7×10^4 (D2), and 12.5×10^4 (D3) hills ha^{-1} and the sub-sub plots were assigned to three rice cultivars. The results showed that the grain yield had significantly positive correlation with the stomatal conductance (Gs), net photosynthesis rate (Pn), transpiration rate (Tr), chlorophyll content (SPAD value), leaf area index (LAI), panicles per unit area, and spikelets per panicle. The N rate and planting density had significant interaction effects on grain yield, and the maximum values of Shendao 47, Shendao 505 and Jingyou 586 appeared in N3D2, N2D1, and N3D3, respectively. The higher grain yield of the selected cultivars was mostly ascribed to both panicles per unit area and spikelets per panicle. We found that the treatments N3D2, N2D1, and N3D3 could optimize yield formation factors for Shendao 47, Shendao 505, and Jingyou 586, respectively. Across years and sites, the regression analysis indicated that the combinations of nitrogen fertilization of 195.6 kg ha^{-1} with planting density of 22×10^4 hills ha^{-1}, 182.5 kg ha^{-1} with 25×10^4 hills ha^{-1}, and 220 kg ha^{-1} with 13.1×10^4 hills ha^{-1} are recommended for medium-, small-, and large-sized panicle rice cultivars, respectively.

Abstracts of Papers on Economics and Marketing
Panel Chairs: Steve Martin and Brian Mills

Review of Panel Data on Row Rice Production System in Arkansas: (2016-2018)

Mane, R.U., Watkins, K.B., and Henry, C.G.

Row rice (or furrow-irrigated rice) is an upland rice production system that involves irrigating rice with furrows. Since 2016, row rice production in Arkansas has increased from 40,000 acres to an expected planting of 200,000 acres in 2020.

The objective of the paper is to compare the economics of the row rice 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 2018, and data with respect to production costs and net revenues are summarized and reported in this paper.

The University of Arkansas 2016 - 2018 Crop Enterprise Budgets are used to study profitability of rice under row rice production systems when compared with conventional flooded system from the Rice Research Verification Program (RRVP). Economic data from ten different row rice 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.

Based on the average results from 2016 to 2018, the average fertilizer and nutrient cost for row rice is $77.18 per acre lower when compared conventional flooded production systems. Likewise, the total average chemicals cost for row rice is $95.46 per acre, which is relatively high when compared to conventional flooded fields. However net returns to row rice have a variation from a minimum of $38.02 per acre to a maximum of $353.97 per acre. There was no significant statistical difference in net returns when compared to the controlled fields.

An Evaluation of Changes in Rice Acreage and Irrigation Water Sustainability in Arkansas

Gautam, T.K. and Watkins, K.B.

Arkansas is the number one rice producer in the nation and rice is the state's second-highest-valued commodity. Rice is one of the major export products in Arkansas, accounts for more than 25,000 jobs, and contributes billions of dollars to the state economy. Eastern Arkansas is very important in that 98 percent of Arkansas' rice production occurs in this region. However, increasing production costs, diminishing net returns, and declining groundwater availability induced by large groundwater withdrawals and climatic variation have imposed some threats to the sustainability of rice farming. In general, producers are concerned about productivity and net on-farm profitability, whereas the resource sustainability perspective aims at minimization of resource use without adversely affecting production. In this situation, it is imperative to evaluate Arkansas rice acreage responses with major competing crops, climatic variations, and changes in groundwater levels and suggest potential policy implications that optimize sustainability in terms of both rice farming and water resource management.

Our objective in this study is to identify eastern Arkansas rice acreage responses with respect to major attributing factors utilizing the USDA-NASS survey data, NOAA climatic information, and USGS groundwater information for the period of 1970-2018. We use a fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) methods to estimate the acreage response to relative price, climatic variation and groundwater level change in eastern Arkansas that comprises 26 counties out of 75 counties in the state. These estimators are efficient, consistent, and capable of producing robust estimates due to the fact that both the FMOLS and DOLS take into account of endogeneity problem (correlation between the model's explanatory variables and the model's error term), overcome the omitted variable and measurement error, remove sample bias, and correct for serial correlation.

The panel unit root test and cointegration test results confirm that the series are integrated of order one, which is the required condition for the parameters to be estimated. The preliminary results indicate that the rice acreage allocation is responsive to its own price and competing crop prices in both the long run and short run. However, the long run and short run rice acreage responses seem to be less sensitive to weather variation and groundwater change. A potential reason could be that irrigation water is almost free in Arkansas; the only cost associated with irrigation water is the energy cost for water withdrawal. The findings of this study would be beneficial to those who are directly or indirectly associated with rice production and water resource management.

Impacts of Arkansas Rice Foundation Seed Sales on Proportions of Hectares Planted to Public and Proprietary Rice Lines in Arkansas

Watkins, K.B., Mane, R.U., Wisdom, D.K.A. and Bathke, G.R.

The Arkansas Foundation Seed Program is responsible for the production of rice, soybeans, and wheat foundation seed and assisting breeders in the production of breeder seed. Its primary goal is to make the seed of newly released and proven varieties available to Arkansas growers as quickly as possible. The Arkansas Foundation Seed Program is administered by the Arkansas Agricultural Experiment Station and is based at the University of Arkansas System Division of Agriculture, Rice Research and Extension Center near Stuttgart, Arkansas. When a new rice cultivar is released as foundation seed, the cultivar and its complete description are registered with the National Committee on Registration of Crop Varieties. Foundation seed must be maintained according to registered standards. The objective of this study is to evaluate the impact of the Arkansas Rice Foundation Seed Program on both the total hectares and the percent of hectares planted to public and proprietary rice lines in Arkansas. Public rice lines include Arkansas and Non-Arkansas pure-lines, while proprietary rice lines include non-hybrid Clearfield cultivars and hybrid cultivars (non-Clearfield hybrids and Clearfield hybrids).

This study used data from the Arkansas Rice Foundation Seed Program and rice hectares by cultivar data from various RTWG proceedings for the years 2000 through 2018. Rice hectares per year by cultivar were separated into four different rice cultivar types: 1. Arkansas Pure-Lines; 2. Non-Arkansas Pure-Lines; 3. Clearfield; and 4. Hybrid (both non-Clearfield hybrids and Clearfield Hybrids). Data obtained from the Arkansas Rice Foundation Seed Program include the number of 23 kg (50 pound) bags of Arkansas rice foundation seed sold per year, and the number of registered Arkansas pure-lines released per year (ranging from 0 to 3 for the nineteen-year period). Seemingly unrelated regression (SUR) was used to evaluate the impacts of Arkansas rice foundation seed sales on hectares planted to each cultivar type, while fractional regression analysis was used to evaluate the impacts of Arkansas rice foundation seed sales on the percent of hectares planted to each cultivar type. Dependent variables in each regression analysis included hectares planted (percent hectares planted) to each of the four rice cultivar types. Independent variables for each regression analysis included trend, trend squared, the number of 23 kg (50 pound) bags of Arkansas rice foundation seed sold lagged one year, and the number of registered Arkansas pure-lines released per year.

Results of the SUR analysis revealed downward trends in Arkansas and non-Arkansas pure-line hectares. The downward trend was quadratic for non-Arkansas pure-line hectares (decreasing at an increasing rate) while the trend for Arkansas pure-line hectares was linear (decreasing at a constant rate). Both cultivar types lost ground to proprietary rice cultivars during the nineteen-year period. Clearfield hectares experienced an upward quadratic trend (increasing at a decreasing rate), while Hybrid hectares experienced an upward linear trend over the nineteen-year period. The number of registered Arkansas pure-lines released per year had a significant positive impact on Arkansas pure-line hectares, with an increase of 19,256 hectares (47,583 acres) for every new registered Arkansas pure-line release. The number of Arkansas rice foundation seed bags sold in the previous year had a significant positive impact on Arkansas pure-line hectares and a significant negative impact on Non-Arkansas pure-line hectares and Hybrid hectares. For every bag of Arkansas rice foundation seed sold, Arkansas pure-line hectares increased by 16.3 ha (40.5 ac), while Non-Arkansas pure-lines and Hybrid hectares decreased by -7.5 ha (-18.6 ac) and -9.0 ha (-22.1 ac), respectively. Clearfield hectares planted increased by 4 ha (10 ac) for every bag of Arkansas rice foundation seed sold, but the impact was not statistically significant.

The results of the fractional regression analysis revealed similar results for proportions of hectares planted to each cultivar type. Significant downward trends were found in the percentage of hectares planted to both Arkansas and Non-Arkansas pure-lines during the nineteen-year period, with a downward linear trend for Arkansas pure-lines and a downward quadratic trend for Non-Arkansas pure-lines. Percent hectares planted to proprietary cultivars (Clearfield and Hybrids) experienced an upward trend during the nineteen-year period, with both trends being quadratic. The number of new registered Arkansas pure-lines released per year had a significant positive impact only on the percentage of aces planted to Clearfield cultivars. Releasing one new registered Arkansas pure-line per year resulted in a percent increase in hectares planted to Clearfield cultivars of 1.68 percent. The number bags of Arkansas rice foundation seed sold in the previous year had a significant positive impact on the percent of hectares planted to Arkansas pure-lines and Clearfield cultivars (an increase of 2.32 percent and 2.52 percent, respectively, per 1,000 bags sold) and a significant negative impact on the percent of hectares planted to Non-Arkansas pure-lines and Hybrids (a decrease of -1.26 percent and -0.79 percent, respectively, per 1000 bags sold, respectively).

Impact of Commodity Programs of the 2018 Farm Bill on Arkansas Rice Farms

Wilson, G., Durand-Morat, A., Watkins, K.B., and Wailes, E.J.

Commodity programs (Farm Bill's Title I) remain an important part of the U.S. farm safety net. According to USDA, Arkansas farmers received $493 million in safety net payments in 2017, of which $280 or 57% was commodity program payments. Under the 2014 farm bill, almost all Arkansas rice and peanuts acres enrolled in the price loss coverage (PLC) program, while 88% and 95% of the corn and soybean acres enrolled in agricultural risk coverage (ARC) program.

The 2018 Farm Bill maintains the two main Title I commodity programs, namely PLC and ARC, originally introduced in the 2014 farm bill, and incorporates slight changes, explicitly:

(1) An elevator mechanism that allows for increases in the statutory PLC reference prices to as much as 115 percent of their current levels should national prices rise;
(2) Adds a Risk Management Agency-specified trend-adjustment factor to ARC yields each year;
(3) Allows producers a one-time update of their program payment yields, and
(4) Allows producers to choose between ARC and PLC for the 2019-2020 crop years, and beginning in 2021, producers can determine program enrollment on an annual basis.

We analyze the impact of Title I commodity programs under the 2018 farm bill on the economic viability of Arkansas farms. Agriculture is Arkansas largest industry, and rice is the third largest agricultural activity in the state after poultry and soybeans. We conducted the assessment using the representative farm models designed using financial data files made available by the Texas A&M Agricultural and Food Policy Center. The farms are located in McGehee, Hoxie, Mississippi County, Stuttgart, and Wynne. Each farm has a varying mix of commodities and crop acreage that reflect a typical farm in the area it represents. The models were extended to project economic conditions up to 2023 based on projections generated by the Food and Agricultural Policy Research Institute. Historical countywide commodity yields were taken from USDA's National Agricultural Statistic Service (NASS) for each farm and used to predict future yields over the 2019-2023 period.

Our findings suggest that, under the projected market conditions, farm programs will generate payments in all five years covered by the 2018 farm bill, and that the PLC program will generate more payments than the ARC program for every commodity/farm/year except for non-irrigated soybeans on the Hoxie farm in 2019-2021. Federal government support via commodity programs is vital for Arkansas farms: without commodity program payments, only one farm (Mississippi County) has a positive net income throughout the analysis period when government program payments are not included, but when commodity program payments are included all farms are substantially better off. Commodity program payments increase the odds of farmers making a positive net income and reducing income risks.

Commodity programs are projected to generate significant payments to Arkansas farms under the 2018 Farm Bill. All representative farms are expected to receive commodity program payments every year during the 2019-2023 period. This Title I financial support will help improve the probability of making a profit and reduce income risks. Under current and projected market conditions, the PLC program is likely to generate more program payments than ARC under most farm/crop/year conditions, and therefore be the preferred Title I program choice among farmers.

Economic Forces and Assumptions Driving USDA's 2019/20 Global Rice Market Baseline Forecasts

Childs, N.W.

USDA's 2019/20 long-term annual supply and demand baseline results for the global rice market are presented. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, and stock holdings for 33 countries (including the United States) and 9 multi-country regions. Aggregated, these 42 models account for total global rice production, supply, trade, and use. Economic factors driving long-term supply and use trends in key individual countries and regions are explained, as well as significant changes and reasons for changes from the previous baseline. Markets are not segmented by class, quality, or type.

Each year, USDA develops both a domestic and international 10-year supply and demand baseline for rice. The baseline effort stretches across multiple commodities including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding population and income growth for individual countries, interest rates, and exchange rates. The 2019/20 baseline forecasts were developed in October 2019. USDA's annual baseline projections are used by market participants and policy makers for planning, budgeting, and decision making. The current baseline forecasts the global rice market through 2029/30.

Economic Forces and Assumptions Driving USDA's 2019/20 U.S. Domestic Rice Market Baseline Projections

Childs, N.W.

USDA's 2019/20 long-term annual supply and demand baseline results for the U.S. rice industry are presented for both long-grain and combined medium- and short-grain rice. An all-rice baseline—an aggregate of the by-class model results—is reported as well. Emphasis is placed on forecasting area response, yield growth, export and import levels, domestic use, stock holdings, and season-average farm prices by class. Underlying economic factors driving these projections for both classes of rice are explained. Because almost half of the total U.S. rice crop is exported annually, expectations regarding the world rice market—including trading prices—affect domestic baseline forecasts as well.

Changing market conditions necessitate annual long-term baseline projections, as market participants and policy makers need updated forecasts for planning, budgeting, and decision making. Each year, USDA develops both a domestic and an international 10-year supply and demand baseline for rice. By-class models are developed only for the domestic market.

The baseline effort cuts across multiple commodities including grains, oilseeds, cotton, specialty crops, dairy, livestock, and poultry. The baseline assumes normal weather over the 10-year period and that current U.S. and global farm policies remain in effect. The baseline forecasts are made under given assumptions regarding global and domestic population and income growth, interest rates, and exchange rates. The 2019/20 domestic baseline forecasts were developed in October 2019.

Do Rice Markets in Ghana Work Efficiently?

Peterson-Wilhelm, B.E., Nalley, L.L., Tsiboe, F., and Durand-Morat, A.

In Ghana, rice is the second most important staple crop, behind only corn. Rice consumption is continuing to expand in Ghana. With just under a quarter of the population living below the national poverty line, rice price has many food security implications. Weaknesses in the grades and standards system in Ghana undermine the transparency of the rice market. This, combined with the open-bag nature of the market, can make it difficult for consumers to assess rice quality. If rice price does not reflect its quality, then inefficiencies may lead to welfare losses. Importantly, if rice is not being priced based on quality there is a chance that the poor are being priced out of the market based on inflated prices. The objective of this study is to assess the efficiency in the rice market by estimating the impact of selected rice quality attributes on rice prices.

We collected 110 samples in Ghana. We obtained: price, location of production, market purchased from, and if it was parboiled. Each rice sample was analyzed in a food science lab for the quality attributes: percentage of chalk rice, percentage broken rice, length, and width. We used multiple regression analysis to regress price against each variable and each market to see if quality and production attributes were the drivers of price.

The expected results from this study are important on two levels. If we find that quality attributes and location of production are not driving rice price, then markets are inefficient, suggesting that the Ghanaian government impose stricter standards. This is especially true for low quality rice, which should be priced accordingly to allow the poor to enter the market. If rice quality attributes are the drivers of rice price, this study will give insight as to which quality attributes Ghanaian consumers desire.

Improving pricing efficiency can help combat food insecurity in Ghana. Because Ghana is a net importer of rice, there are many trade implications associated with market efficiency and consumer preferences. Broken and chalk rice is sound nutritionally,but is often sold at a lower price for pet food and brewing rather than human consumption. With efficiently working markets, rice that was previously used for non-human consumption can instead be exported for human consumption in Ghana at an appropriate price. With rice being such an important staple in a Ghanaian's diet, having lower priced rice available has the potential to reduce food insecurity.

Abstracts of Posters on Economics and Marketing
Panel Chairs: Steve Martin and Brian Mills

Evaluating Return Risk among Rice, Crawfish, and Soybean Crops in Southwestern Louisiana

Deliberto, M.A., Hilbun, B.M., and McCann, J.E.

Rice producers in southwestern Louisiana have remained true to a crop that is a major economic driver to the region as well as a rich part of the culture of south Louisiana. In an attempt to weather the downturn in rice prices, producers have diversified their crops over a portion of their rice acres, either by converting acres that had once been held as fallow and incorporating them in the farm's rotation-system acreage so as to add additional enterprises as a way to mitigate risk. Rotational crops common to the rice production region of southwestern Louisiana include crawfish and soybeans. Over the past few years, both crops have not been insulated from both production and price risk. Weather can influence water temperature and the crawfish reproduction cycle as well as provide unwanted moisture during the maturing phases of soybean plant development. However, prices for crawfish have remained favorable as compared with both the commodity prices for rice and soybeans, thus making a rice/crawfish rotation a popular option among producers.

In an attempt to measure the net returns of rice, crawfish, and soybeans, the per-acre net return variability was approximated through simulation analysis to capture both market and input price volatility. Stochastic efficiency with respect to a function (SERF) has been shown to be an effective method of ranking risky production alternatives - in this case, cropping options. SERF provides a cardinal measure of a producer's conviction for preferences among alternatives (e.g. rice, crawfish, and soybeans) at each risk aversion level by interpreting the differences between certainty equivalent (CE) values as risk premiums. SERF evaluates CE values as a measure for the net returns per acre under a sub-set of alternative cropping options and then graphically ranks those options both ordinally and cardinally ranks over a spectrum of risk aversion levels.

Net returns above variable production cost is an appropriate metric one may use when making production decision comparisons among crops over the short run period of one crop year. Net returns above variable production cost and land rent charges are calculated and the differences between these values gives an estimate of the net return advantage that one crop would theoretically have for an assumed level of risk. As the assumed level of risk changes, the corresponding difference in net returns will change accordingly.

Actual data for county (parish) yields are combined with national marketing year average prices to develop a multivariate empirical yield and price distribution for each cropping option. Stochastic simulation based on the historical relationships of national market prices, regional crop yields, and selected farm production inputs with a multivariate empirical distribution includes a correlation matrix that generates correlated stochastic variables that are then entered into a financial simulation model for each cropping option. SERF was used to rank the various cropping option systems using utility-weighted CE's for various degrees of risk aversion. The risk premium for a risk-neutral decision maker reflects the minimum amount (dollars per acre) that a decision-maker has to be paid to justify a switch from the preferred strategy to a less-preferred strategy under a specific risk aversion coefficient.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Zhongli Pan

Effect of Nitrogen Fertiliser Rate and Timing on Grain Quality Parameters and Protein Composition of Rice

Wood, R.M., Dunn, B.W., Waters, D.L.E., Blanchard, C.L., Mawson, A.J., and Oli, P.

Nitrogen (N) fertiliser is an important crop management practice used to increase yield. Growers use the previous growing history of a paddock to determine the correct N rate, as there is no appropriate soil N test for rice. In south-eastern Australia, the total N rate is often split into two applications to reduce the risk of sterility induced by cold temperatures and high N uptake. This strategy involves a basal N application applied pre-permanent water (PW) and the second application following panicle initiation (PI). While previous research demonstrates that split N application (Pre-PW and PI) affects crop yield, data investigating the impact on grain quality is relatively sparse. Using the medium-grain, semi-dwarf rice variety Viand, we compared the effect of eight N treatments (five N rates applied pre-PW and three split treatments with the same total N rate) on grain quality parameters and protein composition. These data revealed increasing the rate of N applied pre-PW significantly increased head rice yield (HRY; the proportion of unbroken grain expressed as a percentage of harvested grain), however, splitting the same total N rate into two applications reduced HRY. HRY decreased as the rate of the first N application decreased and the second dose increased. This trend was also observed for RVA setback with the split N treatments producing a more negative setback than the pre-PW N treatments. When analysing protein composition, glutelin and globulin showed significant positive correlations with N uptake at PI while albumin was negatively correlated. Prolamin concentration increased as the N rate applied after PI increased which concurrently reduced the globulin concentration. We found that albumin and globulin were significantly negatively and positively correlated HRY and RVA setback, respectively. Applying N after PI increases the prolamin and albumin concentrations which significantly decreases HRY and RVA setback. These results indicate altering the nutritional management of rice changes the protein composition affecting grain quality parameters.

Evaluating the Role of Moisture Removal in a Drying Pass on Rough Rice Fissure Formation

Odek, Z. and Siebenmorgen, T.J.

Fissure formation in rice kernels leads to head rice yield reduction due to breakage that occurs during milling. Minimizing fissuring is thus an important goal of the rice industry. The objective of this study was to determine the percentage points (pp) of moisture content reduction that can be achieved in a drying pass without adversely causing fissuring. Rough rice of cultivars CL XL745 and Diamond at initial moisture contents of 19%, 18%, 17%, 16%, 15%, and 14% were dried using air at 45°C/20% RH, 50°C/15% RH, 55°C/12% RH, 60°C/10% RH, and 65°C/8% RH to moisture contents of 18%, 17%, 16%, 15%, 14%, 13%, and/or 12% with and without post-drying tempering. The resulting samples achieved between 1 and 7 pp of moisture content reduction in a single pass. The pp of moisture content reduction that can be achieved in a single drying pass without causing adverse fissuring varied across the cultivars tested. Generally, 1-2 pp of moisture content reduction was achieved in a single pass drying for CL XL745 and 1-3 pp for Diamond without causing adverse fissuring when samples were not tempered after drying. However, with sufficient tempering, 3-5 pp of moisture content reduction was achieved in a single drying pass for CL XL745 and 4-6 pp for Diamond without causing adverse fissuring. These findings provide information on how much moisture can be removed in each drying pass and may be applied to different types of driers to reduce fissuring hence minimizing head rice yield reductions due to fissuring.

The Effect of Water Saving Practices on Rice Grain Quality in South Eastern Australia

Wood, R.M., Dunn, B.W., Waters, D.L.E., Blanchard, C.L., Mawson, A.J., and Oli, P.

Drought and competition from the environment and other crops have seen a reduction in the availability of water for irrigated rice production in south eastern Australia. The need to maintain rice yields with less water has led to the development of water saving techniques suitable for temperate environments referred to as delayed permanent water (DPW) and delayed permanent water with a post flower flush (DPW+PFF). DPW improves nitrogen and water use efficiency of without a substantial reduction in grain yield. Although yield is important in rice production, Australia remains globally competitive by producing high quality grain for premium markets yet the impact of DPW and DPW+PFF on grain quality of rice grown in south eastern Australia is poorly understood. We compared the effect of DPW and DPW+PFF with conventional irrigation practices on grain development and grain quality parameters of four commercial Australian rice varieties (medium-grain varieties; Sherpa and Reiziq; long-grain; Topaz and Langi). We demonstrated growing rice with water saving techniques significantly affects grain quality. Under adequate N, head rice yield (HRY; the proportion of unbroken grain expressed as a percentage of harvested grain), was higher in water stressed plants compared to plants grown with conventional drill and aerial sowed irrigation methods. Water stress during the vegetative stage (DPW and DPW+PFF) reduces grain filling duration while prolonging the grain ripening phase due to a slower infield grain drying. Furthermore, water stress during the vegetative stage altered the grain protein composition, which significantly affected the cooking qualities of rice. These results are important for Australian and global rice producers who need to reduce their water inputs due to drought and receive financial penalties for poor quality grain. Our study is the first to provide a multi-year analysis of the effect of delayed permanent water and delayed permanent water with post flower flushing on grain quality.

Differentiating Sub-Population, Production Environment and Grain Chalk by Hyperspectral Imaging

Barnaby, J.Y., Huggins, T.D., Lee, H.S., McClung, A.M., Pinson, S.R.M., Oh, M.R.,
Bauchan, G.R., Tarpley, L., Lee, K.J., Kim, M.S., and Edwards, J.D.

Rice grain quality influences crop value and is important to growers, millers, and processors as well as consumers. Grain quality in rice is determined by multiple factors including starch composition, cooking quality, and grain size, shape, and translucency (chalky appearance). High grain chalk causes grain breakage during milling and loss of crop value impacting domestic and export markets. Molecular markers are sought as tools for marker-assisted selection (MAS) in rice breeding for traits like grain quality that are complex, difficult to phenotype and are influenced by the environment. Furthermore, Genome-Wide Association mapping Studies (GWAS) have been used in rice to map a wide range of traits. One of the bottlenecks, however, in mapping of genes for grain quality traits is the intensive labor, time, and expense required to phenotype the diversity of physicochemical traits impacting rice quality. High throughput Vis/NIR spectroscopy phenotyping is a rapid analytical tool that assesses samples by utilizing visible and invisible regions of the spectrum.

The aim of this study was to determine if Vis/NIR hyperspectral imaging of whole grain rice can discern differences in rice sub-population structure and production environment, as well as grain quality traits. Whole grain (brown) rice samples from the USDA mini-core collection grown in multiple locations were evaluated using hyperspectral imaging and compared with results from standard grain quality phenotyping. Loci associated with hyperspectral values were mapped in the mini-core with 3.2 million SNPs in a genome-wide association study (GWAS). Our results show that visible and near infra-red (Vis/NIR) spectroscopy can classify rice according to sub-population and production environment based on differences in physicochemical properties. The 702-900 nm range of the NIR spectrum was associated with the undesirable chalky grain trait. GWAS revealed that grain chalk and hyperspectral variation share genomic regions containing several plausible candidate genes for grain chalkiness. Hyperspectral quantification of grain chalk was validated using a segregating bi-parental mapping population. These results indicate that Vis/NIR can be used for non-destructive high throughput phenotyping of grain chalk and, potentially, other grain quality properties.

Sensory Evaluation of Non-Mutant Rice Varieties High in Apparent Amylose and Resistant Starch

Chen, M.-H., Bett-Garber, K., Lea, J., McClung, A.M., and Linscombe, S.D.

Resistant starch (RS) is a type of dietary fiber that resists digestion in the small intestine and passes to the colon to be fermented by microbiota. Its consumption is reported to improve gut health and insulin resistance while decreasing cardiovascular disease risk factors and the risk of colon cancer. Rice varieties higher in resistant starch are known to have lower glycemic index. Previously, we identified non-mutant high-RS/high-amylose rice varieties from two diverse sets of germplasm collections. However, because amylose content is known to influence cooked rice texture, the impact of the higher RS content on sensory attributes needs to be understood. Eight high-RS rice varieties, five having high-amylose-weak paste viscosity (HAWP) and three having high-amylose-strong paste viscosity (HASP), along with U.S. varieties of L202 (HAWP), Dixiebelle (HASP), Wells (intermediate-amylose), and Hidalgo (low-amylose), were selected for the study. All varieties were grown in field studies conducted in Arkansas and Louisiana. Apparent amylose content, protein and paste viscosity were determined. Fourteen cooked rice texture attributes which were divided into four chewing phases were evaluated by a human sensory panel.

Resistant starch, the average of the two growing locations, of these eight high RS rice varieties ranged from 3.6-4.4%, and were 24-55%, 86-131% and 19 to 24 times greater than those of the high-amylose varieties (L202 and Dixiebelle), Wells, and Hidalgo, respectively. Across all high amylose rice varieties, RS correlated with apparent amylose content ($r = 0.8$). When only the intermediate gel temperature types were included, RS was correlated with pasting temperature ($r = - 0.83$).

Cooked rice texture is known to differ based upon paste viscosity curves as measured by RVA, thus, the comparison of texture attributes of cooked rice was carried out within each of the HAWP and HASP classes separately along with the high-amylose U.S. varieties (L202 and Dixiebelle), as well as, with the intermediate amylose variety, Wells. The texture attributes of most of the high-RS HAWP were not significantly different from those of L202 but were significantly different from Wells for four of the five attributes in phase I (evaluated with tongue without chewing)– initial starch coating, slickness, roughness and stickiness to lips; one of the three attributes in phase II (evaluated at first bite) – cohesiveness; one of the three attributes in phase III (evaluated during chewing) – uniformity of bite, and none of the three attributes in phase IV (evaluated after chewing or swallowing). The texture attributes of most of the high-RS HASP were not significantly different from those of Dixiebelle but were significantly different from those of Wells for five of the five attributes in phase I – initial starch coating, slickness, roughness, stickiness to lips, and stickiness between grains; one of the three attributes in phase II – cohesiveness; two of the three attributes in phase III (2 of 3) – cohesiveness of mass and uniformity of bite; and one of the three attributes in phase IV (1 of 3) – intactness of masticated particles. In conclusion, regarding the range in RS observed in these germplasm lines, higher RS content does not result in changes in cooked rice texture as compared with US varieties that have the same amylose/paste viscosity types, but they do hold promise to increase the nutritional and health beneficial value of rice.

Consistency of Rice Milling Quality: Results from USDA-FGIS Laboratory Mill and Commercial Mills

Khir, R., Ning, Z., Brenner, C.A., McHugh, T., and Pan, Z.

The objective of this study was to assess whether the official USDA laboratory mill and procedures provide consistent results to those obtained from commercial mills. To conduct this study, samples of rough and milled rice were collected quarterly according to a sampling protocol from four different commercial mills in California, Arkansas, and Louisiana. They included long grain (pure and hybrid), medium grain (unmixed and mixed), short grain (unmixed and mixed). The samples were milled, inspected and graded according to the FGIS standard procedures in an official and licensed laboratory in Sacramento, CA. The milling results of the rice from the same lots at commercial mills were also collected. The temperature and relative humidity of milling environment in the laboratory and commercial mills were recorded. Additionally, the moisture contents (MCs) of rough and milled rice were measured using Dickey-John GAC 2100 (DKJ) and standard oven method. The results showed that the laboratory mill had significantly ($P<0.05$) higher total rice yields (TRYs) and head rice yields (HRYs), but lower whiteness index (WI) than commercial mills. The overall average TRYs and HRYs were 70.1±2.3% and 68.5±3.2%, and 59.0±6.7% and 56.4±6.0% for the laboratory and commercial milled rice, respectively. The overall average WIs were 40.3±2.7 and 44.7±3.4 units for the laboratory and commercial milled rice, respectively. The MCs of rough and milled rice measured using the standard oven method were significantly lower than those measured in the laboratory mill and commercial mills

(P<0.05). There was a difference among dockage values for rice collected from different commercial mills. Although the temperatures and relative humidity at the commercial rice mills varied and were higher than those of the laboratory mill, resulting in high rough rice temperatures before entering the mills, but the temperatures of milled rice from the laboratory mill were much higher. No clear relationships were identified among the temperatures, relative humidity and milling quality results. The grades of the commercial milled rice were aligned well with those of the laboratory milled rice.

Real-time Monitoring and Early Detection of Insect Activity in Storage Rice using Imaging Technique

Khir, R. and Pan, Z.

The elimination of insect contamination in rice is an important need in the industry. Early insect-detection is considered as an effective technique to determine the optimal pest management practice to eliminate the infestation risk and maintain storage longevity, quality, grade and safety of rice. The objective of this research was to develop and upgrade a real-time monitoring and early detecting system for insect activity in stored rice using an imaging technique. The system consisted of the traps, a server, and a user interface. The system was equipped with a micro-breadboard that was installed in each trap cap. The sensors to measure temperature and relative humidity and independent power source by using batteries were added to each trap. The user sends a command to the server, then the server receives the commend and holds it, and further sends it to the trap to take an image of the collecting chamber. User can control how many photos should be taken by setting the time. The taken images are sent back to the server. In the server, images are saved, cropped and processed with an accounting algorithm to count the insects captured per trap and store the numerical data over time. The data related to the numbers of insect, temperature and relative humidity are sent back to the user interface. The user interface was designed to allow the user to easily visualize the data. The new system was evaluated through experiments conducted in a laboratory and a commercial rice storage facility. The obtained results from lab and commercial storage tests were consistent and revealed that the new system had high effectiveness and accuracy for monitoring and early detection of the insect activity in stored rice. It took only less than 20 minutes to detect the insect activity during the laboratory and commercial storage tests with an accounting accuracy more than 90%. Moreover, the system could accurately record the temperature and relative humidity in the rice mass. It was concluded that the new system could be used to early detect insect activity in stored rice with a high accuracy, reliability and low cost and labor.

Effect of Plant Density on Grain Quality Parameters of Short- and Medium-Grain Rice Varieties

Wood, R.M., Dunn, B.W., Waters, D.L.E., Blanchard, C.L., Mawson, A.J., and Oli, P.

It is well established that crop yield is not significantly affected by sowing rate due to the compensatory growth behaviour of rice. However, few studies have investigated the effects of sowing rate on grain quality parameters. Studies that have reported on the impact on grain quality have assessed plant densities too low for comparisons with large scale systems yielding 10 tonne ha^{-1} or more. Furthermore, the varieties evaluated were of the one grain type, long grain, only. We investigated the effect of sowing rate and nitrogen (N) fertilizer management, and their interaction, on the quality traits of a short- and medium-grain rice variety over two seasons. Sowing and N rate significantly affected the plant parameters of both varieties, however, changes in these parameters did not affect crop yield. The changes in plant architecture as a result of different density significantly affected grain weight and milling quality and the response differed between varieties. Decreasing sowing rate increased the number of grains per panicle, reduced grain dimensions (length, width, and thickness), the thousand-grain weight (TGW), and slightly increased milling quality in the medium-grain variety Viand. In the short-grain variety YRK5, decreased sowing rate increased TGW and reduced milling quality in the second season. There was a negative correlation between protein content and TGW but a positive relationship between protein content and head rice yield (HRY; the proportion of unbroken grain expressed as a percentage of harvested grain) in both varieties. We observed no consistent differences in the physicochemical and cooking parameters between densities over both seasons in both varieties. Moreover, the physicochemical and cooking parameters were more significantly affected by N rate than sowing rate. These results indicate plant density has an indirect effect on milling quality and the response differs between varieties. Our study is the first to analyze the grain quality parameters of short- and medium-grain rice varieties under varying sowing rates found in large-scale systems yielding above 10 tonne ha^{-1}.

Prediction of Grain Appearance Traits as Assessed by the USA Rice Industry Using High Throughput Imaging Systems

McClung, A.M., Chen, M-H., Jodari, F., Famoso, A.N., Addison, C.K., Linscombe, S.D., Ottis, B.V., Moldenhauer, K.A.K., Walker, T.W., Wilson, L.T., and McKenzie, K.S.

Grain appearance traits are important in determining the economic value of milled rice to the end user. Rice milling companies evaluate grain appearance traits for bran streaks, chalkiness, kernel color (whiteness), uniformity of grain length, and overall grain appearance to meet the specifications of their customers. This is generally a subjective assessment made by experienced industry evaluators. In some cases, an end user may request an independent determination made by federal grain inspection (FGIS) staff using their established protocols and criteria. Breeders strive to develop new rice varieties that have high grain quality that will result in greater economic value for the rice industry. However, because of the large number of genotypes that breeders evaluate each year, they prefer to use high throughput objective methods for grain quality assessment. Thus, to assure that new varieties developed by breeders meet the grain appearance standards expected by the industry, it is important to understand how the subjective methods used by grain inspection staff relate to objective methods used by rice breeding programs.

During 2012, 19 southern U.S. long-grain varieties including the inbreds Antonio, Bowman, Cheniere, CL111, CL142-AR, CL151, CL152, CL162, Cocodrie, Colorado, Francis, Presidio, Rex, Roy J, Taggart and Wells, along with three hybrids, XL723, XL729 and XL745 (RiceTec, Inc., Alvin, TX) were grown in an unreplicated trial at five locations in the southern U.S. For all but one location, the varieties were also planted at an optimum and a late planting date (delayed by a month). Similarly, one California variety, L206, was grown in CA using two planting dates. Cultural management practices were according to local recommendations and plots were harvested at approximately 18% moisture and dried to 12% moisture. Rough rice was milled at one location and NIR was used to verify the degree of milling was the same among the samples. In addition, imported milled samples from Thailand and Uruguay were

included for comparison. The milled samples were randomized and identities coded and then were sent for visual inspection (VI) to ten rice milling (ML) companies, two FGIS offices (% chalk), and one rice export (RE) company (% chalk) and to three breeding programs for analysis using different digital imaging systems (IS) including WinSEEDLE (WS), SeedCount Image Analyser (SC), and S21 Rice Statistical Analyser (S21). The objective was to compare grain chalkiness as determined by VI and IS and to identify objective criteria that are associated with the five grain appearance traits commonly determined by the rice industry (using a 1 poor - 5 good scale). Using the three IS, the mean % chalk using WS (3.4) was similar to SC (6.7) but much lower than S21 (32.2). Of the IS methods, WS and SC % chalk had higher correlations with ML chalk (r= -0.52 and -0.66, respectively) as compared with S21 (r= -0.33). Rankings were similar among the varieties for chalkiness regardless of the assessment method used. Although there was a lot of overlap in values for each of the varieties, Presidio was consistently rated as having the lowest chalk while XL 729 and CL151 were the chalkiest among those grown in the southern U.S. Using the five VI traits, the mills ranked the imported sample from Thailand as the best (VI traits ranged 4.7 – 5.0), followed by L206 grown in CA (4.2 – 4.8), and Presidio, grown in the south (4.0 - 4.6). Multiple linear regression analysis was performed using all of the parameters measured using each of the IS to determine which of objective measurements were the best predictors of each of the five visual traits assessed by the mills. The total model variation explained for each of the VI traits ranged 62 – 70% using SC parameters, 34-63% for S21 traits, and 32 – 50% using the WS method. The SC method determined more parameters than the other IS methods, which may explain the better model prediction. In addition, regardless of the IS used, the first parameter entered into the model explained over 37% of the model variation for each of the five ML traits. In exception to this was using the SC to predict uniformity of length, S21 to predict chalkiness, and WS to predict uniformity of length where the first parameter entered into the model accounted for 27%, 17%, and 17% of the total variation, respectively. The regression analysis also revealed that regardless of the ML trait (bran streaks, chalkiness, kernel color, uniformity of grain length, overall grain appearance), these were largely explained by IS parameters associated with chalkiness and discoloration, and to a lesser extent broken kernels. These results demonstrate the importance of chalkiness and color in grading U.S. long-grain cultivars by the rice industry. In addition, the SC imaging system, in particular, offers an efficient and effective way of measuring grain appearance traits in milled rice. Although imported rice from Thailand had an average rank by the mills that was consistently better than U.S. cultivars, the varieties Presidio, adapted to the south, and L206, adapted to CA, also have very desirable grain appearance traits and may be sources of interest for future breeding efforts.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2022 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 39th RTWG meeting must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the proceedings.

1. An electronic file is required and should be submitted to the respective panel chairs 2 ½ months prior to the 39th RTWG meeting in 2022, or earlier as stated in the Call for Papers issued by the 39th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2022 RTWG meeting and their email and mailing addresses are presented following this section. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Michael Salassi
   Dept. of Agricultural Economics and Agribusiness
   LSU AgCenter
   104 Efferson Hall
   Baton Rouge, LA 70803
   Phone: (225) 578-2391
   Fax: (225) 578-2716
   Email: msalassi@agcenter.lsu.edu

2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
    a. Include a statement of rationale for the study.
    b. Briefly outline methods used.
    c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 39th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 39th 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 39th RTWG meeting and submitted to Michael E. Salassi, RTWG Publication Coordinator, to accommodate preliminary preparation of the proceedings prior to the meeting. These materials will be merged in the final proceedings in the format submitted. Final editing will be done by the Publication Coordinator, Rice Research Station secretarial staff, and the incoming Chair.

In addition, panel chairs are to prepare and submit both a paper copy and MS Word computer file version of the (1) final Panel Recommendations and (2) a list of panel participants by the conclusion of the meeting. A copy of the previous recommendations and panel participants will be provided to each panel chair prior to the meetings.

ADDRESSES FOR 2022 PANEL CHAIRS

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IN MEMORY OF

Shu-Ten Tseng

Dr. Shu-Ten Tseng passed away on July 4, 2019. Dr. Teng was a rice breeder at the California Rice Experiment Station. His contributions to both the California and U.S. Rice Industry were monumental.

- He introduced the computer (an Apple IIe) as a tool for breeding management to the Rice Experiment Station, personally writing the software for field books and statistical analysis of yield experiments.

- He developed the first commercially successful long-grain varieties for California.

- His release of L-202 has contributed as a parent to the development of several successful long-grain varieties released by LSU.

- His work on cooking quality not only led to the development of long grains for California but provided a model for cooking quality evaluation for the medium- and short-grain programs.

- He was the recipient of the 1st U.S. Rice Technical Working Group Team Award for California Rice Varietal Development given in 1984 for increasing California average rice yield from 5,000 to 8,000+ lbs./acre.

- He was the 1998 California Rice Industry Award Winner.

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	B. Wells	S.D. Linscombe	
	S.-T. Tseng			
			Advances in Rice Nutrition Team	
2000	D.M. Brandon	R.K. Webster	P.K. Bollich	C.E. Wilson
Biloxi, MS	J.W. Stansel		R.J. Norman	
			Bacterial Panicle Blight Discovery Team	
2002	F.L. Baldwin	M.A. Marchetti	M.C. Rush	D.E. Groth
Little Rock, AR	R.H. Dilday	J.F. Robinson		A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
	P.K. Bollich	J.A. Musick	F.N. Lee	M.A. Marchetti
2004	A.D. Klosterboer	J.E. Street	A.K. Moldenhauer	
New Orleans, LA	F.N. Lee	J.F. Williams	Individual	
	W.H. Brown	S.L. Wright	R.D. Cartwright	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			LSU Rice Variety Development Team	
			S. Linscombe	X. Sha
2006	T.P. Croughan	J.N. Rutger	P. Bollich	R. Dunand
The Woodlands, TX	R. Talbert	F. Turner	L. White	D. Groth
			Individual	
			R. Norman	
			Bakanae Team	
			J. Oster	R. Webster
2008	M.C. Rush	R. Dunand	C. Greer	
San Diego, CA	C. Johnson			
			Individual	
			D. Groth	
2010	T. Miller	J. Thompson	Individual	
Biloxi, MS	J. Kendall		E. Webster	
			Advances in Nitrogen Use Efficiency Team	
2012	E. Champagne	G. McCauley	D. Harrell	N. Slaton
Hot Springs, AR	J. Hill		G. McCauley	B. Tubaña
			R. Norman	T. Walker
			T. Roberts	C. Wilson
			J. Ross	
			Individual	
			A. McClung	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Rice Entomology Team	
			J. Bernhardt	M. Stout
2014	R. Fjellstrom	J. Oster	G. Lorenz	J. Gore
New Orleans, 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	

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

- 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

2020

I. Purpose and Organization

The Rice Technical Working Group (RTWG) functions according to an informal memorandum of agreement among the State Agricultural Experiment Stations and the Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, and the Agricultural Research Service (ARS), the Economic Research Service (ERS), the Cooperative State Research, Education, and Extension Service (CSREES), and other agencies of the United States Department of Agriculture (USDA). Membership is composed of personnel in these and other cooperating public agencies and participating industry groups who are actively engaged in rice research and extension. Since 1960, research scientists and administrators from the U.S. rice industry and from international agencies have participated in the biennial meetings.

The RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by the States, Federal Government, and other members. The current disciplines or Panels represented are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization & Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Each Panel has a Chair who, along with the Secretary/Program Chair, solicits and receives titles, interpretive summaries, and abstracts of papers to be presented at the biennial meeting. The papers are presented orally in concurrent technical sessions or via poster. Each Panel over the course of the meeting develops proposals for future work, which are suggested to the participating members for implementation.

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

Other members of the Executive Committee are elected biennially by the membership of the RTWG; they include the Chair who has served the previous term as Secretary/Program Chair, a Geographical Representative from each of the seven major rice-growing states (Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas), the Immediate Past Chair, and an Industry Representative. The rice industry participants elect an Executive Committee member from one of following areas: i) chemical, ii) seed, iii) milling, iv) brewing industries, v) producers, or vi) consultants. The Publication Coordinator also is on the Executive Committee. The Coordinator of the RTWG website is an ex-officio member of the Executive Committee.

Standing committees include: i) Nominations, ii) Rice Crop Germplasm, iii) Rice Variety Acreage, iv) Awards, and v) Location and Time.

II. Revised Memorandum of Agreement

The previous Memorandum of Agreement is published in the 33rd RTWG Proceedings in 2010. The following is a revised Memorandum of Agreement accepted by the 34th RTWG membership in 2012.

REVISED MEMORANDUM OF AGREEMENT

FEBRUARY 2012

INFORMAL UNDERSTANDING

among

THE STATE AGRICULTURAL EXPERIMENT STATIONS

and

THE STATE AGRICULTURAL EXTENSION SERVICES

of

ARKANSAS, CALIFORNIA, FLORIDA, LOUISIANA, MISSISSIPPI, MISSOURI, AND TEXAS

and

THE AGRICULTURAL RESEARCH SERVICE,
THE ECONOMIC RESEARCH SERVICE,
THE COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

and

OTHER PARTICIPATING AGENCIES

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

and

COOPERATING RICE INDUSTRY AGENCIES

Subject: Research and extension pertaining to the production, utilization, and marketing of rice and authorization of a Rice Technical Working Group.

It is the purpose of this memorandum of agreement to provide a continuing means for the exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by State Agricultural Experiment Stations, State Agricultural Extension Services, the United States Department of Agriculture, and participating rice industry groups. It is believed this purpose can best be achieved through a conference held at least biennially at the worker level of those currently engaged in rice research and extension. Details of the cooperation in the seven states are provided in formal Memoranda of Understanding and/or appropriate Supplements executed for the respective state.

The agencies represented in this memorandum mutually agree that overall suggestions of cooperative review and planning of rice research and extension in the several rice producing states and the United States Department of Agriculture shall be developed by a Rice Technical Working Group (henceforth designated RTWG), composed of all personnel actively engaged in rice investigations and extension in each of the agencies, as well as participating rice industry groups.

It is further agreed that there shall be a minimum of three Administrative Advisors to the RTWG to represent the major agencies involved, including:

1) A director of an Agricultural Experiment Station from a major rice-growing state elected by the Station Directors of the rice-growing states,

2) A director of a State Cooperative Extension Service from a major rice-growing state elected by the Extension Directors of the rice-growing states, and

3) A USDA Administrative Advisor from ARS named by the Administrator of Agricultural Research Service.

The RTWG shall convene at least biennially to review results and to develop proposals and suggested plans for future work. It is understood that the actual activities in research and extension will be determined by the respective administrative authorities and subject to legal and fund authorizations of the respective agencies.

Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (chair and secretary), subject to consultation with the remainder of the Executive Committee.

The Executive Committee shall consist of 15 members:

Officers (2):

Chair -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

Secretary/Program Chair -- (normally moves up to Chair).

Geographic Representatives (7):

One active rice worker in state or federal agencies from each of the major rice states -- Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas.

These Geographic Representatives will be responsible for keeping all governmental rice workers and administrators in their respective geographic areas informed of the activities of the RTWG.

Immediate Past Chair -- provides guidance to incoming chair to facilitate a smooth transition between biennial meetings.

Administrative Advisor (one from each category) (3):

State Agricultural Experiment Station
State Agricultural Extension Service
USDA - Agricultural Research Service

Publication Coordinator -- serves to handle matters related to the publication of the RTWG Proceedings.

Industry Representative -- to be elected by industry personnel participating in the biennial meeting of the RTWG; represents all aspects of the U.S. rice industry and serves as liaison with other rice industry personnel; and is responsible for keeping all interested rice industry personnel informed of the activities of the RTWG.

The Officers, Geographic Representatives, and the Publication Coordinator of the Executive Committee shall be elected on the first day of each biennial meeting to serve through the close of the next regular biennial meeting.

A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the active subject matter panels. Such election shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the panel program in close cooperation with the Secretary-Program Chair and for seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective panel sessions.

Participation in the panel discussions, including presentation of rice research findings by rice industry representatives and by representatives from National or International Institutes, is encouraged.

At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund,' established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

This type of memorandum among the interested state and federal agencies provides for voluntary cooperation of the seven interested states and agencies.

III. Description of Committees, Positions, Duties, and Operating Procedures

A. Executive Committee

The Executive Committee conducts the business of the RTWG, appoints standing committees, organizes and conducts the biennial meetings and presents the awards. Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (Chair and Secretary), subject to consultation with the remainder of the Executive Committee. A quorum (i.e., eight members, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. A simple majority vote is needed to pass any motion and the Chair only votes in the case of a tie. The Executive Committee is composed of the following 15 members: i) three officers—Chair, Secretary/Program Chair, and Immediate Past Chair; ii) seven Geographical Representatives from each major rice producing state; iii) three administrative advisors from the major agencies of Agriculture Experiment Stations, State Agricultural Extension Services, and the USDA; iv) a Publication Coordinator; and v) a Rice Industry Representative. The Officers, Geographical Representatives, and the Publication Coordinator shall be elected to the Executive Committee at the Opening Business meeting of each biennial meeting to serve through the close of the next regular biennial meeting. Industry personnel participating in the biennial meeting elect the Industry Representative.

1. **Chair**
   The Chair provides leadership to the RTWG by organizing the agenda and presiding over the Business and Executive Committee meetings, presiding over the Awards process, appointing temporary or ad hoc committees to explore and address RTWG interests, and being the official spokesperson for the RTWG during his/her period of office. If the nomination process for selecting geographical representatives and members of the Nominations committee fails to produce a candidate, then it the responsibility of the Chair to work with the state delegation in selecting a candidate from that state. The Secretary/Program Chair is usually nominated by the Nomination Committee to be Chair at the next biennial meeting. If the Chair nominated cannot serve or complete the full term of office, it is the responsibility of the Executive Committee to appoint a new Chair.

2. **Secretary/Program Chair**
   The Secretary/Program Chair serves a two-year term and is responsible for organizing, conducting and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair appoints a Local Arrangements Committee and Chair from their home state to help with organizing and conducting the biennial meeting. The Secretary/Program Chair is responsible for the minutes of all Business and Executive Committee meetings, the publishing of the minutes of these and other committees (i.e., Rice Crop Germplasm, Rice Variety Acreage, and Nominations) at the RTWG in the Proceedings and ensuring the Panel Chairs correctly publish their minutes and abstracts in the Proceedings. The Secretary/Program Chair is responsible setting up the RTWG website. The Secretary/Program Chair is responsible for the resolutions pertaining to the biennial meeting and for the Necrology Report when appropriate. The Secretary/Program Chair authors the Resolutions section of the RTWG Proceedings that expresses appreciation to individuals and organizations that contributed to making the biennial RTWG meeting a success. The Secretary/Program Chair is a member of the Executive Committee and usually resides in the state the biennial meeting is conducted. The Secretary is usually chosen by active rice workers from the meeting host state and the candidate identified to the Nominations Committee for election. If the Secretary/Program Chair nominated cannot serve or complete the full term of office, it is the responsibility of the member on the Nominations Committee of the hosting state to appoint a new Secretary/Program Chair.

3. **Immediate Past Chair**
   Provides guidance to the incoming Chair to facilitate a smooth transition and lend continuity between biennial meetings. The Immediate Past Chair assists the Publication Coordinator in editing the nontechnical sections of the proceedings and revises the MOP as required. The Chair is nominated by the Nominations Committee to be the Immediate Past Chair at the next biennial meeting. The Immediate Past Chair will incorporate the changes approved by the Executive Committee in the MOP.

4. **Geographical Representatives**
   There are currently seven geographical representatives representing each of the major rice producing states, Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, on the Executive Committee. Each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to serve a two-year term on the Executive Committee. If the Geographical Representative nominated cannot serve or complete the full term of office, it is the responsibility of the delegate on the Nominations Committee from that state to appoint a new Geographical Representative.

5. **Administrative Advisors**
   The Administrative Advisors provide advice and lend continuity to the Executive Committee. A minimum of three Administrative Advisors will be appointed to the RTWG to represent the major agencies involved. They shall consist of: i) a Director of an Agriculture Experiment Station from a rice-growing state elected by the Station Directors of the rice-growing states; ii) a Director of a State Cooperative Extension Service from a rice-growing state elected by the Extension Directors of the rice-growing states; and a USDA Administrative Advisor from the ARS named by the Administrator of the Agricultural Research Service. No term limit is established.

6. **Publication Coordinator(s)**
The Publication Coordinator is responsible for assembling, editing, and publishing of the RTWG Proceedings from the biennial meeting. The Coordinator is assisted in the editing the nontechnical session portions of the proceedings by the Immediate Past Chair. The Coordinator serves on the Executive Committee to handle all matters related to the publication of the RTWG Proceedings. Currently, one publication coordinator serves this position. This is a voluntary position requiring the approval of the RTWG Executive Committee to serve. No term limit is established.

7. **Industry Representative**
The Industry Representative represents all aspects of the U.S. rice industry to the Executive Committee and serves as liaison with other rice industry personnel. Responsibilities include keeping all interested rice industry personnel informed of the activities of the RTWG. Industry personnel participating in the biennial meeting elect the Industry Representative. If the Industry Representative nominated cannot serve or complete the full term of office, it is the responsibility of the Industry members of the RTWG to appoint a replacement.

B. Standing Committees
The Executive Committee has appointed the following Standing Committees.

1. **Nominations Committee**
The purpose of the Nominations Committee is to nominate the Secretary/Program Chair, Chair, Immediate Past Chair, and Geographical Representatives to the Executive Committee, and the members or delegates to the Nominations Committee. The Nominations Committee is composed of eight members. Seven of the members represent each of the seven major rice-producing states and one delegate is from the U.S. Rice Industry. As with the Executive Committee, each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to be their delegate on the Nominations Committee and the Rice Industry is responsible for designating who their delegate is on the committee. The Chair of the Nominations Committee is from the next state to hold the RTWG biennial meeting. If a delegate on the Nominations Committee cannot serve or complete the term of office, it is the responsibility of the Geographical Representative from that state to appoint a replacement. Each delegate is responsible for polling the active rice workers in their state or industry to determine who their Geographical Representative is on the Executive Committee and who their delegate is on the Nominations Committee. The Chair of the Nominations Committee is responsible for obtaining the results from each delegate on the Nominations Committee, compiling the results, and reporting the results to the RTWG at the Opening Business meeting for a vote. When a state is next in line to host a biennial meeting, it is the responsibility of the delegate from that state to nominate the Secretary/Program Chair. Since the Secretary/Program Chair moves up to RTWG Chair and the RTWG Chair to Past Chair, it is the responsibility of the Chair of the Nominations Committee to nominate them to the RTWG members.

2. **Rice Crop Germplasm Committee**
The Rice Crop Germplasm Committee functions not only as an RTWG committee but also as the Rice Crop Germplasm Committee for the National Plant Germplasm System. In this capacity, it is part of a specific national working group of specialists providing analysis, data and recommendations on genetic resources for rice and often-related crops of present or future economic importance. This committee represents the user community, and membership consists of representation from federal, state, and private sectors; representation from various scientific disciplines; and geographical representation for rice. There are also ex-officio members on the committee from the National Plant Germplasm System. The Rice Crop Germplasm Committee, along with the other Crop Germplasm Committees, is concerned with critical issues facing the NPGS including: i) identifying gaps in U.S. collections and developing proposals to fill these gaps through exchange and collaborative collecting trips; ii) assisting the crop curators in identifying duplications in the collections, and in evaluating the potential benefits and problems associated with the development and use of core subsets; iii) prioritizing traits for evaluation and developing proposals to implement these evaluations; iv) assisting crop curators and GRIN personnel in correcting passport data and ensuring that standardized, accurate, and useful information is entered into the GRIN database; v) assisting in germplasm regeneration and

in identifying closed out programs and other germplasm collections in danger of being lost and developing plans to rescue the important material in these programs; vi) working with quarantine officials to identify and ensure new techniques for pathogen identification that will assist in the expeditious release of plant germplasm; and vii) maintaining reports on the status of rice for Congress, ARS National Program Staff and Administrators, State administrators, and other key individuals involved with the NPGS. The Committee members serve six-year terms. They rotate off of the Committee in two-year intervals. The Rice Crop Germplasm Committee Chair appoints a committee who nominates a slate of members. This committee maintains the diversity of the membership. Nominations also are requested from the floor and elections take place among the voting members to fill the six-year terms of office. A Chair is then elected from the voting membership for a two-year term. The Chair can only be elected to two consecutive terms of office unless completing the term of a previous Chair.

3. **Rice Variety Acreage Committee**
The purpose of the Rice Variety Acreage Committee is to collect and summarize data on varieties by acreage for each state and publish the summary in the RTWG Proceedings. The Committee consists of the rice specialists from each of the seven major rice-producing states and one other representative, usually a breeder or a director of an experiment station. No more than two members can represent any one state. The Chair of the Rice Variety Acreage Committee solicits information from each of the states then compiles it for the Committee report published in the RTWG Proceedings. Members of the Rice Variety Acreage Committee solicit their own members, first based on state and then on knowledge and interest expressed by active members of the RTWG to be part of the Rice Variety Acreage Committee. The Chair of the Rice Variety Acreage Committee is elected by the members of the Committee and may serve more than one term. No term limits have been established for members of the Rice Variety Acreage Committee. English units of measure should be used for the acreage tables for continuity.

4. **Awards Committee**
The Awards Committee is composed of the Executive Committee. See section IV. C., ‘Guidelines for RTWG Awards’ for details regarding responsibilities and duties of the Awards Committee.

5. **Location and Time Committee**
The Location and Time Committee is made up of three individuals, two from the state next to hold the biennial meeting and one from the state following the next host state. This Committee explores when and where the next biennial RTWG meeting will be held. The incoming Chair appoints the Location and Time Committee members.

C. Website Coordinator

A third-party website host and developer will be used to maintain a permanent RTWG website. A permanent (100 years from 2010) address (www.rtwg.net) has been purchased through www.networksolutions.com. The Chair and Secretary Program Chair are to meet and transfer responsibilities no later than one year after the preceeding meetings to ensure a smooth transition from one host state to the next.

D. Revisions to the Manual of Operating Procedures

The Executive Committee with a majority vote has approved this ‘Manual of Operating Procedures’ for use by the Rice Technical Working Group. This ‘Manual of Operating Procedures’ is a working document that should be amended or modified to meet the needs of the Rice Technical Working Group. Amendments or modification to this ‘Manual of Operating Procedures’ can only be made by a quorum of the Executive Committee with the approval of the majority of the Executive Committee. The RTWG Chair can only vote in the case of a tie. The Immediate Past Chair will incorporate the approved changes in the MOP.

IV. Biennial Meeting Protocols

A. Biennial Meetings

The biennial meetings are hosted by the participating states in the following rotation: Arkansas, Louisiana, Texas, California, Missouri, and Mississippi. A state is allowed to host a biennial meeting if the state is deemed by the Executive Committee to have a sufficient number of rice scientists to properly conduct a biennial meeting. The Secretary/Program Chair is responsible for organizing, conducting, and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair is responsible for setting up the RTWG website. The Chair organizes the agenda and presides over the Business and Executive Committee meetings and the Awards process. Panel Chairs coordinate the oral and poster presentations in their discipline with the Secretary/Program Chair, editing of abstracts with the Publication Coordinator, updating of panel recommendations, and choosing their successor. Detailed information on the business meetings; detailed responsibilities of the Publication Coordinator, Panel Chairs, and the Local Arrangements Committee; timeline of preparation for the biennial meeting; instructions for preparation of abstracts; and guidelines for the RTWG awards are listed in this section.

1. Executive Committee Meetings

The agenda for the Executive Committee meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Executive Committee meetings. Following is a typical agenda.

a. Opening Executive Committee Meeting (held on day prior to start of meeting)

Old Business

i) The Chair opens the meeting
ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

New Business

The Necrology Report read by Chair.
The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.
The Chair leads a discussion of any New Business that has developed since the last RTWG meeting. Several months prior to the RTWG meeting the Chair should solicit any New Business items from the Executive Committee.

b. Closing Executive Committee Meeting (held on last day of meeting)

Old Business

i) The Chair opens meeting
ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. Opening General Session and Business Meetings

The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

a. Opening General Session and Opening Business Meeting (begins the RWTG meeting)

i) The Chair opens the meeting and thanks the host state delegation for preparing the program.

ii) The Secretary welcomes the RTWG membership to their state.

iii) The Chair opens the Business Meeting by asking the Secretary to read the minutes of the Closing Business meeting from the previous RTWG meeting and the Chair then entertains a motion for acceptance of the minutes.

iv) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.

v) The Chair reads the Necrology Report and asks for a few moments of silence.

vi) The Nominations Committee Chair reads the nominations for the Executive Committee and Nominations Committee to the RTWG membership. The RTWG Chair then entertains a motion to accept the nominations.

vii) The Chair calls on the Chair of the Location and Time Committee of the next biennial meeting to report when and where the next RTWG meeting will be held.

viii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.

ix) The Chair asks for a motion to adjourn the Opening Business Meeting.

x) The General Session usually ends with invited speaker(s).

b. Closing Business Meeting (ends the RTWG meeting)

i) The Chair opens the meeting and calls for Committee reports from Rice Crop Germplasm, Rice Variety Acreage, Rice Industry, and the Publication Coordinator.

ii) The Chair thanks the Publication Coordinator(s) for their efforts in coordinating, editing, and publishing the RTWG Proceedings.

iii) The Chair thanks the host state delegation for hosting the RTWG Meeting.

iv) The Chair then passes the Chair position to the Secretary/Program Chair. The incoming Chair thanks the Past Chair for service to the RTWG and presents the Past Chair with a plaque acknowledging their dedicated and valuable service to the RTWG as the Chair.

v) The incoming Secretary/Program Chair informs the membership of the time and place for the next RTWG meeting.

vi) The incoming Chair invites everyone to attend the next RTWG meeting and asks for a motion to adjourn the RTWG meeting.

3. Publication Coordinator(s)

The Publication Coordinator(s) are responsible for providing instructions for manuscript preparation, collecting abstracts from the Panel Chairs, assembling all pertinent information for inclusion in the Proceedings, final review, and publication of the Proceedings upon the conclusion of each RTWG meeting. The Publication Coordinator(s) solicit input from the Executive Committee, Panel Chairs, and the general membership for changes and/or adjustments to the RTWG Proceedings content, style, format, and timetable. It is, however, the Publication Coordinator(s) responsibility to make the final decision on changes appropriate to insure the Proceedings is a quality product and reflective of the goals and objectives of the organization. This flexibility is needed to insure that publication of this information through their respective institution is done in accordance with university or other agency requirements. The Publication Coordinator(s) are responsible for updating the guidelines for submitting abstracts as needed and including this information in the published Proceedings and also on the RTWG host website once the call for abstracts is made. The Publication Coordinator(s) are responsible for mailing proceedings in electronic and hardcopy format to the general membership and also placing the Proceedings on the internet.

4. **Panel Chairs**
A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the six disciplines or Panels. The current Panels are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Postharvest Quality, Utilization, and Nutrition; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Such elections shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the Panel program in close cooperation with the Secretary-Program Chair. Program development involves scheduling of oral and poster presentations, securing moderators to preside at each panel session, editing of abstracts, seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective Panel sessions, and election of a successor. Since the Secretary is from the RTWG host state, the Panel Chairs elected should also be from the host state if possible to facilitate close cooperation with the Secretary and other Panel Chairs. If an elected Panel Chair cannot serve or fulfill the duties, then it is the Secretary's responsibility to replace the Panel Chair with someone preferably from the same discipline.

   Each Panel Chair is responsible for collecting all of the Panel abstracts prior to the RTWG biennial meetings. The appropriate due date will be identified in the Call for Papers for the RTWG meeting. Each Panel Chair is responsible for assembling the Panel abstracts into one common MS Word file that is consistent with the above guidelines, with the abstracts appearing in the order presented. Paper abstracts will be presented first and poster abstracts second. A Table of Contents should be included with each panel section. Panel Chairs are responsible for editing all abstracts for their panel. A common file should be developed prior to the beginning of the RTWG meeting and submitted to the Publication Coordinator(s) to accommodate preliminary preparation of the Proceedings prior to the meeting. The Panel Chairs are strongly encouraged to edit the abstracts for content clarity and RTWG format to expedite publication of the Proceedings. These materials will be merged in the final Proceedings in the format submitted. Final editing will be performed by the Publication Coordinator(s), Rice Research Station secretarial staff, and the incoming Chair.

   In addition, Panel Chairs are to prepare and submit both a paper copy and MS Word computer file version of the (1) final Panel Recommendations and (2) a list of panel participants by the conclusion of the meeting. A copy of the previous recommendations and panel participants will be provided to each Panel Chair prior to the meeting.

   Panel Chairs are to organize the oral presentations in the concurrent Technical Sessions and the posters for the Poster Sessions with the Secretary/Program Chair.

5. **Local Arrangements**
The Local Arrangements Committee and the Chair of this Committee are typically appointed by the Secretary/Program Chair to help with meeting site selection and organizing and conducting the biennial meeting. Thus, they usually reside in the state the biennial meeting is conducted due to logistics. Typical responsibilities include: a survey of possible meeting sites and establishments; working with the hotels for rooms, meeting space, and food functions; securing visual aids; helping with spouse activities; solicitation of donations; and providing speakers and entertainment.

6. **Financing Biennial Meeting, Start-up Money, and the Contingency Fund**
   a. The biennial RTWG meetings are financed through registration fees and donations from industry and interested parties. The Executive Committee established a base amount of $6,000 that is to be transferred from one host state to the next as start-up money to begin preparations for the RTWG meeting prior to when donations or registration fees can be collected.

b. At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund', established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical Representative in the state where the next meeting is to be held will be designated by the RTWG Secretary to receive and deposit funds in station or foundation accounts.

c. The Contingency Fund was established as a safety net for states hosting the biennial meetings. It is to be used by the host state when the startup money transferred from the previous state to host the biennial meetings is insufficient or when a state goes into debt hosting the biennial meetings.

   i. If the previous host state is unable to provide any or all of the $6,000 in start-up money for the next host state to initiate meeting preparations, the current Chair should be informed of this situation as soon as possible (as the Chair will normally have served as Secretary of the previous meeting, he/she will probably be aware of this situation). The Chair should then communicate to the Executive Committee how much money will be needed from the Contingency Fund to provide the next host state the full $6,000 in start-up funds. The Chair will then ask for approval from the Executive Committee to make arrangements to have the appropriate funds transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the next host state. Providing the next host state adequate ($6,000) start-up funds will be the highest priority for the use of contingency funds.

   ii. If a host state has gone into debt as a result of hosting the annual meeting and will request the use of contingency funds to cover all or part of that debt (over and above the inability to provide the $6,000 in start-up funds to the next host state), it must submit a detailed request for approval of the use of these funds to the Chair, who will than make this request available to the Executive Committee. The request should include a detailed accounting of all financial aspects of the hosted meeting, including all funds received and sources thereof, as well as a detailed accounting of all expenses incurred as a result of hosting the meeting. The Chair will have discretion on how to proceed with polling the Executive Committee (e.g., email or conference call) on approval of the use of contingency funds to cover all or part of the incurred debt. The Executive will then decide through parliamentary procedure whether to use contingency funds to cover all or part of the incurred debt. The Chair will then make arrangements to have the amount of any funds approved by the Executive Committee for this purpose transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the host state. No repayment of these funds will be required.

7. Complementary Rooms, Travel Reimbursements, and Registration Fee Waivers

Complementary rooms (Suite) are provided during the meeting for the Chair and Secretary. Typically, the hotel will provide rooms free of charge in association with a certain number of booked nights. Invited speakers may be provided travel funds, free room, or registration, depending on meeting finances. The Local Arrangement Committee usually does not provide any travel assistance for attendees. Registration can be waived or refunds given on the discretion of the Local Arrangement Committee based on their financial situation. Possibly, a certain amount should be specified non-refundable before registration is begun. Distinguished Service Award recipients usually have their registration fee waived for the day of the Award Banquet if they are not already registered.

8. Biennial Meeting Preparation Timeline

May 1, 2020	Secure Hotel
May 1, 2021	Pre-RTWG planning meeting
June 15, 2021	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 2021	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 2021	First call for papers and a call for award nominations
Sept. 15, 2021	Second call for papers (Reminder; e-mail only)
Oct. 15, 2021	Titles and interpretive summaries due
Dec. 1, 2021	Abstracts due
Dec. 1, 2021	Award nominations due to Chair
Dec. 1, 2021	Registration and housing packet sent
Jan. 3, 2022	Reminder for registration and hotel (e-mail only)
Jan. 29, 2022	Last day for hotel reservations
Jan. 30, 2022	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 2022	Registration due without late fee
Feb. 20, 2022	39th RTWG Meeting

9. Program Itinerary

The biennial meetings begin on Sunday afternoon with committee meetings followed by a social mixer in the evening. The meetings end on Wednesday morning with the Closing Business meeting. The Awards presentations are made at dinner Monday or Tuesday evening or at a luncheon on Tuesday. See programs from previous RTWG meetings for more details.

Sunday: Registration usually begins Sunday afternoon and standing committees and ad hoc committees meet Sunday afternoon. A Sunday evening social mixer is hosted by the RTWG.

Monday: Registration continues Monday morning and posters are usually setup prior to the Opening General Session. The Opening General Session starts the biennial meeting with opening remarks from the Chair, a welcome from the Secretary/Program Chair, the opening business meeting, and ends with invited speakers. The concurrent technical sessions (i.e., oral presentations) of the six Panels begins after the Opening General Session on Monday. Posters are on display throughout the meeting or removed Monday evening and new ones placed on display Tuesday morning and removed Tuesday evening, depending on the number of posters and poster sessions.

Tuesday: The concurrent technical sessions continue on Tuesday and extend through Tuesday afternoon, depending on the number of papers. Each concurrent technical session ends with the review of the panel recommendations. If there are a sufficient number of posters, a second poster session is held on Tuesday.

Wednesday: The biennial meeting usually ends on Wednesday with the Closing Executive meeting and then the Closing Business meeting.

10. **Symposia**
Symposia are welcomed in conjunction with the RTWG biennial meetings. Symposia must not interfere with the RTWG biennial meetings and are to be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting.

11. **Functions by Industry and Other Groups**
Functions held in conjunction with the RTWG biennial meetings are welcomed as long as they do not interfere with the RTWG biennial meetings. Thus, these functions must be held prior to the committee meetings on the first day (i.e., Sunday) of registration or after the Closing Business meeting. Exceptions are informal, brief functions held at the meal breaks of breakfast, lunch, or dinner.

B. Instructions for Preparation of Abstracts for Biennial Meetings

Beginning with the Proceedings for the 24th Rice Technical Working Group meeting, Desktop Publishing software was chosen for expediting the post-meeting publication process using Microsoft Word (Windows). If individuals do not have access to MS Word, submission of materials in ASCII format (DOS compatibility is essential) is acceptable. Each electronic file should include: i) title of materials, ii) corresponding RTWG Panel, iii) corresponding author's name, daytime telephone number, e-mail address, and iv) computer format (i.e., MS Word and version number). These criteria apply uniformly to i) presented paper abstracts, ii) poster abstracts, iii) symposia abstracts, iv) panel recommendations, and v) list of panel participants. More details with respect to each of these items follow below.

As soon as a web page is established by the host state, a link will be provided to the RTWG web page where current submission instructions will be maintained.

1. Presented Paper, Poster, and Symposia Abstracts

To be published in the printed Proceedings, presented paper, poster, and symposia abstracts for the RTWG meetings must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the Proceedings.

a. Both a paper copy and an electronic file are required. Hard copy and electronic file are to be submitted to the respective Panel Chairs 2 ½ months prior to the RTWG meeting, or earlier as stated in the Call for Papers issued by the RTWG meeting Chair and/or Panel Chairs. Please e-mail the abstract to the Panel Chair by the deadline and mail the hard copy thereafter. If e-mail is not available, mail the electronic file to the panel chair on a IBM compatible CD or floppy disk.

The respective Panel Chairs for each RTWG meeting and their e-mail and mailing addresses are presented in the 'Instructions for Preparation of Abstracts" in each Proceedings. In case of other questions or if unable to access the Call for Papers, contact:

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b. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

c. Type: Do not use any word processing format codes to indicate boldface, etc. Use 10 point Times New Roman font.

d. Heading:
   i) Title: Center and type in caps and lower case.

ii) Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
iii) Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

e. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

f. Content is limited to one page.
   i) Include a statement of rationale for the study.
   ii) Briefly outline methods used.
   iii) Summarize results.

g. Tables and figures are not allowed

h. Literature citations are not allowed.

i. Use the metric system of units. English units may be shown in parentheses.

j. When scientific names are used, *italicize* them -- do not underline.

C. Guidelines for RTWG Awards

1. The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

a. <u>The Distinguished Rice Research and/or Education Award</u>

   i) <u>Individual category</u> – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research and (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress, and promise technical advances in the rice industry.

   ii) <u>Team category</u> – Same as the individual category, one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

b. <u>The Distinguished Service Award</u> - Awards to be made to designate individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, or industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2. The Awards Committee shall consist of the Executive Committee.

3. Responsibilities and duties of the Awards Committee are as follows:

a. To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee members cannot nominate or write letters of support for an individual or team for the RTWG awards. If a member of the Awards Committee is nominated for an award in a given category, it is common courtesy to abstain from voting in that category.

b. In the event that a real or perceived conflict of interest regarding award nomination packets exist, the Chair reserves the right to pass the responsibilities of award elections to the immediate past chair, the secretary, or an executive committee member who does not have a conflict of interest.

c. To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority (highest number of votes) vote once a quorum is mustered. A quorum for the Awards Committee is when at least eight members vote, excluding the Chair. The Awards Committee Chair (RTWG Chair) can only vote in the case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

d. The Awards Committee shall arrange for a suitable presentation at the biennial RTWG meeting. The Chair of the RTWG shall present the awards by speaking briefly about the accomplishments of the award recipient(s) and after presenting the award allow the recipient(s) an opportunity to express their appreciation.

e. The Awards Committee shall select appropriate certificates for presentation to the recipients of the awards.

4. **Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three recommendation letters, pertinent biographies of each nominee, and a concise but complete explanation of the accomplishments. Electronic submissions of the nominations are preferred; these should be submitted as a single pdf file, with exception of a one-page summary of accomplishments that should be provided at the same time, but as a MS Word file. Hard copies can be submitted, in which case fifteen (15) complete copies of each nomination must be submitted, and a one-page summary of accomplishments included with each nomination. This summary will be published in the RTWG Proceedings if the award is granted.**

a. Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

b. A member of an organization, described in 4.a, may nominate or co-nominate two persons.

c. Nominations are to be sent to the Awards Committee for appropriate consideration.

d. The deadline for receipt of nominations shall be three months preceding the biennial meeting. The executive committee reserves the right to entertain Distinguished Service Award packets at the opening executive committee meeting.

e. Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

D. Off-Year Executive Committee Business Meeting

The Executive Committee of the 2004 RTWG Meeting voted to have an Off-Year Executive Committee Business Meeting to add continuity, indoctrinate new Executive Committee members, and discuss pertinent topics more timely. The time and place of the Off-Year meeting is flexible and the possibility of conducting the meeting through distance education is a viable alternative to meeting at a designated location. The best time for the meeting is from February to August in the off-year, and it can be held in conjunction with such meetings as the Breeders' Conference or the organizational meeting for the next RTWG. The meeting can also be held independently at a central location or at the next RTWG meeting site to allow the Executive Committee to become familiar with the hotel and available facilities. A quorum (i.e., eight members are present, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. It is the responsibility of the RTWG Chair and the Secretary/Program Chair to call this meeting and set the agenda in concert with the other members of the Executive Committee.

Drafted by Richard J. Norman and approved by the 31st RTWG Executive Committee on March 1, 2006; revised by Garry McCauley and approved by the 32nd RTWG Executive Committee on February 21, 2008; revised by Cass Mutters and approved by the 33rd RTWG Executive Committee on February 25, 2010; revised by Tim Walker and approved by the 34th RTWG Executive Committee on March 1, 2012.

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