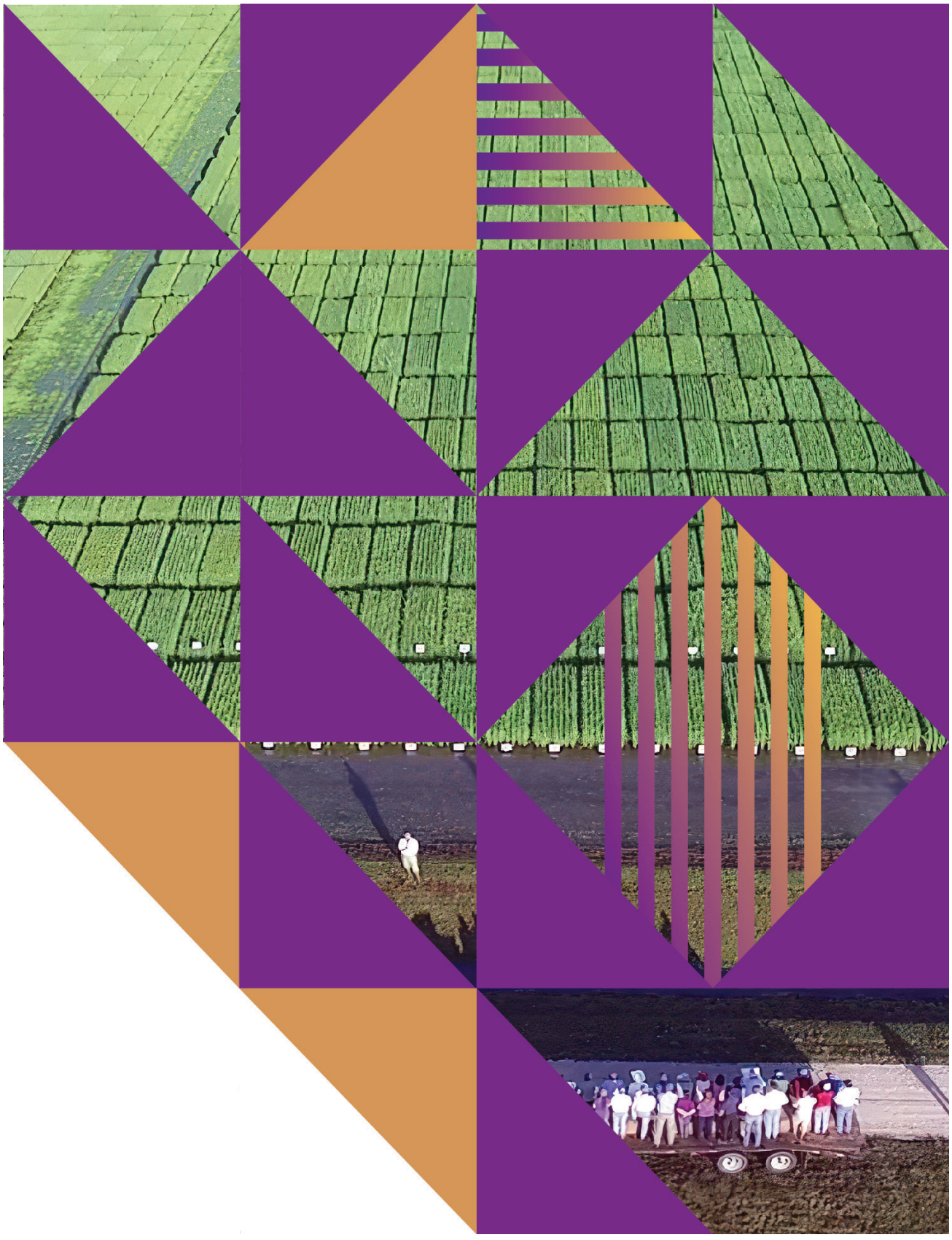
2024 INTERNATIONAL TEMPERATE RICE CONFERENCE



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PROCEEDINGS

2024 INTERNATIONAL TEMPERATE RICE CONFERENCE

The International Temperate Rice Conference (ITRC) is a global initiative dedicated to bringing temperate rice growing countries together for discussion, promotion, and advancement of research, technology, and innovation in the field. This initiative enables information exchange among leading scientists and other stakeholders engaged in sustainable rice production in temperate zones of the globe.

The 2024 ITRC was held in New Orleans, Louisiana, at the Marriott New Orleans Hotel on Canal Street in the Historic French Quarter, June 5-8, 2024. The meeting brought together rice scientists and others from around the globe and provided for exchange of information, cooperative planning, and networking to facilitate all aspects of rice research, extension work, supply chain dynamics, and all other areas of production. Past meeting locations have included Australia (2), California, Italy, Uruguay, Thailand, and Brazil (most recently in 2020). The meeting has grown through the years and includes keynote speakers, symposia, research discipline panels, and poster sessions. The research discipline panels for this meeting included Breeding and Genomics, Plant Protection (Entomology and Pathology), Culture and Soil Science, and Weed Science and Postharvest (Economics and Quality). There were student competitions for oral and poster presentations in all of these discipline panels. The highlight of the meeting was a field tour of the rice production region of Southwest Louisiana. The Louisiana meeting was hosted by the Louisiana State University AgCenter and the USA Rice Federation.

2024 ITRC OUSTANDING RESEARCH AWARD

The 2024 ITRC presented an Outstanding Rice Scientist Award.

The criteria for nomination were that the recipient be an individual who has achieved distinction in basic or applied research and/or significant advances in education programs that have advanced rice science and led to significant technical advances in temperate rice production areas of the world.

The recipient of the 2024 ITRC Outstanding Rice Scientist Award is Russell Ford of Mairjimmy, New South Wales (NSW), Australia. Russell is an outstanding applied rice scientist who has significantly contributed to the development of temperate rice in Australia and elsewhere through his cooperative work with scientists, educators, farmers, and industry. He has contributed internationally through his work in other countries and his contributions to the Temperate Rice Consortium and involvement with the International Temperate Rice Conferences. After his appointment as manager of the Rice Research Australia Pty. Ltd., he dedicated himself to providing facilities, labor, and equipment to support many rice research programs. His support for the Australian Rice Breeding Program has been significant in hastening the release of new cultivars and providing pure seed of established rice cultivars. He also worked cooperatively with scientists to study weed control, nitrogen management, other agronomic studies, and greenhouse gas emissions. He noted shortcomings in the rice production systems of NSW, Australia, and set about devising more efficient systems. One significant example was the development of direct seeding (drill seeding) for soils that had been considered too sodic and had been dedicated to aerial sowing. This facilitated more efficient seed production but also paved the way for water savings. His work extended beyond direct seeding and included better weed control, irrigation systems, application of digital technologies, and better and more efficient irrigation systems. He became a go-to person to modify temperate rice systems for other rice producing areas. These included Queensland, Northern Territory, Western Australia, and Vietnam among other locations. His reputation as a practical researcher, free thinker, and exceptional cooperator enabled the development of applied research programs in these areas. His knowledge of the rice production systems and access to resources meant that he was able to support many students in their undergraduate, postgraduate, and work experience projects. He was recognized for his talent by becoming an adjunct scientist with Charles Sturt University. His co-operative abilities, understanding and experience of the temperate rice production systems meant that he was an excellent colleague across the whole system. He was able to liaise between rice producers, extension officers, and researchers across many countries. He was the Australian representative on Temperate Rice Consortium for many years and ensured it provided real value and coordination of this group. He was the head of the committee that oversaw the International Temperate Rice Conference in Griffith, Australia, in 2017 and has always been an enthusiastic advocate for these conferences. Russel Ford is a very deserving recipient of the 2024 ITRC Outstanding Rice Scientist award.

AWARD WINNERS – STUDENT COMPETITIONS

Culture and Soil Science

First Place: Katie French, University of Arkansas
Second Place: Gabriela Andrade Leite Mengez, University of Arkansas

Plant Protection and Genetics

First Place: Mary Jane Lytle, Mississippi State University
Second Place: Jyoti Sharma, Louisiana State University

Weed Control and Post-Harvest

First Place: Maranda Hains, Louisiana State University
Second Place: Alex Mangialardi, Mississippi State University

Poster Competition

First Place: Reuben Kudiabor, Texas A&M University
Second Place: Hannah Vickmark, University of Arkansas
Third Place: Wesley Carr, Louisiana State University

SYMPOSIUM 1 – ABSTRACT

PaddyVision®: New Instrument for Rapid Analysis of Paddy Rice Quality Across the Supply Chain

Talbot, M.J.

The PaddyVision® is new innovative technology that non-destructively measures the amount of defective (cracked and immature) paddy rice at the point of receival. Defective grains are likely to break during milling, thereby reducing Head Rice Yield (HRY).

As well as detecting quality traits directly influencing HRY, the PaddyVision® also quantifies color and measures length and width. Instrument calibrations have been built over three years and include ground-truth training sets containing thousands of grains per quality class, as well as hundreds of PaddyVision® measurements correlated with HRY, enabling development of machine learning models for prediction of milling quality. The instrument returns results in less than 2 min for a 370-grain sample, significantly streamlining analyses that are otherwise prone to subjective, labour-intensive and time-consuming assessment.

The PaddyVision® has successfully analyzed over 55,000 loads of rice over three consecutive harvests in the Australian Riverina rice growing region, with the measurements captured correlating well with conventional HRY appraisals. The instrument has also performed well at the SunRice Lap Vo mill in Vietnam.

The PaddyVision® was adopted by the SunRice Group for the Australian 2023 harvest to calculate a discount/premium payment structure for final grower payment, replacing the HRY-based appraisals process. This progression has meant that growers receive immediate feedback on their quality from every load delivered, and SunRice receives more timely information on potential milling quality of stored grain.

The PaddyVision® offers benefits to growers, dryers, storers, and millers, through objective, efficient, accurate, and non-destructive assessment of paddy rice quality at different points in the supply chain. PaddyVision® measurements are independent from differences in milling equipment types and manufacturers, meaning it has the potential for widespread application across the global rice industry. Following successful trials and implementation of PaddyVision® in Australia and Vietnam, we are seeing growing interest from external stakeholders, including agronomists, rice breeders, university research groups and growers in Australia, Vietnam, and the United States, who are looking for solutions to manage quality risk at multiple points in the rice supply chain.

SYMPOSIUM 2 – ABSTRACTS

Twenty Years of Herbicide-Tolerant Rice in the Southern USA

Walker, T.W.

The launch of the Clearfield Production System with resistance to herbicides in the imidazolinone family of acetolactate synthase (ALS) inhibiting herbicides for rice (*Oyryza sativa* L.) in 2002 marked changes for southern USA rice production on multiple fronts with the obvious being cultural practices. Prior to the adoption of the Clearfield Production System, especially in southwest Louisiana, fields were prepared in flooded conditions and water-seeded to minimize red rice (*Oyrza sativa* L.) germination. In addition to excessive wear on equipment, sediment loss could be extreme. Finally, nitrogen efficiency was lower due largely to continuous wet soil conditions. The Clearfield system benefitted the southwest Louisiana production area with the ability to adopt the drill-seeded, delayed-flood production system which allowed the simultaneous control of red rice and ultimately improve the overall sustainability of rice. Adoption of Clearfield rice was not limited to southwest Louisiana. The other southern USA rice producing states adopted the system as rapidly as southwest Louisiana, and many of those areas did not have the extreme level of red rice infestations compared to much of southwest Louisiana. By introducing the technology to fields with light red rice pressure coupled with crop rotation where residual herbicides are used that have efficacy against red rice like s-metolachlor, the Clearfield system is still very effective against red rice even 20 years or more after its adoption.

After about 10 years, the Clearfield Production System had lost efficacy on many farms in southwest Louisiana and isolated monocrop rice production systems in Arkansas, Mississippi, and Missouri. In 2018, the Provisia Rice System with resistance to acetyl Co-enzyme A carboxylase (ACCase) inhibiting herbicides, specifically quizalofop, was launched by BASF in partnership with Horizon Ag. By the time of the Provisia launch, fields where the Clearfield system became ineffective first were either no longer being planted or still being planted with very questionable economics. In turn, these became the first fields to be planted with Provisia Rice System varieties. The biggest negative of the Provisia Rice System compared to the Clearfield Production System is that the Provisia Rice System uses only quizalofop, a graminicide with no residual activity compared to imazethapyr in Clearfield that has excellent residual control of grasses and non-ALS resistant red rice. Unfortunately, multiple fields were identified in southwest Louisiana and in Arkansas in 2022 where weedy rice has both traits of quizalofop and imi-resistance. Adoption of the Provisia Rice System rice has been much slower compared to the Clearfield Production System. In 2023, approximately 61,000 ha of the Provisia Rice System rice were planted in the southern USA. The adoption rate since the original 12,000 ha in the first year of launch has been about 10,000 ha per year. The adoption rate of Clearfield rice was about 4X greater than Provisia.

In summary, the difficulty of controlling a weed that is the same genus and species as the crop is tremendous. The Clearfield Production System and the Provisia Rice System are both successful technologies. Maximizing stewardship of these and potential new technologies is critical and only possible with a multi-faceted approach by the farmer, industry, and academia.

The ROXY® Rice Production System, 2024

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

Albaugh LLC has partnered with the California Cooperative Rice Research Foundation, Inc. to introduce a new non-GMO herbicide-tolerant rice production system for rice weed control, the ROXY® Rice Production System, (ROXY® RPS). The system will include a patented herbicide tolerance trait, branded herbicides, adapted germplasm, and a production system stewardship program. The ROXY® trait was recovered by Rice Experiment Station in M-206, California's most widely grown Calrose rice variety, using conventional mutation breeding and is inherited as a single recessive gene that can be transferred and selected through conventional breeding. M-521, a Calrose medium grain with the ROXY® trait, has been released and is ready for commercial seed increase for California growers.

The ROXY® trait provides tolerance to the herbicide oxyfluorfen, a Group 14 mode of action for weed resistance management against Group 2 (ALS) and Group 1 (ACCase) weed resistance. As a pre-plant herbicide, it provides early season control of yield robbing grass and broadleaf weeds and has potential value for weedy rice management. It will serve as a new tool to broaden the best management practices for weed control systems in rice production. Albaugh will register and launch two branded herbicides to help manage weeds and weed resistance in rice production. ALB2023 is a 479 g/l (4 lb/gallon) AI Flowable formulation that is applied pre-flood and pre-plant in water-seeded rice and will be applied post plant and pre-flood in drill-seeded rice. ALB2024 is a 240 g/l (2 lb/gallon) AI EC formulation that will be applied early post emergence targeting weedy rice infestations and other seedling grasses. The two ROXY® RPS herbicides are being reviewed for registration by EPA and a concurrent review by the California Department of Pesticides Regulation. ROXY® RPS Grower Stewardship Agreements will include a stewardship program focused on prolonging the use and utility of the ROXY® RPS through the use of certified seed and implementing best management practices to help manage and slow the development of resistant weed biotypes.

Nine years of field testing in California, including replicated small plot and large-scale field testing in growers' fields, have demonstrated the performance of the system as a strong foundation weed management tool for both water- and drilled-seeded rice. The system has also undergone several seasons of evaluations in rice weed control programs by the University of Arkansas, Louisiana State University, and Mississippi State University. Introgression agreements and breeding to incorporate the ROXY® trait into adapted and elite long-grain varieties are underway.

Dodhylex™ Active: A Novel Mode of Action Herbicide Inhibiting Dihydroorotate Dehydrogenase (DHODH) Enzyme for Effective Management of Herbicide-Resistant Grass Weeds Globally

Puri, A., Pan, Y., Selby, T., and McKenna, R.

The last new herbicidal mode of action holding commercial significance was introduced to the marketplace multiple decades ago. Serious weed resistance has since emerged with widespread use to the most herbicidal classes. Currently in development by FMC Corporation, Dodhylex™ active (tetflupyrolimet) is the first new mode of action (MOA) herbicide for season-long control of major grass weeds in rice globally. Dodhylex™ active belongs to a new herbicidal class of aryl pyrrolidinone anilides that interferes with de novo pyrimidine biosynthesis via inhibition of dihydroorotate dehydrogenase enzyme that is localized to the mitochondria in the plants. Dodhylex™ active is the first active ingredient in the HRAC/ WSSA Group 28. An extensive field program over the last 7+ years has shown that it provides season-long control of important grass weeds in the rice, including *Echinochloa* spp, *Leptochloa* spp*, Digitaria* spp*, Ischaemum* spp, as well as key broadleaf weeds such as *Monochoria* spp. and sedges such as *Fimbristylis* spp. Dodhylex™ active has excellent crop safety to both *japonica* and *indica* rice biotypes as well as transplanted or direct seeded rice under diverse soil and environments. Due to its novel mode of action, there is no evidence of Dodhylex™ active having cross-resistance with existing classes of herbicides. FMC anticipates launching Dodhylex™ active in both the transplanted and direct-seeded rice markets worldwide starting in 2025.

BREEDING AND GENOMICS – ORAL PRESENTATIONS

Chromosomal Segment Substation Lines Show a Major QTL for Mexican Rice Stem Borer Resistance in Cybonnet Background

Ali, M.P., Angira, B., and Stout, M.J.

Chromosome segment substitution lines (CSSLs) are genetic stocks representing the complete genome of any genotype in the background of a cultivar as overlapping segments. Ideally, each CSSL has a single chromosome segment from the donor with a maximum recurrent parent genome recovered in the background. Recently, Singh et al. (2020) developed two introgression libraries (n = 63 to 81 lines per library) in crosses of Cybonnet with two bio-geographically diverse wild donors representing the *Oryza nivara* and *O. rufipogon* Species Complex from Laos and Indonesia, respectively. Cybonnet is an elite tropical japonica from the United States adapted to the sub-tropics and was released by the Arkansas Agricultural Experiment Station in 2004. The libraries were genotyped using an Infinium 7K rice SNP array (C7AIR) and analyzed under greenhouse conditions for several simply inherited (Mendelian) traits. In this study, we collected 125 CSS lines and conducted field evaluations against a major pest, Mexican rice stem borer, in 2023 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, USA. The phenotypic data borer damaged symptom "whitehead" was recoded at the reproductive stage of rice, analyzed, and finally used for QTL mapping using previously genotyped data.

A total of 2,396 donor chromosome segments were identified from 12 chromosomes of the Cybonnet X O. nivara population, comprising 61 CSS lines. In the Cybonnet X O. rufipogon population, 2,191 donor chromosome segments were identified from 12 chromosomes, consisting of 64 CSS lines. QTL mapping and additive effect were investigated using the RSETP-LRT-ADD mapping method with QTL IciMapping V4.2 software. In the Cybonnet X O. rufipogon population, it shows a significant QTL with a 7.4 LOD score. The marker C1_35513654 was found to be linked with the QTL, contributing to 43% of the phenotypic variation (PVE) for the whitehead trait. However, no significant QTLs were identified in the Cybonnet X *O. rufipogon* population. Further linkage analysis and gene cloning are necessary to identify the causal genes underlying Mexican rice stem resistant QTL providing major sources for stem borer resistance breeding.

This research has shown that some CSS lines have resistance against Mexican rice stem borer. The identification of these genomic sites or QTLs that effectively respond to whitehead trait will aid in the quest of understanding the stem borer tolerance mechanisms. This study will facilitate marker-assisted rice breeding and handy in the breeding of Mexican stem borer-tolerant rice varieties.

Logistics of Marker Application in Marker-Assisted Selection, Genomic Selection, and Seed Purification in LSU AgCenter Rice Breeding Program

Angira, B., Roberto, F.N., Dartez, V., Dartez, J., Madeline, L., and Famoso, A.N.

DNA markers have proven to be a cost-effective and transformative technology in plant breeding programs. The LSU AgCenter's rice breeding program has successfully developed native trait markers, informative genome-wide markers, and tailored marker sets, enhancing efficiency, accuracy, and speed in breeding.

The program strategically deploys DNA markers at all stages of the variety development process for specific applications and objectives. Native trait markers linked to genes controlling essential qualitative traits are deployed for marker-assisted selection (MAS). Seedlings from greenhouses or field-collected panicles are used for MAS. The number of plants selected depends on targeted genes and logistical considerations, typically 50 or 100 plants per population are selected. These plants are grouped based on distinct genetic profiles at the designated locus, and the groups are prioritized for subsequent selection.

Genomic selection is another key marker application utilized by the AgCenter breeding program, implemented at the F_2 or F_3 generation. Labeled and tracked panicles undergo genotyping and prediction using customized training sets and robust models. The selected panicles are strategically planted as panicle rows in the field, enabling a comprehensive evaluation of agronomic traits. Following this assessment, the selected rows undergo yield testing in subsequent seasons.

Markers also play a pivotal role in seed purification. The breeding program now uses selected markers across the genome to identify heterogeneity within lines, replacing reliance on agronomic characteristics. Each panicle designated for breeder seed production undergoes genotyping and genetic purification, ensuring the production of a uniform and genetically pure line.

The objective of this talk is to provide an overview of the logistical considerations and approaches utilized to incorporate DNA marker activities in the context of the existing variety development program.

Rapid Evolution of Rice Varieties in a Market and Weather Driven Environment in Italy

Biloni, M., Mazzini, N., Conti, F., Piombino, M., Fregonara, S., and Baino, M.

In Italy, old traditional varieties are grown close by many new released ones every year. In 2022 and in 2023, drought stress affected the rice cultivated area in a dramatic way. In 2023 the rice surface dropped down to 210 thousand hectares, the minimum value in the last 25 years. The increase in temperature during the crop growth together with the reduced water availability increased the susceptibility to major diseases such as leaf and neck blast.

In Italy, the first IMI-resistant rice was introduced in 2006. Recently, many cases of IMI-resistant red rice have been discovered. A new technology with rice varieties resistant to the ACC-ase inhibiting herbicides was released and is being largely adopted by the farmers.

Weather on one side and weed control on the other side are pushing for a fast release of new varieties and are causing a rapid evolution of the variety set. In 2023, more than 180 varieties were grown in Italy. New varieties need to be tested for understanding the main traits, such as production ability, grain quality and agronomic values.

A multilocation variety trial has been set in Italy in 2022 and 2023 to determine the main traits of traditional and new released varieties. The collected data include early vigor, duration, plant height, yield, milling yield, disease resistance, and post-harvest quality values.

Developing a High-Throughput Phenotyping Pipeline to Estimate Yield and Plant Height in Rice

Borges, B.R.C., Silva, A.V., Borges, K.L.R., Famoso, A., and Fritsche-Neto, R.

Phenotyping large populations poses a challenge for breeders, as traditional methods rely on manual measurements that are laborious, inaccurate, and time-consuming. On the other hand, modern tools such as Unmanned Aerial Vehicles (UAVs) and image-based technologies have revolutionized plant breeding by enabling precise monitoring of key traits. Visible light imaging captured by RGB (Red, Green, and Blue) sensors is widely used for high-throughput phenotyping due to its speed, cost-effectiveness, and the ability to simultaneously collect multiple traits throughout the crop cycle. Integrating sophisticated algorithms allows for accurate estimation of target traits, such as grain yield (GY) and plant height (PH), assisting breeders in making selections in early breeding stages when replicates in the field are often lacking. This technology-driven approach enhances the efficiency of the breeding cycle, empowering researchers to make informed decisions and develop resilient, high-yielding rice varieties to address global food security challenges. In this context, we aimed to develop a pipeline for image-based phenotyping and evaluate the robustness of RGB-based vegetation indices to estimate productivity in rice.

During the physiological maturity stage (ripening stage), a UAV Phantom 4 (version 2.0) equipped with an RGB camera with 4K resolution was used to capture images from the Clearfield Preliminary Yield Test (CLPYL) trials in replicated design and planted in 2023 at the LSU Rice Research Station. The collected images were used to reconstruct a high-resolution orthomosaic using Agrisoft Metashape (version 2.0) and QGIS (version 3.32.3). Among many indices described in the literature, we have assessed the following ones: 1) Excess of Green Index (ExGI), 2) Normalized Green-Red Difference Index (NGRDI), and 3) Visible Atmospherically Resistant Index (VARI). Downstream analysis was performed using the software R. Briefly, shapefiles were generated, and masks were applied to remove the soil background from the plots to separate only the pixel area representing the reproductive part, in this case, a surrogate of grain yield. Then, based on the difference of the pixel altitude at canopy and soil level, we estimate the plant height per plot.

All tested vegetation indices were negatively correlated with the target traits, limiting their use for indirect selection. However, the indices helped remove the vegetative part of the plants, enabling the estimation of the plot area corresponding to the panicles (the reproductive part). Subsequently, the panicle area was used to estimate GY as a productivity indicator. The estimated productivity showed a 34% correlation with field GY data. Regarding PH, the correlation was even higher at 61% between estimated values (derived from the images) and field data. The proposed pipeline will be validated in the coming years and applied to other breeding fields at the Rice Research Station. Additionally, using a multispectral camera and ground control points, we expect that higher precision and other indices will boost the prediction accuracies.

Progress in Inbred Rice Breeding and Variety Development Program in the University of Arkansas

De Guzman, C.G., Sha, X.S., Hardke, J.A., Nicolli, C.A., and Counce, P.A.

Arkansas is the biggest U.S. rice producing state with 1.1 million acres planted in 2022. About 20% of rice acreage in Arkansas is planted with the University of Arkansas inbred lines. With the support of check-off funds, more than forty rice varieties have been released in the University of Arkansas since 1983.When the program was started in 1980, the average rough rice yield in Arkansas was only 4,607 kg/ha (4,110 lbs./acre) compared to an estimated 8,306 kg/ha (7,410 lbs./acre) state average yield in 2022. Adoption of these newer varieties provided an estimated monetary gain of about $58 million for the 220,000 acres planted to Arkansas varieties.

Additionally, rice lines with herbicide tolerance are continuously being bred and incorporated into the rice breeding pipeline. Release of these new herbicide tolerant varieties gave farmers more options to manage and control weeds in their production systems.

Various breeding methods are employed to increase genetic gain. Pedigree selection is mainly used in combination with single seed descent, backcross breeding, and marker assisted selection. Genomic selection is currently being optimized to be used in the breeding program for long grain and aromatic rice. We are actively using high throughput phenotyping for grain quality and currently investigating spectral images for field phenotyping and differentiation of rice genotypes under Arkansas conditions. The breeding program is supported by groups from agronomy, plant pathology, and grain quality/cereal chemistry. Advance lines in the pipeline are extensively evaluated in multi-year and multi-environment trials. Every year, potential varieties are planted in at least six locations in the Arkansas Rice Variety Advancement tests (ARVAT) and more than twenty locations for pre-commercial tests (PC) in Arkansas, Louisiana, Texas, and Mississippi for up to three years before release. Disease screening for sheath blight and rice blast are routinely employed on early and late generation lines both in the greenhouse and under field conditions. Each potential line harvested in various locations is tested for grain quality analysis such as seed dimension, chalk, amylose, gelatinization temperature and RVA profile. This paper presents the progress in varietal development evidenced by the release of high yielding varieties over the years in the University of Arkansas rice breeding program.

Grain Quality and Sensory Evaluations Aid in Variety Development

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

The California Rice Experiment Station has successfully developed and released 57 rice varieties. Over time, Calrose became synonymous to high quality medium grain rice. In 2015, California's Calrose rice was recognized as "World's Best Rice" in the 7th World's Rice Conference, beating 25 other rice entries in the competition including Thai Jasmine. To date, the station continues to breed rice for all market classes of long, medium, and short grain, for conventional, premium, and specialty types of rice. The station employs traditional pedigree methods, mutation breeding, mass selection, rapid generation advance, and wherever possible DNA markers are utilized for selection of traits, fingerprinting, and purity testing. The station adheres to rigorous evaluation of breeding lines for deployment of excellent rice varieties to California growers. A notable part of variety development and release process in California is the external participatory role of rice growers, mills, and marketing companies in grain quality and sensory evaluations for market acceptability of a promising line. With several years of statewide yield testing and grain quality characterization, an advanced promising line along with current check varieties are sent for external blind test evaluations. Bags of paddy or milled rice are number coded for blind evaluations. Participants of the evaluations meticulously assess the rice samples for grain quality, cooking, and eating quality for the market class for which the promising line is being bred. Multivariate analysis indicated that Calrose's taste value is positive and highly correlated to mouthfeel, aroma, softness, cohesiveness, and whiteness of cooked rice. Furthermore, these eating characteristics are significant and positively correlated to grain uniformity, translucency, low chalk, and overall appearance of milled rice. Overall, the market acceptability of California's Calrose and specialty rice varieties is highly dependent on high grain quality and premium eating qualities.

Breeding Resilience: Climate-Adaptive Rice Varieties for Mechanized Dry DSR

Dixit, S., Heredia, M.C.C., Argayoso, M.A., and Ponce, K.

Direct-seeded rice (DSR) cultivation accounts for nearly 30% of the global rice area, predominantly relying on outdated cultivars and traditional farming techniques. Amidst the contemporary challenges posed by climate change, water scarcity, and labor availability, the adoption of mechanized dry DSR emerges as a pivotal strategy for enhancing sustainability in rice farming. This approach offers notable benefits, including reduced water consumption, lower greenhouse gas emissions, and decreased production expenses—the transition towards mechanized dry DSR fosters environmental conservation and bolsters economic viability for rice farming enterprises.

Despite the recognized advantages of mechanized DSR, its widespread adoption encounters hurdles primarily attributed to the dearth of suitable cultivars. The existing rice genotypes necessitate substantial transformation to ensure robust crop establishment and growth, particularly during prolonged dry spells characteristic of direct-seeded systems. Research endeavors undertaken at the International Rice Research Institute (IRRI) have pinpointed nine pivotal traits crucial for the success of rice varieties across various growth stages within DSR frameworks.

These traits encompass early and uniform germination, sustained vegetative growth, efficient utilization of water and nutrients, tolerance to drought stress, and resistance against nematode infestations, among others, addressing both biotic and abiotic stressors inherent in DSR ecosystems.

To address the breeding challenges associated with DSR, IRRI has initiated establishing and characterizing a founder panel comprising elite breeding lines. This initiative aims to delineate a comprehensive trait profile and ascertain the breeding values of these elite cultivars. Leveraging genomic selection-based breeding methodologies, coupled with utilizing this closed pool of elite cultivars, IRRI endeavors to expedite the pace of genetic improvements within the DSR domain. This approach entails adopting rapid generation advancement techniques and parental recycling strategies based on breeding values, facilitating the swift and sustained accrual of genetic gains in DSR systems.

In essence, the transition towards mechanized dry DSR heralds a paradigm shift in rice cultivation, offering a pathway towards enhanced sustainability and profitability for farmers. By addressing the inherent challenges associated with cultivar suitability through targeted breeding efforts, coupled with the utilization of cutting-edge genomic selection techniques, IRRI endeavors to spearhead the advancement of DSR technologies. Through collaborative efforts and strategic interventions, the realization of a resilient and productive DSR landscape beckons, ensuring food security amidst evolving climatic and agricultural landscapes.

Pre-Breeding Studies Focused on Rice Grown in Temperate Regions at the USDA-ARS Dale Bumpers National Rice Research Center

Eizenga, G.C., Edwards, J.D., Huggins, T.D., Pinson, S.R.M.,
Schläppi, M.R., Rohila, J.S., and Jia, Y.

The USDA-ARS Dale Bumpers National Rice Research Center (DBNRRC) mission is to improve the competitive-ness of the U.S. rice industry in global and domestic markets through research and technology development that assures high yields, value-added grain quality, pest resistance, and stress tolerance. A key component for rice improvement is understanding the genes controlling desirable traits. Based on current resequencing data, rice (*Oryza sativa* L.) is composed of nine subpopulations with U.S. rice mainly represented by the *tropical japonica* (TRJ) and *temperate japonica* (TEJ) subpopulations. Examination of the founders of U.S. rice revealed short grains are TEJ, medium grains are admixtures of TEJ and TRJ, and long grains are TRJ with California cultivars having more TEJ than those grown in the Midsouth. Assembling a SNP database of private/nearly private alleles for each of the nine subpopulations from three resequencing studies revealed the U.S. medium-grain cultivars were an admixture of TEJ and TRJ alleles with *indica* introgressions in chromosomes 1, 8, 9, 11, and 12.

DBNRRC studies identified rice cultivars grown in temperate regions are a source of fissure resistance, cold tolerance, and salt tolerance. Studies focused on fissure resistance determined resistance to kernel fissuring, first noted in the southern U.S. cultivar Cypress (TRJ, long-grain), was also inherited by its progeny cultivar Cybonnet (TRJ, long-grain) and was attributed to three

QTLs presumably inherited from the California long grain parent, L-202 (TRJ). The QTL with the largest individual effect explained from 10 to 30% of the total phenotypic variance in three mapping populations and was fine-mapped to a 1.28 Mb region approximately 8 cM distal to the semidwarf locus (*sd1*) on chromosome 1. Resistance to kernel fissuring is especially important and prevalent in California rice cultivars because the wide extremes between hot day and cool nighttime temperatures in California cause heavy dew to develop daily, which induces kernel fissuring due to pre-harvest rewetting of the mature grains.

Evaluation of the Rice Minicore (RMC) composed of 202 *O. sativa* accessions, for cold tolerance at the germination and seedling stages revealed TEJ accessions (34) were the most cold-tolerant for the five traits measured and the *aus* accessions (38) and *indica* accessions (68) were the most cold-sensitive. To further dissect the QTL regions associated with seedling stage cold tolerance, two mapping populations were developed. Specifically, cold-tolerant TEJ accessions, Krasnodarskij 3352 and WIR911 were crossed with the cold-sensitive *aus* accession, Carolino 164. Mapping within these populations identified 25 candidate genes most of which were cold temperature regulated and had deleterious nucleotide variants in the Carolino 164 parent, which might contribute to its cold-sensitive phenotype. The functionality of two genes, *OsFKBP13* and *CYP59A*, is currently being analyzed to determine if these genes belong to a new module regulating the trade-off between stress response, and growth and development. If confirmed, markers will be developed for use in marker-assisted breeding schemes to improve rice cold tolerance.

The RMC also was evaluated for early seedling vigor under salt stress in the greenhouse to identify salt tolerant accessions. This study identified M-202, a California TEJ medium-grain, as extremely salt tolerant which was subsequently validated in a greenhouse study using salty Atlantic Ocean water. Currently, a M-202/Carolina Gold (TRJ, long-grain) mapping population is being developed to uncover the QTL for seedling stage salt tolerance and potentially develop markers for selected genes associated with salt tolerance to be used in marker-assisted breeding.

Recently, Eclipse (PI 701081), a blast-resistant rice germplasm with the ‘Calrose’ type medium-grain quality was developed by the DBNRRC. It was selected from a backcross between Katy, a blast-resistant Arkansas TRJ long-grain cultivar and M-202. Eclipse has the blast resistance genes, *Pi-ta* and *Ptr* and like Katy, exhibits resistance to both leaf and panicle blast infections under natural infections in Louisiana and Puerto Rico field conditions. Similar to Katy, Eclipse also exhibits resistance to blast races IA45, IB1, IB49, IB54, IC17, IE1, IG1 and IH1. Eclipse is a semidwarf, carrying the *sd1* allele from Dee Geo Woo Gen (*indica*), has a glabrous leaf texture, low apparent amylose content and low gelatinization temperature, like to M-202, with Calrose quality. In the southern US, Eclipse has an average height of 98.5 cm and yields 6,710 kg grain/ha. It reaches 50% heading at 84 days after emergence with a lodging incidence of 28.5% and 59% head rice yield. It can be used for breeding improved disease resistance and grain quality or used directly by rice growers for premium medium-grain rice production.

Objectives, Stages, and Strategies of the LSU AgCenter Rice Breeding Program

Famoso, A., Angira, B., Dartez, V., and Fritsche-Neto, R.

The Louisiana State University (LSU) AgCenter H. Rouse Caffey Rice Research Station, located in Crowley, Louisiana, has played a crucial role in the rice industry since its establishment in 1908. Over the years, its primary focus has been on the development and release of new rice varieties, contributing significantly to the US and global rice industry. The program has released 63 varieties across multiple grain and herbicide segments.

The program's current efforts are directed towards the development of rice varieties across three herbicide classes: Clearfield, Provisia, and Conventional. These varieties are tailored to meet diverse grain and quality classes, including Long, Medium, Jasmine, Della, and high-amylose rice. While the fundamental objectives and target deliverables of the program have remained consistent over the last century, the continuous evolution of technology has allowed for ongoing efficiency improvements.

The talk will cover various aspects of the LSU Rice Breeding Program, including 1) Program Objectives: Highlighting the overarching goals and mission of the rice breeding program. 2) Activities at Each Breeding Stage: Detailing the specific activities and processes involved in each stage of the rice breeding program, from initial selection to final release. 3) Resource Allocations: Discussing how resources such as people, funding, and technology are allocated to support the program's activities. 4) Marker Utilization: Explaining the use of markers and molecular techniques in rice breeding. 5) Future Directions and Goals: Providing insights into the program's vision for the future, potential areas of expansion, and upcoming goals.

The continuous adaptation to advancements in technology reflects the program's commitment to staying at the forefront of rice breeding and contributing to the sustainability and productivity of the rice industry. This talk serves as a comprehensive overview of the LSU Rice Breeding Program, showcasing its historical significance, current activities, and future aspirations.

Introgression and Algorithms of Training Set Optimization Effect in Long-Term Breeding Programs: A Study Case in Self-Pollinated Crops

Fritsche-Neto, R.

Optimization algorithms using empirical data have been employed to fine-tune the selection process by efficiently identifying the combination of genetic markers or training set composition that boosts the prediction accuracy. Additionally, based on empirical results or sometimes just feelings, breeders have introduced new materials in a breeding program as a pivotal strategy to diversify and enhance the genetic pool. These materials come from other breeding programs, and the rate of introgression may vary across the years and market segments. Despite these procedures being deployed as a routine, their effects on the accuracy of prediction models in the short and long term still need to be made clear. In this context, simulations can help breeders determine which selection procedures and breeding management options to adopt or adjust for future cycles.

Therefore, the present study estimates the introgression and algorithms of training set optimization effect in long-term breeding programs.

For that, we use stochastic simulations and rice as a study case to represent self-pollinated crops. Moreover, we used the current breeding scheme of the LSU Rice breeding program as the main framework. Regarding the factors analyzed, we considered the use or not of optimization algorithms (PVmean) to update the genomic prediction training set and tree levels of parent ingression per breeding cycle (0, 10, 20, or 30% coming for external but elite breeding programs). Also, we considered a breeding horizon of 10 cycles (about 50 years) and repeated the simulations 50 times for each scenario using the AlphaSimR package.

Overall, optimization algorithms don't provide any gain in genetic improvement, retention of genetic variability, or even accuracy over time. A possible explanation is that it accumulates "constraints/overfitting" over cycles. Moreover, closed breeding programs provide higher gains than using introgressions, mainly because introgression reduces the GS accuracy. Therefore, genetic variability is less important than accuracy in terms of repose to selection. If the introduced parents come from the same source, over the years, these effects reduce as long as the cycles of introgression. Finally, as a consequence, for breeding programs where introgressions are "mandatory," "test and shelf" would be an alternative.

Ratoon Rice: Optimizing Sustainable Rice Production

Heredia, M.C.C, Argayoso, M.A., Ponce, K., and Dixit, S.

Rice (*Oryza sativa* L.) stands as a preeminent staple agricultural crop, pivotal for sustaining 70% of the global populace. Its utility transcends mere sustenance and extends to encompass applications in industrial, cosmetics and medicinal formulations. However, the imperative to bolster rice production while ensuring its sustainability mandates exploration into novel cultivation paradigms. Direct-seeded rice (DSR) has emerged as a promising alternative, lauded for its efficiency in water utilization, labor, and time to maturity, thus garnering significant farmer interest owing to favorable net returns.

The optimization of DSR hinges upon the synergistic integration of suitable varieties with efficient crop management methodologies, particularly those harnessing high yields under the given seasonal and geographical context with the least expense on input requirements. The ratooning rice system capitalizes on the plant's innate ability to germinate dormant buds and generate tillers post-primary harvest, culminating in a secondary harvest. This approach epitomizes resource efficiency, manifesting in diminished input requisites for labor, fertilizers, seeds, pesticides, and water, thereby augmenting farmers' economic gains.

In this study, elite DSR breeding lines underwent cultivation within a puddled DSR system across two distinct seasons (wet and dry) in the Philippines. The adoption of the alternate wetting and drying (AWD) technique, complemented by drip irrigation during maturity and the subsequent cropping phase, underscored the experimental protocol. Fertilization protocols entailed a nuanced approach, with the dry season necessitating 160:40:30 N:P2O5:K2O (in kg/ha) and the wet season

requiring 120:30:20 N:P2O5:K2O (in kg/ha). Pre-harvest fertilization, involving 163.04 kg/Ha of N and 95.24 kg/Ha of P2O5, preceded the primary harvest by seven days, with a supplementary 163.04 kg/Ha of N fertilizer applied post-harvest. Harvesting was executed uniformly at 35 cm height, 30 days post-flowering, with subsequent assessments encompassing first and second crop yields and head rice recovery. The derivation of Genomic Estimated Breeding Values (GEBVs) via multi-trial analyses facilitated the computation of a selection index, informing the identification of superior lines exhibiting stable yield and grain quality traits across both seasons in each harvest. The economic value of ratooning over the conventional rice growing approach with one and two separate plantings was calculated to understand better the suitability of this technology in the target environment.

In summary, our study allows us to standardize a ratooning protocol for the direct-seeded rice system and identify breeding lines with stable yields across harvests in the dry and wet seasons. Initial results have indicated a substantial increase in yield and a prominent genetic control underlying the ratooning capacity of breeding lines. Selected lines are currently being reevaluated and will be further shortlisted and sent to the target environment of multi-location testing.

Genetic Improvement of Aerobic Adaptation in Australian Rice

Gong, W., Vinarao, R., Proud, C., Wood, S., Snell, P., Fukai, S., and Mitchell, J.

Australian rice is currently grown under permanent water conditions to maximize yield (>10 t ha^{-1}) in the Riverina region. However, the increasing scarcity and variability of water supply have become significant constraints on production, threatening the sustainability of the rice industry. Aerobic rice production is a non-flooded but well-watered system and has been shown to improve water productivity. For an aerobic rice system to be considered as an alternative in temperate aerobic conditions, maintenance of high grain yield and tolerance to low and high temperature are required. Furthermore, putative adaptive traits such as enhanced root system architecture, high stomatal conductance (g_s), high canopy temperature depression (CTD) required exploration alongside the identification of genomic regions linked to these traits for inclusion in the Australian rice breeding programs. A *japonica* diversity set and several bi-parental populations were utilized to investigate the genotypic performance and genomic regions of traits related to transpiration, root architecture and low and high temperature tolerance under aerobic conditions. Our findings demonstrated that the yield advantage in a series of aerobic field experiments was conferred by narrow and deep roots, high g_s and the resultant cooler canopies that were maintained during the mild water deficit period between irrigation events. In total, 10 quantitative trait loci (QTL) were found to be associated with root cone angle, 6 QTL were associated with deep roots, and 34 QTL were associated with g_s, CTD and stomatal anatomical traits. There were two QTL associated with heat tolerance during flowering and 15 QTL associated with young microspore stage low temperature tolerance. Furthermore, QTL validation and marker development have been conducted for a number of QTL related to root architecture and low temperature tolerance. This research offers novel insights by establishing a comprehensive physiological and morphological framework and understanding of the genetic basis of key traits for aerobic adaptation. The integration of these identified key traits, significant QTL, and potential donors into breeding programs will pave the way for new strategies in aerobic adaptation.

Breeding Indica Germplasm for Early Sowing and Other Stresses in the Temperate Zone of South America

Sanabria, Y., Cruz, M., Corredor, E., Molina, F., Pérez, F., and Graterol, E.

Most of the rice producing areas in Argentina, Southern Brazil, and Uruguay are sowed with indica varieties, resulting in high yields. Most years Septembers offer optimal soil conditions for early direct seeding, which is the method practiced in the region. However, that month is still cold and heavy rains in October can flood the seeded fields, reducing germination rate and crop establishment. More tolerant germplasm to these early sowing conditions is needed, without risking yield, quality, and disease resistance given by indica background. Since japonica varieties are more adapted to cold and anaerobic conditions, the aim of this study was screening, along several breeding generations, germplasm from the FLAR temperate rice program that was originated from crosses where at least one japonica accession was used as a parent in the last three generations but maintaining most indica traits. To guarantee good performance of the germplasm, in terms of productivity, we previously selected the breeding lines based on yield data. Eight breeding lines originated from two different populations (FL16618 and FL16688) were identified as the best for germination under cold and anaerobic conditions (>50%). Cold and anaerobic germination were evaluated together and separately, and significant correlation was found (0.73).

Early sowing tolerant lines were crossed with FLAR, IRGA-Brazil, and INIA-Uruguay elite lines in 2021 at CIAT in Colombia. Resulting F2 populations were sowed in greenhouse and placed underwater, in controlled conditions, for anaerobic germination. Germinated Individuals under anaerobic conditions were transplanted to the field for seed production and F3 was placed in a germination room at 14°C for selection in low temperature. Selected F4 families were sowed in Santa Rosa Experimental Center in Colombia for evaluation in a rice blast hot spot. F5 families were placed under anaerobic conditions and lines with germination >50% were selected. Seed from 396 lines are being increased in Colombia for yield trials in Uruguay and Argentina in 2024/2025 growing season. Promising lines can impact rice production in temperate South America because good plant standing in early seeding will make coincide reproductive stage with the highest radiation driving to increase yields.

Mutant Rice Traits I Have Known

McKenzie, K.S.

Mutant rice traits have made some significant contributions toward rice varietal development in the United States, especially in California. A few have been selected as spontaneous mutations; however, the majority have been induced mutations using ionizing radiation or chemical mutagens beginning in the 1970s and continuing to the present. Some have directly achieved variety status, but most mutant traits have made the jump to the rice variety level through cross breeding and backcrossing to adapted germplasm. Traits have included morphological traits like semidwarf height, maturity, starch characteristics, nutritional traits, and herbicide resistance. Some mutation breeding work was done to improve rice germplasm lines with disease or insect resistance or for

genetic research with many getting registered in the USDA-ARS World Rice Collection. Over the years several have secured U.S. Plant Variety Protection, U.S. utility patents, and trademarks.

Many of these rice mutants have seen little or no use and impact. Some like the sd_1 from Calrose 76, after an initial significant varietal contribution, have just blended into the germplasm. M-401, a direct induced mutant selection with a different sd_1 allele, continues in commercial production in California after four decades. BASF's Clearfield®, a non-GMO herbicide-resistant trait for rice weed control, developed at the LSU H. Rouse Caffey Rice Research Station, has achieved global impact. It delivered financial rewards to BASF, LSU, inventor T.P Croughan, and the breeding programs and breeders developing the rice varieties with the trait. It has set the stage for RiceTec to develop and market similar herbicide resistant rice technologies with the Full Page® and Max Ace® Rice Cropping Solutions that include other mode of action herbicides. The California Rice Experiment Station is launching its own grower-owned trait (ROXY®) providing non-GMO herbicide tolerance in a partnership with Albaugh LLC, the ROXY® Rice Production System (ROXY® RPS). These herbicide tolerance traits are transforming the funding and activities of U.S. rice breeding programs. The arrival and market acceptance of "gene editing" providing "directed mutagenesis" in combination with the knowledge of the rice genome, portends an electrifying future for rice variety development.

Speed Up the Develop of Rice Varieties in Temperate Regions - Uruguay

Molina, F. and Rosas, J.E.

Speed up the breeding prosses is crucial for small programs, new techniques are essential to shorten the variety development time and obtain genetic gain. The right combination of tools can reduce cost and time. INIA's rice breeding program's target location in the south of South America is a temperate region where only one crop per year is cultivated. Uruguay average yield of the last 3 years was 9.3 t/ha, rice is grown in a crop pasture rotation, 95% of the varieties are indica types and 25-30% of the area is planted with imidazoline- resistant varieties.

Traditionally, variety development using conventional methods and a crop per year takes 12-13 years, with 6 years from F1 to F6 panicle-rows, 4 years from F7 to F10 yield plot trials and 2-3 years for seed purification and multiplication. The objective of this work was to reduce the length of the variety development process for at least 5 years (40%). To achieve that goal, we used a combination of strategies: from F1 to F4 the process was shorten in 2 years with shuttle breeding and field phenotypic selection in Northern Italy, where genotype by environment interaction with Uruguay is neglectable. The yield trials started at F5, and the seed multiplication of selected lines began at F7. The lines were genotyped with the RiCA v4. 1K SNP panel for background selection and recovery of the recipient germplasm genome. This reduced the number of lines to be tested in experimental plots. After two years of yield trials at least two cultivars were selected to begin the early seed purification.

This approach allowed us to test a greater number of lines and to reduce the variety development process in at least 5 years compared to traditional breeding.

The Effect of Haplotype Size on Genomic Selection Accuracy and Epistasis: An Empirical Study in Rice

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

Genomic selection (GS) has revolutionized breeding practices by integrating genotype and phenotype data to predict genomic estimated breeding values (GEBVs), offering the potential to accelerate breeding cycles and intensify and enhance early-stage selections. This approach relies on the concept of linkage disequilibrium (LD) between genetic markers and quantitative trait loci (QTL) within populations. LD is the non-random association between alleles at different loci and provides valuable insights into recombination rates.

This study aimed to investigate the influence of recombination on haplotype sizes and LD, assess the impact of additive (A) versus additive + epistasis (A+I) genetic models on GS prediction accuracy, and demonstrate how haplotype resolution in the training set (TS) impacts the prediction accuracy of GS. For this, we used biparental (MP2) and multiparent (MP6-8) populations, where the only difference between them was the recombination rate. Results revealed a direct relationship between LD decay and the number of recombination opportunities within populations, with smaller haplotype blocks observed in populations experiencing more recombination.

The use of A+I models increased heritability but did not improve prediction accuracy. Finally, populations with smaller haplotype sizes in the TS exhibited enhanced prediction accuracy. This study demonstrates the effect of haplotype size on GS accuracy, and its uniqueness lies in its focus on populations where the sole differentiating factor is haplotype size. It offers an important tool for breeders in designing GS strategies, providing valuable guidance for future breeding efforts.

New DYNAGRO Rice Varieties for U.S. Growers

Ouzts, S.R., Shao, Q., and Chou, N.Y.

Rice is one of the most important crops in the world and plays a very important role in daily life. Growers prefer to plant rice varieties with high yield potential, good grain quality and strong disease resistance. Farmers in the USA prefer to grow rice varieties which perform their best depending on climate and traditional culture.

Three new DYNAGRO rice varieties DG263L, DG245L and DG353M from Nutrien Ag Solutions have been released recently. DG263L with high amylose and intermediate gel temperature content, is a semidwarf long-grain rice. With very high yield potential, good grain quality and agronomics, it has been rapidly adopted on over 500,000 acres since its release. DG245L, with intermediate amylose and intermediate gel temperature, is a semidwarf long-grain rice variety showing very high yield potential in first and second (ratoon) crops. DG353M, with low amylose and low gel temperature, is a semidwarf medium-grain rice variety with high yield potential. It has shown to be comparable to Jupiter in maturity but has better agronomic traits and overall disease package.

These new DYNAGRO varieties give rice farmers more opportunities to choose and grow rice varieties in the United States.

Commercial Hybrid Rice Breeding Program in India

Gangashetti, M., Somanagoudra, C., Babu, R., Ram Kumar, S., Boreddy, S., and Pandravada, A.

The plant breeding team creates and delivers locally adapted products across Asia Pacific focusing on four main crops – Corn, Rice, Millet and Mustard. The group leverages the global breeding engine and learnings from the legacy Corn breeding program in Pioneer and brought in innovations to accelerate the rice breeding program. The opportunity of integrated products and disruptive innovation through transformative sciences are huge with a crop like rice where Asia alone accounts for 140 MM Ha of area. We discuss the commercial breeding program and its implications especially in the context of climate change, integrated product strategy and sustainable rice production system.

Back to Basics: Accelerating Genetic Gains in Australian Rice Breeding

Proud, C. and Pengilley, G.

Water is the largest limiting resource to rice production in Australia and its availability for rice is reducing due to a multitude of factors. There is a need to increase the water productivity ($/ML or t/ML) of the Australian rice industry to ensure its long-term sustainability. Rice Breeding Australia Ltd. (RBA) was established in 2022 to accelerate rates of genetic gain in breeding for the Australian rice industry and lead the transformational change to meet the water productivity target. One major goal for RBA is to rapidly improve cold tolerance of rice at the reproductive stage to reduce the need for deep permanent water, or the raising of the water to 25 cm above the surface during cold periods, which provides a significant thermal buffer to protect the developing panicle. The removal of the need for deep water will provide substantial water savings, and adequate cold tolerance will provide the opportunity to remove permanent water or ponding (flooding) all together.

One of RBA's first tasks was to establish clearly defined product profiles and resource allocation which provides definable goals and deliverables to the organization and industry. This has resulted in two broad strategies: backcrossing and modified recurrent selection. Backcrossing aims to introgress four known regions with marker-assisted selection into existing varieties to rapidly increase the level of cold tolerant varieties available to growers with a delivery goal of 6 years. Modified recurrent selection aims to improve a suit of traits (i.e. cold tolerance, lodging and anaerobic germination) which has a longer timeframe to delivery of between 10-12 years. These strategies are implemented through a clearly defined pipeline that is continually evaluated for improvement and has already completed two major changes. Major improvements in the program included removing the need for reselection, increasing the use of molecular markers, adoption of controlled environment screening for cold tolerance, improved analysis, improving accuracy and

timing of pureseed production. The major theme since the inception of RBA is getting the basics right whilst using best breeding methodologies and technology to accelerate rates of genetic gain.

As RBA establishes itself and the breeding strategy, the ever-increasing demand to improve water productivity for sustainable rice production dictates the need to explore methods to further accelerate genetic gain. RBA is currently exploring options for implementing genomic prediction as well as the integration of high-throughput phenotyping. Though early days, RBA has provided substantial change to rice breeding in Australia over the past 2 years and is ready to help transform the rice industry in Australia

Application of Gene Editing to Rice Trait Development

Radtke, J.A.

New rice cultivars, *Oryza sativa* L., have been developed over many years using conventional plant breeding. New tools, such as genetic markers, have been utilized to add precision and speed to the breeding process. The most recent tool in the breeder's toolbox is that of gene editing. Now, by precisely changing one or more nucleotides, new traits can be developed allowing the breeder to focus on developing high yielding new cultivars and adding new traits to the elite cultivars.

Cibus has successfully developed two non-transgenic herbicide tolerance traits for rice which represent new herbicides for the rice market. Both herbicides are most effective on grass weeds along with weedy and red rice. They have been tested for several years at multiple sites in the mid-South United States. The traits were developed first in an experimental rice line using the Cibus *RTDS*® gene editing process and selected using herbicide sprays after plants were regenerated. The traits were then tested in the greenhouse and then the field to confirm herbicide tolerance efficacy. Since the traits are simply inherited, Cibus backcrossed the trait into commercially relevant varieties which were tested in the greenhouse and field. Performance data suggests that the new traits will add value to a weed control program in rice.

Both traits will provide valuable new tools to growers in the United States, including the mid-South and California along with key international markets as growers continue to battle weeds in their fields. The herbicide tolerance traits will enable weed control packages applied to the crop to better control resistant weeds and volunteer rice plants.

Rice Breeding Program at University of Arkansas

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

Rice is one of the most important food crops in the world. In 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 7.2 t/ha in 2002 to 8.6 t/ha in 2021. 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 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 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 Breedbase should lead to much improved efficiency, saves in labor, and 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.

Rice Elite Cultivars with Three-Trait Pyramiding for Low GI, High Protein, and Essential Amino Acids

Badoni, S., Pasion-Uy, E., Kor, S., Kim, S., Misra, G., Tiozon, R.N., Buenafe, R.J.Q., Ramos-Castrosanot, A.R., Pratap, V., Slamet-Loedin, I., von Steimker, J., Alseekh, S., Fernie, A.R., Kohli, A., Khush, G.S., and Sreenivasula, N.

To address the growing incidences of increased diabetes and to meet the daily protein requirements enriched with essential amino acids, we developed low glycemic index (GI) rice varieties with increased protein concentration exceeding 14% protein. The development of recombinant inbred lines using Samba Mahsuri and IR36 amylose extender as parental lines, we identified quantitative trait loci (QTLs) and genes associated with low GI and high protein content (PC). By integrating QTL-seq, QTL, and targeted association studies along with classification models, this comprehensive approach identified candidate genes on chromosome 2 (qGI2.1/qAC2.1 spanning the region from 18.62Mb to 19.95Mb), exerting influence on low Glycemic Index (GI). Notably,

the phenotypic variant with high value was associated with the recessive allele of the gene involved in amylose-amylopectin alteration. The genome edited line confirmed low GI phenotype in milled rice grains. Also, combinations of alleles from the highly significant SNPs from the targeted associations and epistatically interacting genes showed ultra-low GI phenotypes with high amylose and high protein. This allowed for selection of the triple traits of low GI, high PC in high yielding, early maturity background. Metabolomics analysis of rice of the superior lines of high PC, and low GI were preferentially enriched in glycolytic and amino acid metabolism, whereas the inferior lines of low PC and high GI were enriched with fatty acid metabolism. Protein yield estimation after alkali extraction yielded was 8% for Samba Mahsuri but it was 15.99% in the high amylose high protein RIL (HAHP_101). The nearly double PC of HAHP_101 was enriched in essential amino acids like lysine. Such lines may be highly relevant for food product development to address diabetes and malnutrition. These lines represent an important breeding resource to address food and nutritional security.

CRISP-RICE: A Multi-State and Multidisciplinary Effort to Improve Sustainability of Rice Farming

Subudhi, P.K.

Rice is a major food source for more than half the world population. However, increasing rice production has been a challenge due to climate change. As a major rice exporting country, the United States contributes significantly to global food needs. Projected increases in the intensity and frequency of biotic and abiotic stresses due to climate change require a reassessment of our strategy to develop a sustainable rice farming system that aims to increase rice production with reduced production cost and environmental footprint. With support from the National Institute of Food and Agriculture of USDA, LSU AgCenter is spearheading a project entitled 'Climate Resilient Innovations for Sustainable Production of RICE (CRISP-RICE)' in collaboration with seven organizations from five states to develop green technologies and practices to benefit the rice growers of the southern United States.

The overall goal of this multidisciplinary coordinated agricultural project is to develop a sustainable and profitable rice farming system in the southern United States. The long-term objectives are to: (1) design novel genotypes with high yield and climate resilience, (2) develop and optimize management practices to minimize the use of water, chemicals, fertilizers, and energy, (3) assess the social, economic, institutional and environmental contexts that facilitate or hinder the adoption of new production practices to mitigate the impact of climate change, and (4) implement innovative educational and Extension programming to support and advance the sustainable rice farming system.

Multiple sets of rice mapping populations and diversity panels will be evaluated in greenhouse and field for various traits conferring climate resilience at different plant growth stages. Omics and phenomics data will be jointly analyzed to decipher the molecular basis of climate-smart phenotype and predict desirable combinations of parents and genes for maximizing genetic gain in traits under climatic uncertainties. Decision support tools aided will be developed for on-farm management decisions regarding pest and disease monitoring, irrigation scheduling, efficient

nutrient management technologies, as well as forecasting yield and climate-related stresses. Eco-friendly pest and disease management strategies will be explored to reduce the use of chemicals. Cultural management practices, such as alternate wetting and drying, cover crops, crop rotations, precision nutrient management, and remote and proximal sensing for monitoring and need-based application of agricultural inputs, will be evaluated to improve soil health and water quality.

The major outputs of this project are the development of climate-resilient rice cultivars and environmental-friendly production practices, which will usher in a new era of sustainable rice farming. Implementing this climate-smart approach will minimize the use of natural resources, maximize production efficiency, increase land-use efficiency, and reduce environmental footprint. Specifically, the novel rice cultivars with enhanced adaptation to climate change-induced biotic and abiotic stresses, high nutrient use efficiency, water use efficiency, coupled with implementation of precision agriculture and improved crop and pest management strategies will benefit the rice growers of the region. Strengthening the extension and outreach program will help propagate the novel climate-smart tools, technologies, practices, and resources to rice growers, consultants, and researchers successfully.

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

Tai, T.H.

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

There are two specific project goals. The first is to characterize novel traits and mutations affecting rice grain quality, productivity, and climate resiliency. This is being addressed by focusing on a small number of rice mutants with altered endosperm, cuticular wax, and silicon content traits and determining their impact on grain quality and stress tolerance. Bulked segregant sequencing-based approaches (e.g., QTL-seq, MutMap) are being employed to identify the underlying mutations for several of these mutants. The second is to transfer useful rice mutants and populations to the U.S. rice germplasm collections for public distribution to basic researchers and plant breeders, thereby leveraging the genetic variation in these resources to address global food security. Seeds from advanced generation rice mutants and populations derived from three japonica rice varieties are being produced for submission to ARS rice gene banks along with selected phenotypic data to engage the rice community and other potential users. A combination of traditional evaluation and image analysis (e.g., multi and hyperspectral imaging, remote sensing) is being employed to collect trait data.

Completion of the project goals will generate novel genetic resources and associated information for improving rice quality and productivity. Results of this research will contribute to efforts aimed at sustaining and strengthening temperate rice production, the face of climate-driven challenges.

Exploring Morpho-Genetic Variabilities in Diverse Rice Germplasms for Ratooning Enhancement

Talukder, S.K., Singh, G., Shaik, R.Y., Mondal, S., Samonte, S.O.P.B., Harper, C.L., Pradhan, A.K., and Elumalai, P.K.

Rice is the most important crop in the World which is susceptible to cold temperatures, at germination, early seedling, and reproductive stages. Germination at low temperature and seedling cold tolerance (SCT) in rice are important traits for early planting, as well as ratooning in Texas and Louisiana. The study was conducted to explore suitable germplasm and molecular markers to integrate and enhance rice breeding for both main and ratoon crop yield. A set of 206 diverse rice accessions were evaluated for shoot and root traits under three environmental conditions, i.e., natural cold (NC) conditions in outdoor, cold conditions in a growth chamber (GC), and normal temperature conditions in the greenhouse. In each experiment, the number of seedlings emerged at 6DAP (days after planting), 8DAP, and 12DAP, seedling length at two weeks (SL), root length, root surface area, root diameter, root volume, and root forks data were taken. Wide variation was observed among the accessions for all the measured traits. The emergence at 6DAP under NC and GC ranged 0.0-4.4% (average 0.2%) and 0.0 to 66.7% (average 20.6%), respectively. SL ranged from 2.09 to 7.39 cm with an average of 4.24 cm under NC and 1.00 cm in GC condition. Among the evaluated accessions,1.47% had SL of 5.99-7.97 cm under NC conditions. The average root diameter was 0.26 mm with an average fork number of 966.7 and root tip number of 1009. GWAS analysis using 800,000 GBS-SNPs identified 198 significant marker trait associations (MTAs). Among which 38 MTAs were pleiotropic. Blasting the MTAs associated sequences identified available genes in the region contributes to cold tolerance including “Os06g0585950” and DUF247. Germplasms, i.e., Panda, NSF-TV 107, R 67, and Yong Chal Byo, were found having higher germination ability and seedling growth under low temperature compared to U.S. check varieties. Identified germplasm and candidate molecular markers will be used in future rice breeding programs for developing rice varieties with seedling-cold-tolerance for higher ratoon performance.

Transforming Rice from Being Perceived as a "Bad" Source of Carbs to a "Good" One through the Introduction of High Protein and Low Glycemic Cultivars

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Carbohydrates are the primary fuel source for the human body. Both the brain and muscles rely on carbohydrates or glucose for energy. The brain utilizes five grams of glucose per hour, totaling 120 grams per day. Rice is an affordable source of carbohydrates. A single cup of rice supplies 45 grams of carbohydrates. Rice, however, generally has a high glycemic index (GI) of 73 and belongs to a high GI food group. When individuals consume high GI carbohydrates, there is a significant spike

in blood glucose concentration, leading to an increased demand for insulin. While this is manageable for healthy individuals, those with diabetes struggle to address these spikes due to inability to produce enough required insulin. In individuals with diabetes sugar from food lingers in the bloodstream, causing consistently high blood sugar levels. If left untreated, this condition poses long-term risks such as nerve damage, kidney disease, and cardiovascular issues. Consequently, individuals with diabetes need to diligently manage their condition, which may involve medication or insulin injections. People with diabetes are, therefore, advised to avoid rice. The introduction of a new type of rice, high in protein and low in glycemic index, provides a safe option for individuals with diabetes to enjoy rice once again. This innovative rice is transforming its reputation from a perceived bad source of carbs to a health-conscious choice. The first of its kind, the low-GI high-protein rice was developed in the United States and is now available in the market. Additional diabetes-friendly rice lines are on the horizon. Among the new options, the advanced lines LGR20182 and LGR20191 boast glycemic indices of 42±7 and 45±6, along with protein contents of 11.4±1.4% and 11.8±1.1%, respectively. These long-grain, semidwarf advanced lines mature early (83-85 days), show moderate susceptibility to rice blast, and are susceptible to sheath blight. Their yields of 7,132 lbs/A and 6,955 lbs/A, respectively, surpass that of the first released cultivar Frontière. These advanced lines exhibit excellent grain quality, high amylose content, and intermediate gelatinization temperature. These low-GI rice opens a new avenue for managing diabetes, a condition impacting over 500,000 individuals in Louisiana, 38.4 million in the U.S., and a staggering 422 million globally.

Progress in Development of Salt-Tolerant Rice Varieties for South Carolina

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Rice cultivation in South Carolina (SC) enabled the state to develop an economy based on agriculture in the eighteenth and nineteenth centuries. Through a series of political and economic events, as well as natural disasters, this rice industry collapsed more than a century ago. However, traditional rice cultivation continued to persist on a smaller scale. In recent years, there has been a significant resurgence of interest in rice as a food and cultural artifact in SC. Rice cultivation has begun to increase in both acreage and value, but the freshly renewed industry faces significant challenges, including saltwater intrusion and weed infestation in potential rice-growing areas. The premiere rice cultivar in SC is Carolina Gold, a salt-sensitive and less weed-competitive cultivar. This research prioritizes validating a salt-tolerant rice variety with superior weed-competitive traits for commercial production in SC.

This research is conducted in collaboration with USDA-ARS Dale Bumpers National Rice Research Center (DBNRRC) at Stuttgart, Arkansas. Based on preliminary experiments done by Clemson researchers with DBNRRC consultation, a panel of 12 cultivars/germplasm was created. This diverse germplasm panel was screened in Clemson University greenhouses to evaluate the impact of varying ocean water concentrations and native weed pressure on the rice plant vigor when grown organically under controlled environmental conditions. Top-performing cultivars/genotypes under these conditions were further tested in organic research plots by supplementing irrigation with tidal ocean water. Research efforts are being made to develop high

yielding 'Carolina Gold' type rice breeding lines with salt tolerance and desirable agronomic traits for organic production in South Carolina.

In this direction, 'Carolina Gold,' which is a highly desirable variety for organic production in this region, crossed with 'M202' and Doble Carolina, which were identified in preliminary experiments at Clemson University as the most salt-tolerant germplasm in the USDA mini-core collection. Approximately 250-300 BC1F1 'Carolina Gold' type rice lines are being developed and will be evaluated for salt stress screening and then advanced the generation to F6/F7. In addition to advancing the selected line, another important goal is to identify Quantitative Trait Loci (QTLs) associated with salt tolerance, which allows for the understand of the genetic basis of salt tolerance and can provide valuable insights for future breeding efforts. Finally, two to three top performing lines, based on salt tolerance and agronomic traits, will be selected for germplasm release. The outcomes of this research are foundational to successfully establish organic rice production in salt intruded coastal SC land.

Introgression of Blast Resistance Genes, *Pi9*, *Pi35*, *Pi2-A35* into Temperate Japonica Rice Varieties

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Rice blast, a prevalent disease in temperate rice-growing regions globally, poses a significant threat to rice cultivation. The deployment of rice varieties enhanced with broad and durable blast resistance represents a pivotal strategy for effective disease management. In this study, we focused on the development of introgression and pyramided lines targeting five tropical-japonica varieties—namely, IRRI142, IRRI152, IRRI157, IRRI202, and IRRI236—that exhibit adaptability to temperate conditions. These varieties were chosen as recipients for the introgression of three blast resistance genes, namely *Pi9*, *Pi35*, and *Pi2-A35*, known for conferring both complete and partial resistance. Genotypic and phenotypic analysis utilizing diagnostic DNA markers specific to the five resistance genes and differential blast isolates indicated the potential presence of *Pi35* and either *Pi9* or *Pi2-A35* in the selected varieties. However, to enhance the durability of blast resistance, the pyramiding of at least two gene(s) absent in these varieties was deemed necessary. The targeted resistance gene was individually introduced through marker-aided backcrossing. The F_1 progenies exhibiting resistance was selected for backcrossing using a dominant DNA marker. From BC_1F_1 to BC_4F_1 generations, suitable polymorphic molecular markers were used and employed for selecting resistant progenies. A total of 23 and two cross combinations of introgression lines were at BC_4F_1 and BC_3F_1, respectively, in 2023 wet season. There were also 14 cross combinations for the pyramided lines at BC_1F_2 in 2023 wet season. The selected BC_4F_3 and B_1F_3 homozygous resistant introgressed and pyramided lines, respectively, that display phenotypic similarity to the recipient parent will be advanced to BC_4F_4 and BC_1F_4. The selected lines will undergo rigorous selection by molecular markers and artificial screening against different blast isolates to further confirm its resistance. Field evaluations are also necessary to assess its durability to rice blast and improve its morphological traits.

How Did FGB Help in Zhong-Nong-Geng (ZNG) Series of Early Temperate *Geng* / *Japonica* Rice Breeding in China

Zheng, T.

Nowadays, temperate *Geng* / *japonica* rice, especially early-matured type, is becoming more and more important in China's food security system. The planting area for early temperate *Geng* / *japonica* rice is around 4 million ha per year in Heilongjiang (HLJ) province of China, which is about 2.6 times of the total rice planting area in Japan. For this global largest early temperate *Geng* / *japonica* rice planting area, maturing time and adaptabilities against multiple environmental stresses including typhoon, low temperature and blast disease are now major breeding targets. In an era of big data and genome-based breeding, what can be done for rice?

1) Break through the TPS bottleneck in application of *Pigm*

In breeding practice, we found that when breeding lines were crossed to XQ62, a donor for major gene *Pigm* against rice blast with early rice background, the progenies showed transgressive photosensitivity (TPS), which largely constraints wider application of *Pigm* gene in early rice breeding. By genome mapping, we found a photo-sensitivity module [*qHd6*+*qHd7*], of which *qHd6* is closely linked to *Pigm*. Haplotype analysis with FGB showed that allelic variation existed within early rice. We developed a molecular marker set, [M80410+ZLM7-1] for this TPS module. Prediction effects of TPS in F_1 progenies was averagely about 88.6%. By editing the candidate genes of for this TPS module, we got potential breeding materials carrying *Pigm* without TPS for early rice breeding.

With marker aided selection for *Pigm*, we have developed a new cultivar name ZNG 9, which is going to be approved to be released in HLJ in 2024.

2) Transgressive variations may be created by BC breeding

Dominant early maturity or dominant early heading (DEH) without yield penalty is of high breeding value, especially for early rice. We developed a near-isogenic DEH line without yield drag named DEH_229 by sister-line backcross (BC) breeding with Minghui 63 (MH63), a wide-adapted restorer, as the genetic background. DEH_229 harbors only 1.06% variation in the genome sequence relative to MH63. Using QTL mapping by sequencing (QTL-seq) 57 loci were detected. Joint mapping employing GWAS with accessions from the 3,000-rice genome sequencing project (3K-RG), reduced the number of QTL by 43.9%. Using FGB, the number of SNP cluster regions within the QTL regions reduced by 27.3%. Further comparison of the genome variation between DEH_229 and MH63 in addition to gene annotation information revealed a new DEH allele of *DTH3* with multiple variable sites as a possible major factor underlying the DEH phenotype. An InDel marker, ZMEH_1, was designed and explained about 86.0% variations under both SD and LD conditions in randomly chosen progeny derived from extreme lines of MH63 × DEH_229.

3) Cultivar bases -- ZNG11 and ZNG18

For HLJ targeting area, our group has developed new cultivars based selective introgression / pyramiding breeding strategy. For example, Zhong Nong Geng 18 (ZNG18) and Zhong Nong Geng 11 (ZNG11) are both with high yield potential. ZNG18 is 7.4% higher than control Longgeng 31 in RYT for continuous three years. The grain yield of ZNG11 reached more than 11 tons per ha at HLJ in 2022. Interestingly, ZNG11 is more tolerant against lodging, while ZNG18 is more tolerant under blast and cold stresses. On these bases, three types of new cultivars have been developed by bio-technology breeding, e.g. blast resistance by *Pigm* by marker aided introgression, grain quality improvement by CRISPR, and cold tolerance by pyramiding and CT screening. We have also tried editing with the DEH candidate gene in ZNG 11 and to see whether this can be adopted in breeding practices. On this ZNG cultivar based more elite target traits such as water use efficiency could be pyramided if more responsible genes could be dissected in the future.

A new line named ZNG 5205 has been developed based on our above basic parents. It not only incorporates disease resistances of ZNG18 and lodging resistance of ZNG11 but also possesses transgressive cold tolerances.

4) Two versions of FGB correlating phenotype and haplotypes

Germplasm is one of the most important material bases for breeding. After genome sequencing, how to correlate haplotype to phenotype remains a challenge facing breeders. When big genotypic dataset such as the 3,000-rice genome (3K-RG) are becoming open through various platforms, one-stand solutions which could offer user-friendly web services for users with overwhelming phenotyping data based on the sequenced genomes are sincerely desired. We introduced the Rice Functional Genomic and Breeding (RFGB) toolkit, version 2.0 (https://www.rmbreeding.cn). It includes five major modules, which are: Phenotype, Haplotype, SNP & InDel, Restore Sequence, and Germplasm. Among them, Haplotype is one of the most popular modules for users. Then, we extend our FGB strategy and set up the SoyFGB v2.0 (https://sfgb.rmbreeding.cn/) as an example for a general 'omics' data sharing mode for one of the crop germplasm collections which is under strict control for data sharing. More on-line tools are provided to analyses the correlations between phenotypic and haplotypic variations at different genome resolutions with FGB or user-owned unpublished phenotypic data. According to users' test, mining haplotype variations with FGB, the efficiency would be largely improved (of about 60 x) in comparing to work manually by Excel. Global visiting for FGB is more than 10K per year.

Just as the words say, *all roads are leading to Rome*, our breeding attempts with ZNG series of early temperate *Geng* / *japonica* rice are aiming a same target for a better world by temperate rice.

Assessment of the Genetic Basis of Allelopathy in *japonica* Rice Cultivated in Temperate Regions Using a Genome-Wide Association Study

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Allelopathy, considered as the ability of certain plants to release chemical compounds that affects the development of other organisms, has been contemplated as a natural method of weed control in rice. Weeds, in their competition for nutrients, moisture, and light, diminish rice yields and they constitute an increasing problem in many rice fields. Despite the nature of allelochemical compounds that have been studied, little is known about the genetic basis underlying allelopathy. However, it is known that rice exhibits diverse allelopathic potentials across varieties, and breeding for rice plants exhibiting allelopathic potential would be highly desirable. Plants exhibiting allelopathy would help to reduce the presence of weeds in paddy fields as they would display an advantage against weeds. In this sense, knowledge of the gene factors and the identification of the genomic regions responsible for allelopathy would facilitate breeding programs. Taking advantage of the existing genetic diversity in rice, we assessed the allelopathic potential of a collection of *japonica* rice adapted to temperate regions and identified varieties that can inhibit the root growth of barnyardgrass when co-cultured. Employing a Genome-Wide Association Study, we identified four Quantitative Trait Loci, with the most promising loci situated on chromosome 2 and 5. Subsequent inspection of the genes located within these QTLs revealed genes associated with the biosynthesis of secondary metabolites such as *Phenylalanine Ammonia Lyase* (*PAL*), a key enzyme in the synthesis of phenolic compounds, and two genes coding for R2R3-type MYB transcription factors. These results suggest the involvement of phenolic compounds in allelopathy. The identification of these two QTLs associated to allelopathy in rice provides a useful tool for further investigation and targeted breeding strategies.

CULTURE AND SOIL SCIENCE – ORAL PRESENTATIONS

Irrigation and Phosphorous Fertilization Managements to Minimize Rice Grain Arsenic Content

Campos, F., Roel, A., Carracelas, G., Verger, M., Huertas, R., and Perdomo, C.

This research project was focused in minimizing inorganic arsenic levels in polished rice grain while maintaining crop yield and water productivity of the most planted *Indica* cultivar in Uruguay, INIA Merin. Two experiments were conducted during seasons 2018-2019 and 2019-2020. A split-plot experimental design with three blocks was used to test five irrigation treatments applied in main plots and two phosphorous fertilization treatments were applied in subplots. Irrigation treatments consisted in a control traditional continuous flooded (CF) and four alternative irrigation techniques (AIT) with one or two drying events during the crop cycle. Phosphorous fertilization treatments were an unfertilized control with 0 kg P_2O_5 ha^{-1} and the traditional fertilization practice commonly used in commercial farms of 50 kg P_2O_5 ha^{-1}. Accumulated inorganic arsenic in grain was below international maximum levels in all analyzed samples, with an average value of 0.084 mg kg^{-1}. Alternative irrigation treatment with two drying events, implemented at panicle initiation and full flowering stages, was the most effective irrigation treatment in reducing inorganic arsenic accumulation in grain, without neither affecting grain yield or water use. Cadmium rice grain levels that can potentially increase under this irrigation treatment were also well below international maximum levels. This irrigation technique could be considered as an alternative management to the traditional continuous flooded in order to reach minimal inorganic arsenic accumulation in grain to either attend special quality standards or specific market requirements.

Optimizing Rice Crop Management: Assessing Multispectral Images for Irrigation and Nitrogen Monitoring

Carracelas, G., Marchesi, C., Ballester, C., Roel, A., and Hornbuckle, J.

The rice sector is facing the challenge to keep increasing rice yields while maintaining or improving input use efficiency. Nitrogen and water are the main limiting factors to close the gap between actual and potential grain yield. Uruguay has room in specific areas to further increase the already registered high yields and resource use efficiency. The purpose of this study was to investigate remotely sensed indices that could provide useful information for optimizing rice crop management.

The study was conducted in the North experimental unit of Uruguay over the 2022-23 rice season. A split plot experimental design featured two irrigation treatments (main plots): traditional early continuous flooding and safe alternate wetting and drying until the start of the reproductive period. Nitrogen fertilization treatments (split plots) included no nitrogen, recommended rate based on soil analyses, and two additional doses (50% below and above recommendation). Multispectral images were collected at various phenological stages, with a specific emphasis on tillering and panicle initiation. Ground truth crop parameters, including biomass, nitrogen content, Greenseeker

readings, and SPAD measurements, were collected to assess correlation with calculated vegetation indices (VIs).

This research has shown that the recommended nitrogen fertilization rate based on soil analyses, determined the highest yield with no statistically significant differences with the fertilization 50% above it. Alternative irrigation did not reduce grain yield in comparison with the traditional flooded technique. VIs that uses the red edge band were more sensitive to detect crop differences due to fertilization management. This study indicated that it is possible to obtain high rice yields while optimizing water and nitrogen use. The findings are important to assist rice farmers in selecting sensitive and effective VIs for real time remote crop monitoring and management optimization.

Long-Term N-P-K Balances and N Use Efficiency in Contrasting Rice Rotations

Castillo, J., Macedo, I., Bordagorri, A., Roel, A., and Terra, J.A.

The maintenance of an adequate soil nutrient status is crucial for ensuring food security while avoiding nutrient imbalances, mining, or enrichment that may lead to environmental damage. In Uruguay, the traditional rice-pasture rotation, allowing for direct livestock grazing, has gradually shifted towards more intensive rotations over the last decade, primarily adopting a rice-soybean rotation. This has given rise to issues pertaining to the necessity of reviewing the fertilization strategy and assessing its long-term impact on crop yields and nutrient balances associated with these new intensive rotations.

To address these questions, we evaluated three contrasting rotations in a long-term experiment: a) rice-pasture (RI-PAST, involving two consecutive rice crops with *Lolium multiflorum* Lam. used as a cover crop between both crops, followed by three years of improved pasture grazed with lambs), b) continuous rice-soybean (RI-SOY), and c) continuous rice (RI-CONT). The latter two rotations included *Trifolium alexandrinum* L. as a winter cover crop. Fertilization followed a sufficiency level approach for the rice-pasture rotation and a maintenance approach for the other rotations, with soil nutrient levels built up at the start of the experiment. We quantified nitrogen (N), phosphorus (P), and potassium (K) balances, nitrogen use efficiency (NUE), and soil nutrient trajectories (0-20 cm) over 11 years, considering nutrient inputs and outputs. Major P and K inputs primarily consisted of fertilizers, while for N, atmospheric depositions and biological fixation were also considered. Outputs for P and K accounted for nutrients removed in grain and meat, while N outputs also considered losses, estimated based on the DNDC model. Calculations for NUE considered the N removed in food products in relation to all N inputs.

For rice, the common crop in all rotations, grain yield was higher in RI-SOY and RI-PAST compared to RI-CONT over the entire period. Nutrient inputs were greater in RI-CONT followed by RI-SOY and RI-PAST, while nutrient outputs were greater in RI-SOY and RI-CONT compared to RI-PAST for the entire rotation. This resulted in positive P and K balances in all rotations, with RI-CONT and RI-SOY reaching higher balances than RI-PAST. Regarding N, the balance was highly positive in RI-CONT, highly negative in RI-SOY, and approximately neutral in RI-PAST. Despite positive P and K balances in RI-CONT, available nutrient trajectories showed a decrease in the soil solution. For RI-SOY, there was a positive trend for P and a negative trend for K when comparing the beginning and end of the period. In RI-PAST, soil P and K maintained a steady state

throughout the period. Notably, RI-PAST was the only rotation achieving optimum NUE, whereas NUE was very high in RI-SOY (associated with soil N mining) and low in RI-CONT (linked to potential negative environmental issues).

This type of research is crucial when defining more intensive rotations, involving the identification of practices, management techniques, and optimal timing aimed at sustaining grain yields and soil nutrient status. The goal should be oriented towards avoiding excessive nutrient loads that could lead to low nutrient use efficiency, potential negative environmental impacts, and unnecessary costs.

Soil Phosphorus Availability for Rice in Water-Saving Systems

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Phosphorus (P) is a major nutrient for rice, characterized by a limited mobility in soil systems because of its strong retention affinity towards minerals, like iron (Fe) (hydr)oxides. Thus, the investigation of the rhizospheric mechanisms that govern P availability is of primary importance for improving the sustainability of rice agroecosystem. Together with nutrient use efficiency, currently water shortage combined with the need of mitigating methane emissions require new water management practices (i.e. wet seeding and alternating wetting and drying) that are going to replace the traditional continuous flooding. In submerged paddy soils, the rhizosphere cycle of P is strongly influenced by the formation of root Fe plaque, which represents an important sorbing site for P. The increasing application of water-saving techniques may strongly modify Fe plaque composition, crystallinity degree, evolution, and the related impact on P retention and release to plant uptake. However, scant attention has been paid to assess the role of Fe plaque to act as a sink/source of P for rice plants as a function of water management techniques. We, therefore, aimed to investigate the effects of water management techniques on Fe plaque crystallization, forms of P retained by these surfaces, and the availability of P retained by plaque for rice plant uptake.

Rice plants were wet seeded in mesocosms filled with a paddy soil characterized by a low P supply and subjected to continuous soil flooding (WFL) vs alternating wetting and drying (AWD) irrigation combined with two levels of P fertilization. Fe and P in the porewater were monitored during plant growth. Plants were sampled at different stages of rice development, and on roots, sequential wet chemical extractions were applied to investigate the temporal evolution of Fe plaque crystallization. The forms of P retained in the plaque were analyzed by P-XANES and FT-IR spectroscopy.

Our findings showed that porewater chemistry influenced Fe plaque formation and crystallization processes depending on Fe(II) availability and P:Fe molar ratio of the soil solution, since the higher P:Fe observed in AWD compared to WFL resulted in lower Fe plaque crystallization. The P speciation in Fe plaque did not differ between the two water management techniques, albeit different proportions of inorganic over organic P were observed during the growing season. In all cases, the percentage of organic P increased during rice growth to the disadvantage of inorganic P, which was instead progressively depleted from Fe plaque. Such an effect was particularly evident

in AWD where the P contained in the plaque positively correlated with plant P uptake, suggesting a greater P availability compared to WFL. We can infer that the greater P:Fe molar ratio of porewater during AWD favored the formation of Fe(III)-phosphate coprecipitates rather than the P sorption on Fe oxides minerals as observed in WFL. The presence of P within the Fe mineral structures was related to a lower degree of crystallinity and a faster dissolution of Fe plaque in AWD, thus explaining the higher availability of P retained in plaque. These results indicate the complex spatio-temporal fluxes of P from the bulk soil to the root surface. The amount of Fe plaques formed on the root surface and their crystallinity degree can explain the mechanisms that regulate their potential in P retention/release and the consequent effects on plant uptake. Surprisingly, although AWD should decrease the concentration of soluble P, the less crystalline plaque may be a better source of P for plant with respect to WFL. These results can help to define new agricultural decision support systems to improve water and nutrient management technologies, fine-tune resource utilization and environmental protection for a greater sustainability of rice agrosystems.

Flood- and Furrow-Irrigated Rice Response to Phosphorus and Potassium Fertilization

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Efficient fertilization recommendations depend upon our knowledge of how nutrient deficiency influences crop yield and our ability to diagnose deficiency either with timely soil or plant analysis. Changes in rice (*Oryza sativa* L.) crop management practices, such as irrigation (flood vs furrow), have a direct impact on soil nutrient dynamics which may require adjustments in fertilizer-phosphorus (P) and -potassium (K) rate recommendations. Recently, critical Y-leaf-K concentrations were defined for pure-line rice cultivars in Arkansas, but no research has been performed to identify how effective in-season K fertilization is in correcting K deficiency and rescue yield potential. The objectives of this research were *i)* to evaluate flood- and furrow-irrigated rice yield response to fertilizer-P and -K rates, and *ii)* to determine flood-irrigated rice yield response to fertilizer-K application rate and time. Research was performed in 2023 at the Pine Tree Research Station, near Colt, Arkansas. Diamond rice cultivar was planted on a Calloway silt loam with Low soil-test P and K, and flood-irrigated. For furrow-irrigated rice, RT7521 cultivar was planted on a Calhoun silt loam, with Very Low soil-test P and K. Fertilizer rates (0, 34, 67, 101, 135, and 168 kg P_2O_5 or K_2O ha^{-1}) were applied preplant and incorporated in both P and K rate response trials. For the K timing trial, fertilizer-K treatments consisted of 67 and 135 kg K_2O ha^{-1} applied preplant incorporated (PP), pre-flood (PF; V5), three weeks post flood (3WAF), R2, 50% PP and 50% PF, 50% PP and 3WAF, or 50% PP and at R2, plus a nonfertilized control. There was a positive yield increase to P and K fertilization in both irrigation systems. Overall, the greatest yields were observed with K rates equal to or higher than 34 kg K_2O ha^{-1} in the flooded rice and 67 kg K_2O ha^{-1} in the furrow-irrigated rice. A similar trend was also observed for the P trials, where the 34 and 67 kg P_2O_5 ha^{-1} rates maximized grain yield in the flood- and furrow-irrigated production systems, respectively. Although the grain yield of the flooded rice was greater, these results suggest that furrow-irrigated rice is more responsive to P and K fertilization. There was a significant yield increase with K fertilization in the K timing study, with the 67 kg K_2O ha^{-1} applied

at 3WAF and PF and the 135 kg K_2O ha^{-1} applied at 3WAF, PF, and R2 producing equal yields to the 135 kg K_2O ha^{-1} applied PP. Preliminary results show that furrow-irrigated rice is more responsive to both P and K fertilization than flooded rice and that producers have flexibility to correct K deficiency symptoms in flood-irrigated rice with in-season K fertilization if timely diagnosed with tissue analysis.

Managing the Rice Crop under Full Autonomous Irrigation

Ford, R.L.

Drill sown rice in Australia is traditionally grown under initial Alternate Wetting and Drying Conditions (AWD) to the Early Tillering Phase, where the water management transitions to a Fully Inundated state. The rice crop will remain inundated to a level between 50 mm to 100 mm above soil surface until just before Early Pollen Microspore (EPM), where water levels are gradually lifted to a level of at least 250 mm to coincide with EPM.

Water control is traditionally done using a bankless channel layout with manually operated checks that are monitored daily by human surveillance.

This project aims to connect soil moisture monitoring and soil moisture predictions with automated irrigation systems from end to end to eliminate human error, improve Water Use Efficiency (WUE), and improve labor efficiency. The project is split into three (3) key objectives: 1. Introduce connectivity between soil moisture monitoring and irrigation ordering systems, 2. Initiate irrigation with known moisture stress triggers, and 3. Introduce automated irrigation (start/finish) with full "hands off" technology.

A crop of medium-grain variety V071 was selected for the project to be grown in the 2023/24 rice season on an 8.0-ha trial field with two 4.0-ha bays. A reticulated re-use system was in place to capture early drainage from AWD events and utilizing any rainfall excess.

Technology for the water control was supplied by Rubicon Water utilizing the Farm Connect® software system which was remotely controlled and monitored by the project leader.

Results thus far have shown that water levels have been controlled within a 25-mm operating margin for the duration of the project.

Water use figures the V071 rice crop was grown using 11.8 ml/ha of water and yield expectations of 13 ton/ha.

This research is critical in bridging the gap between availability of farm labor and allowing focus on other farming operations.

No-Till and Nitrogen Management Strategies: Planting into a Stale-Seedbed of Sacramento Valley's Rice Fields

Godbey, M.

No-till agriculture is gaining traction as a conservation management approach, offering potential advantages such as reduced soil erosion, enhanced soil health, lower production costs, earlier planting, and sustainable long-term crop productivity. While widely adopted in various agricultural contexts, the application of no-till methods in rice farming is not as prevalent. Previous studies have presented inconsistent yields, emphasizing the need for further investigation to understand the limiting factors. Conducting additional research will contribute to a deeper understanding of these constraints, enabling more informed decisions for refining future rice farming practices. This study specifically explores a modified no-tillage system, where field preparation occurs during the fallow summer period. We are assessing the feasibility of directly flooding and air-seeding these stale seedbeds in the following year without additional tillage both on-farm and on-station. This study aims to evaluate and compare nitrogen management practices in no-till and conventional till systems in order to achieve maximum yields. Data were collected from six on-farm sites throughout the Sacramento Valley in 2022 and 2023 and from a replicated trial at the Rice Experiment Station (RES) in 2023. At each of on-farm sites over these two years, 1-acre portions of the growers' fields were marked off with a no-till area directly adjacent to an area that was conventionally tilled. At the RES, four basins (replications) were managed with the same no-till and conventional treatments as the on-farm trials. Nitrogen rate trials, pest, and weed monitoring areas were set up in each system at all sites. Preliminary data shows that overall, conventionally tilled rice had higher yields than no-till rice, but both system yields reached maximum yield at 175 lb N/acre. Additional findings indicate potential differences in weed and pest pressure between the two systems, with an overall higher percentage of stem rot, aggregate sheath spot, and watergrass, found in conventional till than no-till. This data will be supported by the yields, weed, and pest pressure data from the RES systems site.

Environment and N Rate Effect on Rice Quality Parameters of California Calrose Varieties and ROXY Lines

Harrell, D.L., Zhang, Z., DeLeon, T., Maulana, F., Sharma, N., Zaunbrecher, G., McKenzie, K., Shelton, C., and Linquist, B.

Previous research has shown that genetics and environment are two major factors that can affect rice grain characteristics like milling potential, taste, protein, and amylose content. Agronomic practices like nitrogen (N) fertilization rate can also influence these characteristics. Previous research has shown that increasing the N fertilization rate will also increase the protein content of rice grain and subsequently reduce the taste value. These parameters are often evaluated by rice marketers and buyers of Calrose varieties using the Satake taste instrument. Limited data exists on the extent of variation that can be expected of California Calrose and ROXY lines when grown under variable environments or agronomic practices. The objectives of these studies were to evaluate milling potential, taste value, protein content, and amylose content of Calrose varieties

and ROXY lines varieties when 1) they are grown in multiple environments or 2) a single variety is grown, and the N fertilization rate is varied.

The first trial evaluated six Calrose rice varieties and ROXY lines for quality across seven environments (locations) in California in 2022 and 2023. Varieties included M-105, M-206, M-209, M-210, M-211, and M-521 (a ROXY line). The second trial evaluated M-206 when grown using six different N fertilization rates at the Rice Experiment Station in 2022 and 2023. Nitrogen fertilization rates evaluated were 0, 90, 120, 150, 180, and 210 kg N ha^{-1}.

Understanding the effects of cultural practices and environmental conditions on grain quality is critical to maximize grain quality of California Calrose varieties.

Lessons from a Yield Contest in a High Yielding Environment

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With demand for rice increasing, rice productivity also needs to increase. Knowing the yield potential of an environment is important. It is critical for analysis of yield gaps where the yield potential is one factor in determining the yield gap. It is also important for farmers and breeders. The yield potential is often determined using models; however, yield contests also provide good estimates. Yield contests also provide a very good way of identifying how to achieve high yields, provided the correct information is gathered. From 2015 to 2023 (not in 2022), the University of California Cooperative Extension ran a yield contest. Briefly, farmers entering the contest identified a field and an area within that field for the contest. The field had to be grown to a commercially available medium-grain rice. A minimum of 1.2 continuous hectares were required for the harvest (usual 1.5 to 2 ha were harvested). Harvests were supervised by researchers to ensure quality. The exact area of harvest was measured, and the grain was taken to a dryer facility where yield and moisture were determined. Final yields are reported at 14% moisture, and the dockage (residue/chaff in grain) was also accounted for. At time of harvest, farmers provided information on their field and management practices. In 2018, we also began taking samples for yield component analysis. The Sacramento region was divided into three regions based on differences in yield potential, and growers within each region competed among themselves. Overall, we had 87 contestants participate. Yields ranged from 10.3 to 15.4 t ha^{-1}. Our analysis shows that the primary factors affecting yields were the year, region was grown in valley, variety duration (long vs short), planting date, and the base herbicide program used. In this presentation, we will be discussing these results further, along with how these results compared to statewide average yields.

Novel Climate Smart Rice Production System Based on SRI and New Varieties in Chile for Climate Adaptation

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Rice production faces multiple increasing risks linked to climate change (extreme weather, water scarcity, GHG emissions), as well as the reduction of arable land and the high cost of critical inputs (seed and agrochemicals), among others. Rice is important for food security, but in Chile, national production does not meet demand and the growing challenges are reducing number of rice producers.

Since 2017, INIA Chile and IICA have been working on developing a new rice production system, adapting principles of the System of Rice Intensification (SRI) to Latin American paddy rice fields and integrating new rice varieties. The Climate Smart Rice System (CSRS) is based on low seeding density (less than 70 kg/ha), drill seeding (30 cm between rows), mixed weed control (lower herbicide use combined with mechanical control), soil aeration, and intermittent irrigation during the complete rice life cycle to avoid flooding and GHG emissions. To develop the system, a participatory co-innovation methodology was used. Six Participatory Innovation Groups (GIP) were created in 2021, which included farmers, researchers, extensionists, and farm advisors in the Maule Region and Ñuble Region, which together cover 100% of the Chilean rice production area. Last season (2022/2023), one hectare of CSRS was established in the paddy field of a farmer from each GIP. Three temperate japonica rice varieties were used (Jaspe FL INIA, Quila300502, and Zafiro INIA), two new cultivars (early maturing varieties), and one widely cultivated traditional variety. All fields were managed by adapted agronomic practices of CSRS, defined in participatory workshops with each GIP. Group discussion sessions were held throughout the crop cycle to evaluate the performance of the new system, identify challenges and benefits, and compare it with the conventional rice production system of each farmer. All fields established on time (before October 15) yielded more than 8 t/ha using 50% less water, 60% less seed, and reduced amounts of fertilizers and herbicides compared to conventional production systems using pregerminated seed, drill seeding, and flooding.

Results demonstrated multiple agronomic, environmental, and economic benefits, including addressing the major limitation of water availability for rice production in Chile and should be scaled up.

New Rice Cultivar Tolerance to ACCase-Inhibitor Herbicides

Marchesi, C.E

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In the last decade, the evolution of herbicide-resistant weeds, especially barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), to acetolactate synthetase (ALS) inhibitor herbicides, has accelerated. Although this happened in more intensive systems and those associated with imidazolinone-resistant rice, an increase in the use of other modes of actions has augmented, mainly acetyl-coenzyme A carboxylase (ACCase) inhibitors, also known as grass herbicides.

Uruguay major rice production is based on *indica* subtypes, which can be affected by some grass herbicides, as profoxydim. Reported injuries have been received at plot and field scales in different years or zones associated with cold or cloudy springs and more susceptible cultivars. Even though the actual ACCase herbicide tolerance of the main *indica* varieties planted in the country is known, two new high productive, blast resistance cultivars are being released soon. This research focused on the analysis of the new cultivars ACCase herbicide tolerance. Complete randomized blocks designed were used in two regions, using two new cultivars and early seeding dates. Herbicides tested includes profoxydim in two doses, tank mixed with quinclorac or florpyrauxifen-benzyl, florpyrauxifen alone, a conventional weed control treatment (penoxsulam plus cyhalofop-butyl), and a non-treated control. Apart from getting knowledge about these cultivars' tolerance, it is highly relevant to keep on working on the prevention of weed resistance evolution, maintaining more modes of action operational. This research is important in assisting farmers in their decisions towards reaching good weed control, along with successful crop performances.

Integrating the NFOA Algorithm in Mineral and Organic Farming Systems

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Nitrogen (N) is a crucial mineral nutrient for plant growth and development, significantly impacting crop yield and quality. The high demand for nitrogenous fertilizers, particularly in rice crops, poses economic and environmental challenges. Traditional uniform fertilization practices prove inefficient, leading to suboptimal nitrogen use efficiency (NUE) and environmental risks. Precision agriculture strategies, involving optimized N application methods and in-season diagnostic tools, offer potential solutions. In addition, raising constraints in mineral fertilizer availability highlights the need to replace them with sustainable alternatives, emphasizing the necessity to implement the developed tools for these non-conventional adopted practices. Organic manures have aroused considerable interest due to their locally abundant production. Hence, the development of effective N management strategies for organically fertilized rice, applicable under real-scale conditions, is imperative.

The Nitrogen Fertilization Optimization Algorithm (NFOA) stands out as a widely used method, integrating remote sensing data to estimate crop N status and predict in-season yield potential. Studies have validated the success of sensor-based N rate recommendation models in various crops. Despite the widespread application of NFOA in conventional rice farming, limited research addresses its adaptation to crops with non-conventional fertilization practices, hindering the implementation of tools in commercial production, especially for organic farming practices. Our research is critical to address challenges faced by growers in transitioning from chemical to organic fertilizers, thereby contributing significantly to the establishment of sustainable and profitable farming systems. Herein, the NFOA algorithm is explored for its application in conventional rice farming and its adaptation to non-conventional fertilization practices on commercial fields. This work brings together data from experimental field trials and commercial farms. A set of field N rate experiments with both mineral and organic fertilizers was conducted in Spain during the years 2021 and 2022 to develop NFOA algorithm. The GreenSeeker active sensor was used to collect spectral data from experimental plots at the phenological stage of maximum tillering. An

experimental study was conducted in 2023 to evaluate the performance of the developed method in mineral fertilization plots. Commercial fields employing conventional and non-conventional fertilization practices were assessed in 2023, in collaboration with local farmers. Sentinel-2 images were employed to extract spectral information from the commercial fields.

Mineral fertilization recommendations guided by the current developed algorithm enhance NUE by reducing fertilizer input without compromising yield output. This demonstrates the suitability of the methods used for mineral fertilization recommendations. Ongoing research will provide additional results on both organic and mineral fertilized commercial fields, further demonstrating the efficacy of the developed NFOA algorithm in real-field conditions and organic fertilization practices. Preliminary findings suggest that the current algorithm, incorporating data from non-conventionally fertilized fields, demonstrates better adjustment to the specific requirements of non-conventional commercial fields when contrasted with the algorithm relying solely on data from conventional experimental trials. This observation suggests that the developed algorithm is proficient at accurately capturing the real crop requirements, thus covering a broad and representative range of conditions encountered across real-farm fields at the commercial scale. Varietal differences were not targeted in this work, given that only a single variety was included. Nevertheless, varietal bias in spectral response is an unavoidable consideration for the successful implementation of the developed precision fertilization tool in the commercial agricultural sector. Current research outcomes will provide insights into the spectral behavior of the widely used and future-prospective rice varieties in Spain, which will be crucial to validate the compatibility of our methods and ensure their effective implementation in the sector. This work was commissioned and funded by the Catalan Ministry of Climate Action, Food and Rural Agenda.

Water Savings Study at Field Level in the U.S. Mid-South Rice Production: Challenges and Lessons Learned

Moreno-García, B., Henry, C.G., Reba, M.L., Massey, J., and Runkle, B.R.K.

Globally, rice is a large water consumer, and it is estimated to be responsible for 30% of global water withdrawals. Arkansas is the largest rice producer in the United States, and the associated water demand is triggering groundwater depletion in some critical areas.

In this context, alternative irrigation practices need to be adopted by rice farmers. In the present study, three water-saving practices were implemented in eight farms in Arkansas during three consecutive growing seasons (2021-2023): Furrow Irrigated Rice (FIR) where rice is grown in beds and irrigated down furrows; Multiple Inlet Rice Irrigation (MIRI), where a polypipe is used to deliver water in each paddy of a field with levees instead of the traditional cascade down paddies through levee gates; and Alternate Wetting and Drying (AWD), where fields are under wetting-drying cycles.

In each farm, two fields were chosen to compare the water-saving irrigation practice to the conventional practice. The FIR and MIRI practices were compared to paired fields under the cascade irrigation system. The AWD technique was designed to be practiced in zero-grade fields (precisely graded in all directions with little or no grade) and was compared to a continuously

flooded zero-grade system. However, AWD did also happen unintentionally in other irrigation systems (MIRI and cascade). Soil type, planting dates, cultivars, and other management practices were the same in each pair of fields to limit the influence of potential confounding factors. Flowmeters were installed to record the water applied, and yield values were reported through yield monitors or farmer estimations based on truck load weights. Field sizes ranged from 7-40 ha.

The FIR and MIRI practices showed water savings up to 38% and 36%, respectively, when compared to cascade paired fields. AWD practiced in zero grade fields compared to the continuous flooded practice presented water savings up to 34%. The results showed high interannual and inter-field variability, showing zero water savings or even an increase in water use from some study cases. Different challenges regarding to farmer capacity, weather, or soil properties, among others, were identified as responsible for the high variability:

- Differences in the soil composition between the paired fields even if they were side by side. For example, some fields showed double clay content compared to their paired field which made those fields have higher water holding capacity.
- The high variability in water use between fields and years is sometimes in the same magnitude as the expected water savings.
- It is difficult to design a field experiment of water savings because some of the treatments usually end up being a different treatment than planned (e.g. unintentional AWD or not being able to do drying downs because of the rain). Thus, the two treatments assigned to the paired fields sometimes end up being two controls or two water savings fields, thus making a paired comparison impossible.
- These water saving practices rely on rainfall in most cases to reduce water application rates; thus, it is hard to observe water savings in very dry years.
- Farmers manage irrigation considering the whole farm. Sometimes they need to over pump fields aiming to recover tailwater drainage from these fields for use in other fields. This “overpumping" practice is more common in fields with better access to water. While this practice is convenient from a whole farm level perspective, it represents a challenge when studying water savings at the field study level.

In summary, results from the 3 years of data suggest that the water practices have potential to reduce the water use per field, but they do not yet provide robust conclusions. Data from more years and/or more replicates is needed to derive robust conclusions since water applications show high variability across sites and years due to differences in soil types, weather conditions depending on the year, and different farm management techniques; however, it is difficult to achieve given personnel, material, and financial limitations. While doing research at the field level is important to assess these water saving practices, future research should go in the direction of looking at the whole farm level because this is ultimately how the farmers manage farm irrigation; otherwise, we will miss important information related to farm sustainability.

Shifting Rice-Pasture Rotations to Continuous Cropping Systems: Agronomic, Environmental, and Economics Results from a Long-Term Experiment in Uruguay

Macedo, I., Roel, A., Terra, J.A., and Pittelkow, C.M.

Rice (*Oryza sativa* L.) systems rotated with perennial pastures have intensified in South America. Understanding the implications of such transitions is crucial, as decoupling crops and livestock may lead to specialized systems relying on greater external inputs and potential negative externalities. The study aims to shed light on the trade-offs and benefits associated with this shift, considering environmental, economic, and productivity indicators.

To address the objectives, the study evaluated three rice-based rotation systems over a seven-year period in Uruguay. These systems included (a) rice–pasture, (b) rice–soybean, and (c) rice-cover crop. The researchers employed a comprehensive approach, assessing 10 indicators related to productivity, economic performance, and environmental impact. A multi-criteria performance index was developed to provide a holistic evaluation of the systems. The stability of this index was also examined over the study period.

Findings from the study revealed diverse outcomes across the rotation systems. Rice-soybean demonstrated medium productivity and energy use, with the highest nitrogen and energy use efficiency and among the lowest yield-scaled carbon footprint. Despite similarities in greenhouse gas (GHG) emissions between rice-pasture and rice-soybean, the increase in soil organic carbon in rice-pasture could offset GHG emissions by almost 50%.

Rice-cover crop exhibited the highest economic incomes but also the highest input costs, resulting in the lowest gross margin. While rice-soybean and rice-pasture had a similar gross margin, the variability in rice-pasture was lower, along with lower input costs. The multi-criteria performance index indicated that rice-pasture outperformed rice-cover crop by 65%. Moreover, rice-pasture demonstrated the highest overall stability across various parameters.

The study underscores the importance of considering multiple factors when transitioning from integrated rice-pasture rotations to continuous cropping systems. While intensified systems like rice-soybean may show favorable performance in certain aspects, the overall stability and sustainability of the rice-pasture system prove to be noteworthy. These findings contribute valuable insights for sustainable agricultural practices, emphasizing the role of integrated systems in achieving a balance between productivity, economic viability, and environmental impact.

Exploring the Impact of Arbuscular Mycorrhizal Fungi on Rice Grain Nutrition under Aerobic Production

Nguyen, T.D., Johnson, A.A.T., and Watts-Fawkes, S.J.

Rice (*O. sativa*) serves as the primary dietary staple for over half of the global population, particularly in developing countries. The escalating water scarcity issue in countries cultivating

temperate rice, including Australia, poses a significant concern to stable production. A shortage in water supply has the potential to diminish rice yield, thereby impacting food security. Consequently, the current focus is on transitioning rice cultivation from flooded to aerobic conditions to address climate change and water scarcity on a global scale. To achieve this objective, fundamental research on grain yield and quality under aerobic conditions is imperative. While the associations of arbuscular mycorrhizal (AM) fungi in plant root systems are well-documented, their exploration within the context of Australian aerobic rice production remains limited.

In this study, we explored how inoculation with the AM fungus *Rhizophagus irregularis* and soil phosphorus (P) fertilization impacted the grain yield and nutrition of Australian commercial cultivars under aerobic conditions, in pot-based experiments.

All six rice varieties were well colonized with AM fungi, with an average root length colonized of 50%. However, the impact of AM colonization on grain biomass and nutrition was plant variety-dependent. Generally, AM colonized plants had higher grain yield under low soil P availability than non-colonized plants. While AM rice grain had greater P, magnesium (Mg), and potassium (K) concentrations, they had lower calcium (Ca), zinc (Zn), and iron (Fe) concentrations at low soil P availability.

This work suggests that AM fungi could be a potential management strategy in the aerobic production of rice in Australia but requires further research to reduce potential negative impacts on grain Ca, Zn, and Fe concentrations.

Effect of Nitrogen Application Rate under Organic and Conventional Systems on Rice (*Oryza sativa* L.) Growth, Grain Yield, Soil Properties, and Greenhouse Gas Emissions

Nghia, N., Xiufen, L., Jing, J., Jingqi, G., Anna, M.M.C., Kun, C., Mariana, V.V., Henry, A.T., and Fugen, D.

The use of appropriate nitrogen (N) rates is important to optimize organic rice yield potential while minimizing environmental impact and input costs. A greenhouse experiment was conducted to identify the optimal N rate for organic and conventional rice and determine its effects on rice yield, soil properties, and greenhouse gas emissions. Six N rates (0, 50, 100, 150, 200, and 250 kg ha^{-1}) and two cropping systems (organic and conventional) were included in this study.

Plant dry biomass, panicle number, and yield of conventional rice linearly increased with increasing N rate from 0 to 250 kg ha^{-1}, whereas those of organic rice increased significantly with increasing N rate until 200 kg ha^{-1}. Conventional rice had a significantly taller plant, whereas organic rice had a significantly greater tiller number. At the optimal N rate, the panicle number and yield of organic rice were 77.3% and 92.7% of those of conventional rice, respectively. CO_2 and CH_4 emissions peaked at the reproductive stage, whereas N_2O emissions peaked at the vegetative stage. Global warming potential (GWP) increased with increasing N rate and peaked at 200 and 250 kg N ha^{-1}, respectively, in the organic and conventional system; however, greenhouse gas

intensity (GHGI) was not affected by N rate in both systems. Of the measured soil parameters, total microbial biomass (TMB) was significantly correlated to plant growth, yield, and GWP.

Our study indicated that the optimal N rate was 200 kg ha^{-1} for organic rice and 250 kg ha^{-1} or higher for conventional rice to approach yield potential.

Field-Scale Nitrous Oxide Measurements in Rice: Initial Findings

Reba, M., Reavis, C., Chiu, Y., Adviento-Borbe, A., Massey, J., and Runkle, B.R.

Rice contributes to greenhouse gas emissions due to the amount of rice grown in the world and the manner in which it is grown. Globally, rice contributes between 9 to 11% of anthropogenic methane. Water management in rice production is known to reduce methane production by 20 to 60%. However, these gains made in methane emission reductions could be negated by increases in nitrous oxide emissions which have approximately 230 times the global warming potential of carbon dioxide. These gases are typically measured using static flux chamber methods. Nitrous oxide emissions have been low when nitrogen and water are managed effectively and extremely high when managed poorly. Measurement of field-scale nitrous oxide is challenging due to equipment costs and site requirements. In response, we deployed a tunable-diode laser absorption spectroscopy sensor (TGA 200A, Campbell Scientific, Inc.), a sensor capable of measuring field-scale N_2O, in a production rice field in northeastern Arkansas during the 2022 production season. We compared the field-scale automated measurements with static flux chamber measurements. We found general agreement between the field-scale and chamber-based measurements of N_2O. We also found trends in N_2O related to atmospheric conditions and will share findings in response to specific events, namely nitrogen application and irrigation. These measurements will be important in light of interest in climate smart commodities, especially those related to rice management.

Hairy Vetch Green Manuring for Sustainable Rice Production

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The pressing challenge of obtaining high yields while enhancing the environmental sustainability of rice cropping systems is leading to an increase in the adoption of alternative agronomic techniques that aim at improving soil carbon (C) stocks and nutritional status. In this regard, leguminous cover crops can be used as green manure to enhance C and nutrient inputs to conventionally mono-cropped rice cropping systems. *Vicia villosa* Roth (hairy vetch) is a widely adopted winter-adapted annual leguminous plant that can provide significant quantities of nitrogen (N) to farming systems (100 to 130 kg N ha^{-1}). The fast N mineralization rate due to relatively low C/N ratio represents a readily available source of N, especially in rice paddies where N is one of the most yield-limiting nutrients due to its low recovery efficiency, being globally less than 40%. Although green manure is crucial for rice nutrition and yield improvement, the incorporation of green manure before rice seeding can cause an undesirable increase in methane (CH_4) emissions.

The objective of this work was therefore to evaluate the benefits of hairy vetch green manuring on rice nutrition and productivity in temperate rice, as well as any trade-offs linked to the increase of CH_4 emissions. Four different experimental setups were carried out in a temperate rice mono-cropping system (NW Italy) mainly with dry-seeded and flooding delay about 1 month after seeding to evaluate the effects of hairy vetch green manuring on: (i) rice yield, (ii) apparent N fertilizer recovery and optimal level of N fertilization with hairy vetch, (iii) temporal variation in soil available N and P forms during the hairy vetch growth and rice cropping season, and (iv) CH_4 emissions.

Effects on rice yield were evaluated both in a midterm experimental site and through two years of on-farm field trials. Nitrate, ammonium, P_{Olsen} and P_{NaOH} in the soil were monitored during all hairy vetch and rice cropping cycles in an N fertilization trial using a split-plot design, with green manure or no green manure in the main plot and four N rates in the subplot. Changes in net N mineralization, as well as the total potential mineralizable nitrogen (PMN) as a function of cover crop and/or rice straw incorporation, were also evaluated through a laboratory soil microcosm experiment under both oxic and anoxic conditions. Finally, the effects of green manuring on CH_4 emissions were evaluated in two on-farm field trials by using the static closed chamber approach. Green manure was able to provide between 24 and 164 kg N ha^{-1}, depending on development of the hairy vetch before incorporation into the soil. Rice grain yield benefit from applying vetch green manure increased by 6.9% on average in the experimental site and the on-farm field trials, particularly at low N fertilization levels. Results in the experimental site proved that differences in grain yield were related to the number of spikelets, which showed on average higher values in the presence of vetch, with no significant differences due to fertilization levels. Total rice above ground biomass N uptake showed higher values with vetch, being on average 45% higher than in the plots without vetch across all N fertilization levels. Nevertheless, the apparent fertilizer N recovery was not affected by the application of green manure. Considering soil nutrient availability in the field, available P was more affected by vetch green manure compared to N mineral fertilizer management. Both P_{Olsen} and P_{NaOH} were higher in vetch green manure treatments than no vetch, with a strong increase at the tillering stage. Under anaerobic conditions, a faster and more intense net N mineralization was observed in the presence of vetch compared to the control without vetch, with greater values of potentially mineralizable N even during the last stages of the growing season. On the other hand, the release of mineral N (mainly nitrate) was lower under aerobic conditions and resulted in a generally lower net N mineralization. Cumulative CH_4 fluxes over the rice cropping season revealed no statistical differences between vetch and no vetch green manure plots of the two different field trials.

In conclusion, hairy vetch green manure has been shown to increase rice yields and improve plant nutrition with no negative effects on CH_4 emissions when rice was dry seeded (with a flooding delay of about 1 month after seeding). Apart from the contribution of important amounts of N, noteworthy was the potential of vetch green manure to serve as a source of labile organic compounds capable of increasing the bioavailability of sparingly accessible P forms, especially during the first part of the crop cycle in dry-seeded rice.

Greenhouse Gas Emissions from the Rice-Soybean Rotation in Lowlands of Southern Brazil

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The introduction of rainfed species, as soybeans, in rotation with irrigated rice constitutes a promising alternative to increase the sustainability of lowland production systems of Southern Brazil. Besides the inherent benefits of crop diversification, the decrease in the period of anoxic environment influences crop yield and interferes in the dynamics of soil carbon and nitrogen and, consequently, in greenhouse gas emissions potential. The aim of this study was to evaluate methane (CH_4) and nitrous oxide (N_2O) emissions and global warming potential (*p*GWP) of conformations of the soybean/irrigated rice rotation in lowlands of Southern Brazil.

A field trail was carried out in the growing seasons 2019/2020 to 2020/2021 in a Typic Albaqualf, in Capão do Leão, State of Rio Grande do Sul, Brazil. The 2:1 conformations (soybean/soybean/rice and rice/rice/soybean) and 1:1 conformations of the rotation soybean/irrigated rice (soybean/rice/soybean and rice/soybean/rice) were evaluated. Measurements of CH_4 and N_2O fluxes were performed using static chambers with three replications. The measurements were conducted at least once a week throughout rice and soybean growing seasons. To compare the effect of crop rotations on seasonal GHG emissions, the data from the 2021/2022 growing season were considered, which depict a complete cycle of the 2:1 and 1:1 soybean-irrigated rice conformations. We also compared the sum of CH_4 and N_2O seasonal emissions and *p*GWP of the rotation conformations over the three seasons.

Soybean rotation reduced CH_4 emissions and increased N_2O emissions from the soil; the reduction of CH_4 emissions was more significant than the increase in N_2O emissions. This effect was greater for the soybean-soybean-rice conformation than for the rice-soybean-rice conformation. Methane contributed with almost all (>95%) of the global warming potential of the irrigated rice, while nitrous oxide was the main component of the soybean global warming potential (>90%). The conformations involving two successive (30,231 kg CO_2eq) or intercalary irrigated rice crops (28,153 kg CO_2eq) provided higher *p*GWP than those comprising two soybean crops, being 10,436 and 11,772 kg CO_2eq, respectively, for soybean-rice-soybean and soybean-soybean-rice.

Seasonal CH_4 emissions and global warming potential are associated with the cultivated species, irrigated rice or soybeans, but also with the cropping sequence. Methane emissions and the global warming potential of irrigated rice are reduced when grown in succession to soybeans, compared to two successive irrigated rice crops. Therefore, crop rotation constitutes a promising strategy to mitigate greenhouse gas in the lowlands of Southern Brazil.

Rice Nitrogen Use Efficiency (NUE) Characterization with Digital Technology

Setiyono, T.D., Adhikari, R., Kongchum, M., Gentimis, T., and Tubana, B.

Implementation of Best Nutrient Management Practice (BNMP) has been shown to be effective in mitigating nutrient pollution from excessive use of nitrogen (N) fertilizer in agronomic crops while meeting producers benefit from reduced costs, as well as avoiding N deficiency. Site-specific knowledge is critical for N fertilizer management. However, estimating the right amount of N fertilizer to apply is getting more challenging in the face of changing climate and fluctuation of N fertilizer prices.

Nitrogen demand from rice crops depends on the growing conditions and the genotypic characteristics. The existing recommendation for N fertilizer management in Louisiana stated that previous knowledge of the productivity for a particular field should be used by producer to fine tune N recommendation on field-by-field basis, to adjust the recommended amount based on rice variety selected. By effectively describing spatio-temporal rice-N dynamics, digital agriculture technology, namely remote sensing and artificial intelligence can support scientific effort to better understand rice varietal differences in N use efficiency at a given location and growing condition leading toward resilient rice nutrient management to changing climate.

This study will present research effort to monitor rice N use efficiency using UAV remote sensing and artificial intelligence. The study involves rice N rates and variety trials conducted at the Rice Research Station in Crowley, LA. Time series of crop growth indicators will be compared across varieties and their response to N fertilizer rates.

Arsenic, Cadmium, and Nickel Accumulation in Rice: Surveys and Mitigation Strategies in Italy

Tenni, D., Fontanella, M.C., Beone, G.M., Martin, M., Cadei, E., and Romani, M.

Ensuring high-quality rice with minimal arsenic (As) and heavy metal concentrations in the grain has long been a priority for the rice sector in Italy. The recent reductions in cadmium (Cd) and inorganic arsenic limits for rice, established by the European Commission, along with the proposed introduction of a new limit for nickel (Ni), present additional challenges for rice cultivation. Italy is the largest rice producer in Europe with more than 210,000 hectares under cultivation and rice is grown in uncontaminated soils, mainly with moderately to strongly acid pH and low clay content. Acidic soil condition is known to enhance the availability of heavy metals for plant uptake. Water management practices, influencing the soil oxidation status, have a large impact upon the bioavailability of As and Cd in the soil, showing an opposite behavior. Regarding Ni, research has demonstrated that the bioavailability of the metal in the soil is connected to the dissolution and recrystallization cycles of iron (oxyhydr)oxides, implying a resemblance to the behavior of Cd. However, the global literature on the impact of agronomic practices and the understanding of the bioavailability of Ni in soil, as well as the processes of metal accumulation in the rice grain, remain relatively constrained.

In this complex scenario, rice farmers need to implement strategies aimed at reducing the presence of As and heavy metals in rice grain, to ensure compliance with European standards and enhance the overall quality of Italian rice. To address these concerns, several surveys have been undertaken in recent years to assess the levels of As, Cd, and Ni in both rice grain and paddy soil across Italy. Different experimental trials were conducted to develop agronomic strategies aimed at mitigating the presence of As, Cd, and Ni in rice grain. These strategies include (i) water management, (ii) liming, and (iii) rice variety selection.

The surveys were carried out in 2021, 2022, and 2023 on 160 samples, including both rice grain, collected in the field or farm warehouses, and soil. The analysis focused on determining the content of inorganic As, Cd, and Ni in rice.

The effect of water management on As, Cd, and Ni was investigated through a combination of field and mesocosm trials. Different water management practices, including Alternate Wetting and Drying (AWD), continuous flooding, and aerobic rice, were examined. Field trials were conducted to assess the effect of liming in mitigating the presence of Cd and Ni. Additionally, the influence of genotype was assessed by comparing different Italian rice varieties in dedicated field trials.

The monitoring results provided an overview of the conditions of both Italian soils and rice. It was observed that the concentrations of Cd and Ni in rice were significantly affected by water availability in the cultivation areas, which was contingent upon the climatic conditions during the growing season, as well as the agronomic management practices applied by the farmers.

The trials conducted to assess the effect of water management revealed that the levels of Ni and Cd in rice grains increased significantly when dry periods occurred in the irrigation practices, compared to the continuous flooding. The effect intensified with prolonged dry periods, as seen in aerobic cultivation or with an increase in the severity of dry periods in AWD management. Dry periods seemed to have a greater impact on increasing the concentration of Ni in the rice grain compared to Cd. Conversely, As concentrations in rice were higher with continuous flooding.

Field trials demonstrated that the application of lime to increase pH of paddy soils resulted in a strong reduction of Cd levels in the rice grain. While liming influenced both Cd and Ni, it was notably more effective in reducing Cd contents than Ni levels. Nevertheless, liming has proven to be an important strategy for farmers in mitigating Cd and Ni levels in rice, even under conditions of water unavailability. However, the application of a high lime rate is crucial to obtaining the desired result.

The comparison of different varieties in the same growth conditions showed an important role of genotype in the accumulation of As and heavy metals in the rice grain. The distinct behavior exhibited by different varieties can be ascribed to genetic effects that determine different ability of rice plants to translocate these elements from the soil to the grain.

Rice Productivity and Stability in a Long-Term Rotations Experiment in Temperate South America

Aguirre, M., Macedo, I., Roel, A., Bonilla, C., and Terra, J.A.

In Uruguay, flooded rice historically rotated with perennial pastures (mix of grasses and legumes) for livestock production. Business as usual consisted basically in two years of rice crops followed by two to four years of grazed pastures. This allowed increased yields, diversified incomes, preserved natural resources, and minimized the use of pesticides and fertilizers. However, there is a growing trend in the last decade to avoid the second rice on rice straw, introduce other crops like soybeans and reduce or eliminate the perennial pastures from the systems. There are some concerns about the design and sustainability of new intensified rice systems.

We evaluated the rotation and predecessor effects on rice productivity and stability for nine years (2015-2023) in a long-term experiment initiated in 2012 in Uruguay. Six no-till rice systems were established in an Argiaboll in a field with a 34-year-old rice-pasture rotation. Treatments were: 1) Rice-Rice-Long Pasture of *Festuca arundinacea, Trifolium repens,* and *Lotus corniculatus* (R-LP, 5 yrs); 2) Rice-Short Pasture of *Lolium multiflorum* and *Trifolium pratense* (R-SP, 2 yrs); 3) Rice-Soybean-Soybean-Rice-Pasture of *Festulolium spp.* and *Lotus corniculatus* (R-Sy-LP, 6 yrs); 4) Rice-Soybean-Rice-Sorghum (R-Crops, 4 yrs); 5) Rice-Soybean (R-Sy, 2 yrs); and 6) Continuous Rice (CR, 1 yr). Cover crops of *Lolium multiflorum* and *Trifolium alexandrinum* L. were grown in the winter between cash crops in all rotations. A randomized complete block design with three replications and all rotation phases simultaneously was used.

Previous crop effects on rice yield were higher than rotation effects. The highest productivity was observed in rice following soybeans, secondly after pastures, and the lowest following rice. Rice yield differences between predecessors were magnified in growing seasons with high solar radiation during reproductive stages. In low radiation seasons, rice productivity after pastures or soybeans were similar but both were greater than rice after rice. While in high radiation seasons, rice yield following pastures was lower than soybean but higher compared with rice as a previous crop. Pastures length showed positive effects on rice yield only in high radiation years. Independently of predecessor, maintaining pastures in rotation improved the rice yield stability. There was no chance to achieve high yields on rice straw. Soybeans as a previous crop had significant impacts on rice yield in all systems and climatic conditions, particularly complementing and diversifying rice-pasture rotations to avoid the second rice on rice straw frequently used by farmers.

For Mollisols under rice-pasture systems in temperate-subtropical climates like those prevalent in South America, there are rotation intensification design alternatives (excluding CR) that allow sustainable rice productivity increases even in high yielding potential conditions.

Sensor-Based Nitrogen Decision Tool in Louisiana Rice Production System

Tubana, B., Harrell, D., and Walker, T.

Remote sensor-based nitrogen decision tool for rice (*Oryza sativa*) utilizes both in-season predicted grain yield potential and estimate of available soil nitrogen. The validation of sensor-based nitrogen rate recommendation and its performance in reference to farmers' standard practice are required to evaluate its potential as an alternative nitrogen decision tool for rice. To address this objective, a multi-year study was conducted at different locations in Louisiana and Mississippi using different rice cultivars. Each trial comprised of varying rates of nitrogen applied one time before flooding and in two splits, i.e., preflood and at panicle initiation. The nitrogen rates at panicle initiation were based on farmers standard practice (50 kg/ha) and sensor readings.

The sensor-based recommendation at panicle initiation ranged from 0 to 66 kg/ha. Ten out of 17 site-years recorded higher grain yield using the sensor-based nitrogen recommendation while 12/17 and 10/17 site-years had higher use efficiency and return from nitrogen fertilization, respectively. The optimal nitrogen application rates ranged from 111 to 235 kg/ha, with one site-year having no response to nitrogen fertilization.

The outcomes from this study suggested that nitrogen requirement of rice varied in space and time. Weather, soil factors, and cultural practices affect rice yield potential and available nitrogen in the soil. Decision tools that can account for these variations have the potential to improve fertilizer use efficiency and rice production value, especially in years where nitrogen fertilizers are expensive, and to reduce the risk imposed to the environment.

Can Midrow-Banding Nitrogen Enable High-Yielding, Short-Season Rice without Lodging?

Vial, L.K. and Snell, P.J.

One avenue to high water productivity in NSW Riverina rice is to achieve a very high yield with a short-season rice. Using a 130-day variety, if we can achieve 14 $t.ha^{-1}$ but only use 9 $ML.ha^{-1}$, this will achieve the Australian industry's target of 1.5 t/ML. But, short-season varieties fertilized for high yield require a greater proportion of nitrogen (N) at panicle initiation, increasing cost and reducing N recovery efficiency, and are very prone to severe lodging.

Mid-row banding all required nitrogen, in every second inter-row at seeding, has proved an effective strategy to grow high-yielding irrigated wheat without lodging. The high concentration of ammonium in the mid-row band limits early N supply to the plant, provides a consistent N supply, and better aligns it with peak N demand in the reproductive phase. Could this be applied to lodging-prone short-season rice varieties, to apply high N rates for high yield, without the lodging risk, to get the high water productivity we seek?

In an experiment in 2021-22, the growth and yield of Viand with mid-row banded N at 140 $kg.ha^{-1}$ (a conservative, recommended rate) and 184 $kg.ha^{-1}$ was compared to pre-PW topdressed N at

the same rates. Viand with 184 kgN.ha^{-1} mid-row banded at seeding yielded 12.96 t.ha^{-1} with very little lodging compared to 10.74 t.ha^{-1} and severe lodging with 184 kgN.ha^{-1} topdressed before permanent water. Nitrogen uptake at panicle initiation with mid-row banded N was 26 per cent less than with topdressed N, but it seemed that growth and yield formation after panicle initiation was greater with mid-row banded N.

In a repeat experiment with Viand in 2023-24, there was a similar result. The mid-row band was visibly intact just before permanent water. NDVI, N uptake, and biomass at panicle initiation with mid-row banded N were substantially less than with topdressed N. But, by anthesis, both biomass and N uptake with mid-row banded N were similar. Mid-row banding N again caused superior harvested grain yield, yield components, and much less lodging than pre-PW topdressed N at the same rates.

Mid-row banding appears to have a place in achieving high water productivity with high-yielding short-season, or other lodging-prone varieties, especially when combined with the on-farm efficiency gains of avoiding at least one topdressing event, and possible reduced ammonia and nitrous oxide emissions from avoiding topdressing.

Enhancing Rice Production and Income: Closing the Yield Gap through Technology Transfer in Uruguay

Zorrilla, G., Gussoni, A., Fariña, M.F., Cedrés, S., Rovira, A.,
Bica, M.E., and Carmona, L.

The Uruguayan rice sector faced a severe crisis during the second half of 2010 decade, marked by poor international prices, high production costs, and stagnant yields. To address this, the Uruguayan Rice Farmers Association (ACA) spearheaded a national technology transfer project in collaboration with key stakeholders, aiming to narrow the yield gap among producers and elevate the country's average rice yields.

The project, initiated in the 2019-20 rice season, identified 10 essential management practices for achieving over 10 tons per hectare. These practices encompassed early soil preparation, optimal planting dates, high-quality cultivars, precise fertilization, effective herbicide application, strategic flood management, integrated pest management, and proper harvest. Leveraging the expertise of the Rice Research Program from INIA, Rice Millers Association (GMA), and the Latin American Fund for Irrigated Rice (FLAR), the project implemented a farmer-to-farmer transference program across the country.

Through demonstrative areas on reference producers' fields monitored by project technicians, the platform facilitated horizontal communication among producers. Over four years, the project validated technical proposals in commercial areas, covering 3,411 monitored hectares. Results demonstrated that the recommended practices consistently yielded over 10 tons per hectare, with no increase in costs.

Dissemination activities, comprising 71 field days and 20 results winter sessions, were central to the project. The producer-to-producer transfer method effectively reached less connected producers, fostering the adoption of high-yield management practices. The institutional alliance formed by ACA, INIA, GMA, and FLAR played a crucial role in achieving these results.

The project's impact was evident in the country's average yields, experiencing a notable upturn from 2019. Favorable climatic conditions and the timely release of the high yielding new variety INIA Merín added to successfully address its primary objectives by enhancing yields and narrowing the technological gap among rice producers.

Multispectral Signature of Different Rice Genotypes: A Powerful Tool for Precise Fertilization

Catala-Forner, M., Tomas-Navarro, N., Stefani, O., and Marti-Jerez, K.

Nitrogen is a key element for plant development and yield; however, inefficient application can lower nitrogen use efficiency (NUE) due to denitrification, volatilization, and leaching. Additionally, overfertilization leads to environmental damage such as groundwater contamination and eutrophication. Rice (*Oryza sativa* L.), as one of the most important food crops, has thousands of varieties grown around the world, each with different crop development cycles and fertilization needs. Appropriate fertilization amount and timing are critical factors to achieve an optimal agricultural production while reducing environmental impact. In this context, the FERTISAT project seeks to enhance the efficiency of fertilization practices through the utilization of multispectral data obtained from satellites. In response to the imperative for improved nitrogen fertilization practices in rice cultivation, this study aims to monitor and optimize nitrogen application through satellite-based observations. The objective is to obtain a comprehensive understanding of growth and spectral response nuances among different rice varieties under non-limiting nitrogen conditions, with a specific focus on eight widely used and future-prospective rice varieties in Catalonia.

Two sowing methods were applied: dry seeding and wet seeding, both conducted at the Ebre Experimental Station in Amposta during the spring of 2023. The eight selected varieties were assessed under three high nitrogen fertilization levels to ensure non-limiting nitrogen conditions. These conditions ensured unhindered growth and attainment of representative high yields for each variety under these non-limiting nitrogen conditions. Data acquired from the drone-mounted MAIA camera, which captures information across the same nine wavelengths as those covered by the Sentinel-2 satellite, were used in this work. Measures were taken on six dates throughout the entire growth cycle, enabling an in-depth understanding of the response exhibited by each variety. Our research explored individual genotype behavior in diverse indices, extending beyond NDVI and NDRE. The comprehensive spectral and temporal extent of the data captured provides a nuanced perspective on the growth and varietal profile. This data will serve as basis for the characterization of the optimum potential of each variety.

The outcome of this study is expected to provide insights into the spectral behavior of different rice varieties in response to non-limiting nitrogen conditions. This information will facilitate

accurate fertilization planning by providing growers with real-time insights into the nitrogen requirements of their fields. The deliberate focus on varietal differences in this research is pivotal for the successful implementation of precise fertilization in the commercial agricultural sector. The comprehensive examination of multiple widely used and future-prospective rice varieties within the region of interest ensures that the developed methods not only offer valuable knowledge into the spectral behavior of each variety but also guarantee compatibility across a diverse range of cultivars. This targeted approach enhances the applicability and reliability for rice cultivators. Since MAIA captures identical spectral data as Sentinel-2, this will enable the development of a complementary free mobile application, facilitating rice growers apply nitrogen fertilizer intuitively, according to the specific needs of their fields. This research contributes to the enhancement of sustainable rice cultivation practices by simplifying on-demand precise fertilization while minimizing environmental impact.

This project is funded through Operation 16.01.01 of Cooperation for Innovation of the Rural Development Program of Catalonia 2014-2020.

PLANT PROTECTION (ENTOMOLOGY AND PATHOLOGY) – ORAL PRESENTATIONS

Protocols to Estimate Stability and Accuracy of Rice Disease Reaction

Dalla Lana, F., Lima Reis Borges, K., and Fritsche-Neto, R.

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Disease reactions in classes, such as 'susceptible' or 'moderately resistant,' are frequently used to guide disease management practices. These classes are typically established based on field trial results and are thus subject to environmental influences that can misrepresent the true reaction class. The goal of this study was to develop a protocol to quantify the stability and accuracy of rice disease reactions. We used a 25-year dataset from the LSU AgCenter's Rice Pathology Lab, which includes results of disease phenotyping trials for the most important diseases in Louisiana, including sheath blight, blast, Cercospora, and bacterial panicle blight. We employed two equivalent mixed-model equations, treating genotype as both a fixed and random effect, for each year and disease combination. This was done to estimate heritability (as a surrogate for accuracy) and adjusted means (to assess line performance). From the accuracy distribution per disease, we identified outliers and removed trials with low reliability from the analysis. Next, we ordered the genotypes based on their performance and used linear regression for each genotype and disease combination across years to estimate stability, based on the slope coefficient. Finally, using a bootstrap approach in conjunction with the mixed-model equations, we calculated the minimum number of years necessary to classify the disease reaction class of a new variety accurately. Our results enabled the creation of graphs that combine performance and stability, thereby simplifying the classification process and providing more transparent and informative results. Moreover, our findings suggest that a five-year evaluation period is optimal for accurately classifying the disease resistance of a new rice variety.

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Investigating the Role of *Chromobacterium* Csp P as Biopesticide against Key Rice Insect Pests

Sarkar, N., Pearson, R.A., and Bernaola, L.

Rice (*Oryza sativa* L.) industry faces numerous challenges due to insect pests, prompting the reliance on insecticides as the primary defense. However, the use of traditional insecticides is associated with issues such as resistance development and environmental disruption. In this study, we explored the potential of a bacterial insecticidal protein, Csp_P, derived from *Chromobacterium* Panama (Betaproteobacteria: Neisseriaceae), against key insect pests affecting rice crops.

The objective of this study was to assess the susceptibility of Csp_P toxin against fall armyworm (corn and rice strains) and rice stem borers. Different concentrations (varied with insect species)

of Csp_P along with a control were tested on larval mortality through a 7-day diet toxicity assay. Twenty larvae per treatment were evaluated, and the assay was repeated three times.
All concentrations (1.5, 2.5, and 3.5%) of Csp_P were toxic to second instars of fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] showing 88-100% mortality where fourth instar larvae exhibited 22-73% mortality. In a preliminary assay, 10% Csp_P demonstrated promising results with 20% and 80% mortality against the Mexican rice borer *Eoreuma loftini* (Dyar) and sugarcane borer, *Diatraea saccharalis* (F.), respectively. Our initial findings suggest that Csp_P could serve as a viable alternative to chemical pesticides in controlling fall armyworm and sugarcane borer in rice.

PathoTracer: Genotype-Based System for Pathogen Monitoring, Resistance Gene Recommendation to Combat Bacterial Blight and Leaf Blast of Rice

Pinili, D.S., Quibod, I., Grande, H.G., Yanoria, M.J., Oliva, R., and Schepler-Luu, V.

Addressing the global impact of Xanthomonas oryzae pv. oryzae (Xoo) and Magnaporthe oryzae (Mo), pathogens responsible for bacterial blight and blast, respectively, remain a challenge in many rice-producing countries across Asia and Africa. The deployment of over 147 resistance genes in rice highlights the necessity of monitoring the diversity and distribution of these pathogens' populations. However, traditional monitoring methods, which involve isolating the pathogen and pathotyping using near-isogenic rice lines, are time- and resource-intensive. To facilitate monitoring in regions heavily affected by bacterial blight and blast, we have introduced the PathoTracer, a platform that employs genetic markers to identify pathogen populations and detect avirulence genes. PathoTracer also offers real-time monitoring of the pathogens' global distribution via a publicly accessible website, providing valuable data for deploying resistant rice lines in areas dominated by specific pathogen populations.

The development of genetic markers for Xoo and Mo was based on a comprehensive whole-genome analysis utilizing datasets from local and international partner institutions. From approximately 22,000 SNPs identified across 440 Xoo genomes, we validated 40 SNPs as markers to differentiate 12 Xoo populations and Xanthomonas oryzae pv. oryzicola, a closely related pathovar of Xoo. For M. oryzae, six markers were validated to distinguish the current four blast pathogen lineages. These markers were deployed in analyzing around 4,000 samples submitted by 18 institutions across Asia and Africa, focusing on the diversity and distribution of Xoo. Notably, the predominant Xoo populations in South and Southeast Asia are Xoo 9 and Xoo 12. Xoo isolates from African countries were identified as a mix of Asian populations, indicating potential epidemiological significance. The PathoTracer database for Xoo has been instrumental in assessing the effectiveness of bacterial blight resistance genes, with Xa 4, xa5, Xa7, xa13, and Xa21 proving effective in most surveyed countries. In summary, the PathoTracer platform facilitates high-throughput monitoring of pathogen populations, offering a strategic approach to resistance gene deployment.

Susceptibility of U.S. Rice Varieties to Stem-Boring Lepidopterans in Louisiana

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

The Mexican rice borer, *Eoreuma loftini*, is an increasingly severe pest problem in rice in the United States and has now spread to all rice-producing parishes in southwest Louisiana. Management of *E. loftini* currently relies exclusively on insecticidal seed treatments of chlorantraniliprole, an unsustainable situation. Varietal resistance may be valuable as a component of a multi-tactic management program for *E. loftini*, but little information is available on the resistance of varieties currently grown in Louisiana. Data from 19 separate experiments conducted from 2016 to 2021 were analyzed to determine the susceptibility of commercial varieties to *E. loftini*. Borer infestation as measured by whitehead counts was strongly influenced by rice variety, with whitehead densities almost seven-fold higher in the most susceptible variety compared to the most resistant. A follow-up experiment was conducted in 2023 and again showed significant variation in borer resistance among commercial varieties. Varietal resistance may serve as an important component of an IPM program for stem borers in rice in the southern United States.

Status and Management of Florida's Rice Stink Bug Complex

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

Florida's rice stink bug complex is composed of three species: the native rice stink bug, *Oebalus pugnax*, in addition to two invasive species, *O. insularis* and *O. ypsilongriseus*. Beginning in 2017, industry-wide surveys revealed *O. insularis* as the most abundant stink bug species in Florida rice, prompting additional studies to examine its feeding behavior, as well as potential management strategies. From 2019-2020, field assays were conducted in rice to determine differences in feeding injury among *Oebalus* spp. Mesh cages were tied around rice panicles at three stages of development and exposed to *Oebalus* spp. at varying densities of adults. Results from this study were inconclusive, as major differences in feeding injury were not detected among each species. Additional field and laboratory evaluations were conducted in 2021-2023 to evaluate the efficacy of biological insecticides of botanical (azadirachtin, pyrethrins) and microbial (*Beauveria bassiana*, *Isaria fumosorosea*, *Chromobacterium subtsugae*, *Burkholderia rinojensis*) origin. A pyrethroid (lambda-cyhalothrin) was used as a standard. Whereas the pyrethroid controlled *O. insularis* and *O. pugnax* under field conditions and caused high mortality in under laboratory conditions, the biological insecticides had little to no adverse effects on the stink bugs. Future studies will continue to examine the feeding behavior of *O. insularis* and *O. ypsilongriseus*, as well as additional tactics for managing these pests in rice.

The Value of Insecticidal Seed Treatments for U.S. Rice Farmers

Wilson, B.E., Musgrove, T.R.T., and Villegas, J.M.

The rice water weevil, *Lissorhoptrus oryzophilus* (Coleoptera: Curculionidae), has been the primary economic pest of rice, *Oryza sativa*, in the United States for more than 100 years.

Management of *L. oryzophilus* with conventional foliar insecticides is challenging owing to the difficulty in effectively timing insecticide applications against adults as well as the subterranean, aquatic feeding of larvae on rice plant roots. Two neonicotinoids (thiamethoxam and clothianidin) and two diamide (chlorantraniliprole and cyantraniliprole) have replaced foliar applications against *L. oryzophilus* and other pests in the past two decades. The neonicotinoids control *L. oryzophilus* along with more sporadic pests, including chinch bugs (Hemiptera: Blissidae), *Colaspis* spp. (Coleoptera: Chrysomelidae), and aphids. The diamides have superior activity against *L. oryzophilus* and provide control of several lepidopteran pests. The products used individually or in combination, have greatly improved control of *L. oryzophilus* and other insect pests providing immense value to U.S. rice producers. Currently, the products are used on approximately 80% of rice acreage in Arkansas, Louisiana, Mississippi, Missouri, and Texas. Diamides are predominant in Louisiana and Texas, while neonicotinoids are most prevalent in Arkansas, Mississippi, and Missouri. Across the region, the insecticidal seed treatments were used on 775,000 ha at a total cost of $19 million USD. Estimated return on investment from pest losses prevented range from $100–500 USD per ha, making the total economic value of insecticidal seed treatments in U.S. rice approximately $77.5–387.5 million USD.

POSTHARVEST (ECONOMICS AND QUALITY) – ORAL PRESENTATIONS

Enhancing Rice Processing Efficiency and Quality through Automation Solutions

Atungulu, G.

Opportunities abound in the rice processing industry for automation to enhance process efficiency, quality, and sustainability. Whether it's drying performed on-farm in bin systems or off-farm at elevators, or milling utilizing systems like Satake, Buhler, Zaccaria, or others for regular or parboiled rice, advancements in automation hold the promise of improving overall process efficiencies and product yields and quality.

This presentation will highlight identified pain points in rice processing across various stages of drying and milling. Key automation strategies to enhance overall process efficiency and quality will be explained. Research underscores the increasing significance of integrating CO_2 sensors with grain moisture cables for effective grain quality monitoring and process control during drying and storage. Additionally, automating moisture sampling for process control in crossflow column driers, as well as employing innovative solutions for automated control of rice huskers and polishers along the processing line during milling, can significantly elevate rice quality and processing efficiency.

This presentation aims to provide deeper insights into addressing various pain points in rice processing through automation solutions.

Measuring the Economic Effectiveness of Climate Smart Agriculture Practices in U.S. Rice Production Systems

Deliberto, M.A., Hilbun, B.M., and Dimas-Rodriguez, A.

This research seeks to examine the simultaneous relationship between economic viability and environmental sustainability in adopting climate smart agricultural practices in U.S. rice production. Our approach will be to catalog efforts at the farm level that capture economic returns and resource allocation via adoption of climate-smart agricultural practices via a farm level simulation model that will seek to measure production system profitability under risk (uncertainty).

The anticipated results of this research intend to examine the possibility of maintaining operational profitability with the adoption of climate smart practices. This could be accomplished by measuring the impacts alternative production methods have on grain yields. These alternative production methods aim to reduce input use intensity traditionally associated with U.S. rice production.

Assessing the Production and Economic Gains of Rice Breeding in Argentina

Durand-Morat, A., Nalley, L.L., Durand, M., and Colazo, J.

Rice is a global staple and the main source of calories for over half of the world's population, providing 20% of the world's dietary energy supply. Although rice production and consumption happen mostly in Asia, production and demand are expanding quickly in other regions, primarily in Africa and Latin America. Projections indicate that global rice production must grow 30% by 2050 to meet the increasing demand. In the context of increasing limitations to expand area and water availability, growth in rice productivity is the main avenue to match the growing demand.

Global rice yields are plateauing, driven primarily by the slowdown in yield gains experienced in East and Southeast Asia but are trending up in other regions such as South America and Sub-Saharan Africa. The slowdown in yield is a complex problem that requires complex solutions and a multi-disciplinary approach, including investing in rice breeding to increase the yield potential. Moreover, rice quality is of growing importance for consumers and, therefore, an important aspect to consider throughout the supply chain, including rice breeders and traders.

While there is extensive evidence of the economic benefits of agricultural research, studies of the economic and market impact of breeding programs are scarce. Moreover, there is little evidence of the economic impact of rice breeding programs in developing countries. We assess the productivity, economic, and market impact of the public rice breeding program in Argentina. More specifically, (1) we measure the performance of the National Institute of Agricultural Technology (INTA) rice breeding program in terms of yield and quality, represented by the milling yield (milled rice yield or MRY, and head rice yield or HRY) and presence of chalk rice; (2) estimate the economic contribution of the program, taking into consideration the adoption of the varieties developed by the program; and (3) estimate the market implications of those gains.

We estimate the genetic gains for yield, milling rate yield, head rice yield, and chalk percentage using fixed-effect regression models with cluster-robust standard errors for years. We use 1,288 observations (446 from INTA varieties and 842 from commercial varieties from other programs used as control) from the rice production trials conducted in eight locations around the rice growing area of Argentina from 1991 until 2022. We then use the estimated genetic gains together with the area planted to each INTA variety to estimate the volume and value of the yield gains generated by the program. Finally, we used a partial equilibrium model to estimate the market impact of the INTA program by assessing the counterfactual scenario of removing the genetic gains from the INTA program.

The preliminary results suggest that the INTA rice breeding program generated an annual average of 0.77% ($p < 0.01$) in yield gains. Taking the average yield of the oldest variety in the program (El Palmar), that yield gain amounts to 40.18 kg/ha/year. Interestingly, the results suggest that the MRY increased by 0.035% ($p<0.01$) a year on average, with no significant changes in the HRY and the chalk percentage.

The INTA rice breeding program has released eight varieties since 1984, particularly developed for the growing conditions prevalent in the area. These varieties have had a high rate of adoption in Argentina and beyond. They have dominated the area planted in Rio Grande do Sul, Brazil, the largest rice-growing area outside Asia. These findings highlight the importance of investing in breeding to develop varieties adapted to the local conditions so that they can better express their yield potential and generate the benefits intended.

Drying Kinetics and Functional Attributes of New Aromatic Rice in Arkansas

Luthra, K., Regonda, B., January, R., Owusu, E., Olaoni, S., Ouma, F.,
Chukkapalli, D., Siebenmorgen, J., and Atungulu, G.G.

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The demand for jasmine-type aromatic rice is increasing in the United States and so is the import of Thai-jasmine rice from Asian countries. However, to lower dependency on international sellers and provide business to U.S.-based producers, ARoma 22 aromatic rice variety was released by Arkansas Rice Breeding Program (Arkansas Agricultural Experiment Station, University of Arkansas Division of Agriculture). No study has established its drying characteristics and functional attributes as compared to U.S. long-grain and Thai-jasmine rice. Therefore, the objective of this study was to investigate the drying kinetics, physicochemical attributes, cooking duration, texture, and pasting characteristics of ARoma 22 aromatic rice cultivar. Due to lower bran and husk thickness of ARoma 22 rice kernel as compared to a U.S. long-grain rice, the drying rate was higher both at 25°C and 45°C drying air temperature. ARoma 22 rice cultivar compared with U.S. long-grain cultivars had similar milling duration to achieve surface lipid content of 0.4%. The head rice yield (56.5%) was not significantly different whereas protein content (9.0%) was significantly higher than U.S. long-grain cultivars. The cooking duration to attain well-cooked rice was slightly lower for ARoma 22 as compared with Thai-jasmine rice. The textural properties except final viscosity and pasting temperature were not statistically different from Thai-jasmine rice. Data from the study provide the rice industry with a broad understanding of how the quality attributes of ARoma 22 compared with imported Thai-jasmine and therefore can be used for various end-use applications, as well as provide motivation for U.S. rice growers to cultivate U.S.-based jasmine-type aromatic rice.

A Statistical Approach to Understanding How Inter-Kernel Moisture Content Variability Affects Rice Quality

Atungulu, G. and Luthra, K.

Variability in moisture content between rice kernels due to the drying process within a harvest batch can result in irregularities in yields and the functional quality of the final product. Investigating strategies to achieve greater uniformity in inter-kernel moisture content within dried rice batches is a crucial avenue of research for the rice industry. The objectives of this study were to use a statistical modeling approach to (i) study the influence of the moisture content (MC) variability on head rice yield (HRY) and pasting properties and (ii) describe if preheating rice

kernels with microwaves (MW) of the 915 MHz frequency prior to natural air drying influences MC variability within single rice kernels.

Natural air drying used a chamber with 25°C air temperature and 56% relative humidity. Microwave heating was administered at 3 kW power level for 60, 120, 180, 240, and 300 s. Statistical models were developed to describe the interrelationships among treatments and MC variability, HRYs, and functionality of the rice. There was a strong correlation between the initial average MC of the rice bulk and the inter-kernel MC variability. Microwave heating duration significantly impacted MC variability and HRY. Microwave treatments reduced MC variability within rice kernels and positively influenced rice milling yield and pasting properties. All treatments did not significantly impact rice pasting properties.

This study demonstrates the feasibility of employing MW treatments in tandem with natural air drying to reduce inter-kernel MC variability within dried batches of rough rice.

Interrelationships among the U.S. Domestic and Global Rice Markets: A Time-Series Approach

Mottaleb, K.A., Han, J., Mulimbi, W., and Durand-Morat, A.

In 2022 – marketing year, with a production of 6.1 million metric tons (MMT), the United States was the 13th largest rice producing country worldwide, but with an export of 2.7 MMT of rice, which was 4.6% of the total global rice exports in that 2022 – marketing year, the United States was the fifth largest rice exporter. The major rice export destinations are Mexico, Haiti, Canada, Japan, Colombia, and Honduras, and the major domestic rice markets are Arkansas, California, Louisiana, and Texas. Understanding whether the domestic rice markets of the United States are well integrated internally, as well as with the global rice market, is a question that is worth exploration.

Combining the monthly U.S. prices of long- and medium-grain rice from Arkansas, California, Louisiana, and Texas with rice export prices of long- and medium-grain rice from India, Thailand, and Vietnam, and the prices of wheat, corn, crude oil and fertilizers, this study examines the linkages among the U.S. domestic rice markets and international rice markets. This study relies on data sourced from USDA (United States Department of Agriculture) and World Bank. Using the Prais-Winsten and Autoregressive Distributive Lag (ARDL) model estimation processes, the study shows that the U.S. domestic rice markets are strongly correlated with each other as well as with international market through the U.S. rice export prices. Furthermore, the study demonstrates that there is a bi-directional price transmission between the U.S. export prices and the domestic rice prices of the United States. The findings suggest that despite the size of its rice exports the United States relative to the global market, domestic rice price volatility of the United States can transmit to the global rice market through the U.S. rice exports. The findings of this study highlights the relevance of a sustainable U.S. rice production beyond the temperate rice production region.

Enhancing the Yield, Functional Properties, and Quality of Rice Bran Protein through Innovative Extraction Techniques

Modupalli, N. and Rahman, M.

The USA produces approximately 18 million cwt of rice bran containing 12% protein every year, and this resource is highly underutilized as a source of plant protein. To popularize rice bran protein (RBP) in the alternative plant protein market, this study aims to improve RBP extraction yield and functionality for food applications. The conventional method of alkaline extraction (pH 9.0) and isoelectric precipitation proves to be less effective in terms of both yield and quality of RBP. This study explores the suitability of nonthermal plasma pretreatment, acidic extraction at pH 2.0 and alkaline (pH 9.0) + acidic (pH 2.0) extraction (AA) followed by isoelectric precipitation at pH 4.5 (IEP), and IEP + heat coagulation at 90°C for better yield and protein functionality.

The alkaline + acidic extraction followed by IEP + heat coagulation (IH) yielded 78.18% protein isolate, while alkaline and acidic extractions followed by IH resulted in comparatively lower yields of 58.18% and 18.18%, respectively. This shows that heat coagulation following IEP can increase the yield of RBP significantly. The alkaline extraction followed by IH showed a purity of 87.14%, whereas 56.69% for alkaline + acidic extraction with IH precipitation. The IH precipitated samples of alkaline extraction also exhibited better solubility (%) and water holding capacity of 60% and 240%, respectively. Therefore, heat coagulation coupled with IEP can enhance RBP yield and functionality. The evaluation of other functional attributes, such as emulsification and foaming properties, is underway.

This research will provide information on the improvement of protein extraction yield from rice. In addition, it would help us to find ways to utilize rice bran protein isolate in the food product development by improving functionality and quality.

Capacitating Smallholder Farmers: Effect of Training Programs on Enhancing Rice Productivity in the Southern Philippines

Seriño, M.N.V. and Adusumilli, N.

Capacity building is one of the potentially effective approaches to increasing rice productivity and improving the economic status of smallholder rice farmers in the Philippines. Using cross-sectional farm level data from 415 rice farming households, we estimate the impact of education and capacity building on enhancement of small-scale rice farmers productivity.

We adopted three approaches to evaluate the impact.

1) A treatment effects model to estimate the differences in productivity between trained and non-trained farmers.

2) A spatial effects model to evaluate the influence of peer effects on participation in capacity-building programs.

3) The stochastic frontier model to evaluate the impact of capacity-building programs on addressing the inefficiency in production.

We estimate that trainings had a more pronounced effect on dry season productivity compared to the wet season. The decision to participate in the capacity-building activities had spatial dependence. Farmers with neighbors who have and will participate are more likely to attend the trainings. Finally, the trainings helped with addressing some of the production inefficiencies within the rice system. Results have implications in designing training programs and maximizing the benefits from various capacity-building activities in improving rice productivity in the Philippines.

Examination of Variables Affecting Irrigation Water Application in Rice Production

Watkins, K.B., Badarch, B., Hardke, J.T., and Henry, C.G.

Irrigation in the Mid-South region of the United States (eastern Arkansas, northeast Louisiana, northwestern Mississippi, and southeast Missouri) greatly depends on groundwater supplied by the Mississippi River Valley alluvial aquifer (MRVAA). Large groundwater withdrawals are placing significant downward pressure on this economically important source of irrigation water. Rice, *Oryza sativa* L., accounts for a significant portion of the groundwater withdrawn from the MRVAA. A better understanding of the variables affecting irrigation water application is imperative for future sustainability of rice production in this region.

This study uses field level data from 201 rice fields enrolled in the University of Arkansas System Division of Agriculture's Rice Research Verification Program (RRVP) for the period 2003 – 2023. Only rice fields with irrigation water usage measured by flow meters were included in the study. An econometric model was used to evaluate the impacts of weather (precipitation, temperature), field size, rice variety type (hybrid versus non-hybrid varieties), soil texture (silt loam, clay, sandy), field topography (contour levees with or without multiple inlet rice irrigation, straight levees with or without multiple inlet rice irritation, zero grade, furrow), and a category for "marginal fields" (RRVP fields with extreme amounts of applied irrigation water due to field permeability issues, replanting, disease pressure, etc.) on applied irrigation water measured in cubic meters per hectare.

Statistically significant variables in the analysis included precipitation, variety type, soil texture, field topography, and marginal fields. Precipitation, hybrids rice varieties, clay textured soils, straight levee fields with multiple inlet rice irrigation, and zero grade rice fields all resulted in significantly reduced applied irrigation water. Sandy fields, and "marginal fields" resulted in significantly increased applied irrigation water. The latter results highlight the potential waste of irrigation water when rice is planted on problematic fields. Contour levees with multiple inlet rice irrigation and straight levee fields without multiple inlet rice irrigation resulted in reduced applied irrigation water, but the impacts of these variables were not statistically significant. Furrow irrigated rice fields resulted in increased applied irrigation water, but the impact was not statistically significant. Likewise, higher average summer temperatures resulted in increased applied irrigation water, but the impacts were not statistically significant.

WEED CONTROL – ORAL PRESENTATIONS

Rice Response to Sub-Lethal Concentrations of Paraquat

Bond, J.A., Edwards, H.M., and Bell, L.T.

In Mississippi, row crop producers have predominately remained in a glyphosate-resistant (Roundup Ready) production system; however, glyphosate-resistant weed control is challenging in a Roundup Ready system. Paraquat is widely used for preplant herbicide applications in corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean [*Glycine max* (L.) Merr.] to control glyphosate-resistant weeds. Paraquat applied preplant to these crops is often mixed with other herbicides representing different modes of action for improved postemergence and residual weed control. Due to Mississippi's diverse cropping systems and wide range of planting windows for corn, cotton, and soybean, incidents of paraquat off-target movement to rice (*Oryza sativa* L.) are common across the Mississippi Delta. Off-target movement of herbicide applications containing paraquat to rice often creates a complex situation because multiple modes of action are present. University research has demonstrated the effects of off-target movement of systemic herbicide to rice; however, less is known on how sub-lethal concentrations of paraquat affect rice growth and development.

Since 2015, research has been conducted at the Mississippi State University Delta Research and Extension Center in Stoneville to evaluate rice response to sub-lethal concentrations of paraquat. Three doctoral dissertations have been completed in this area of research. These projects have evaluated early-season rice response to simulated off-target movement of preplant paraquat applications, late-season rice response to simulated off-target movement of soybean harvest aid applications, rice management after paraquat exposure, and rice response to multiple exposures of sub-lethal concentrations of paraquat. In all studies, paraquat was applied at 10% of the suggested rate for the application timing. Timings of exposure ranged from spiking to one-leaf rice (VEPOST) to date of draining prior to harvest. Other work investigated fertilizer and herbicide applications following rice exposure to paraquat.

This research demonstrates the greatest levels of injury, delays in rice maturity, and/or reductions in yield occurred following exposure to paraquat during early reproductive growth stages. Rice exposed at VEPOST stage produced yields comparable to those in the nontreated control following exposure to paraquat; however, rice maturity was delayed 6 days, which could compromise harvest efficiency. Fertilizer applications following rice exposure to sub-lethal concentrations of paraquat have proven ineffective in aiding rice recovery.

Paraquat is recommended for preplant glyphosate-resistant weed control in corn, cotton, and soybean; however, if rice is exposed to off-target paraquat movement, severe rice growth and development issues can occur. Often preplant herbicide applications to soybeans contain both paraquat and metribuzin in mixture. Due to soybean's wide planting window, early-planted rice may be at advanced growth stages when preplant paraquat plus metribuzin to soybean is applied. Applications of non-target herbicides to fields in proximity to rice should be avoided if conditions are conducive for off-target movement.

Field and Mesocosm Evaluation of Green Mulching in Organic Rice

Papandrea, G., Fogliatto, S., Beltramo, A., Di Furia, I., Bennani, Z.,
Moretti, B., Rabbia, M., Martin, M., and Vidotto, F.

Organic rice farming is gaining importance in north-western Italy, particularly in the Vercelli province (Piedmont region). One of the strategies developed by organic farmers to control weeds without the use of pesticides implies the use of cover crops in the intercropping period. This technique consists of sowing a cover crop in the autumn and terminating it in the spring, immediately after rice seeding, either by shredding or crimping. The resulting layer of dead mulch provides soil cover that can help in reducing weed emergence, particularly in the early stages of rice growth. After the cover crop termination, the fields are flooded and the cover crop biomass begins to decompose. Therefore, in addition to the physical effect provided by the mulch, the compounds released during the fermentation may play a key role in inhibiting weed development. The aim of the study is to evaluate the effect of the green mulching on weed development and on rice performance and to attempt to identify the compounds released during the flooding.

The study was conducted in 2023 and consisted of both a field and a mesocosm trial. The field trial was carried out in three fields located in the province of Vercelli, two in Livorno Ferraris (LF1 and LF2) and one in Crescentino (CR). In CR, *Lolium multiflorum* alone was used as a cover crop, while in LF1 and LF2, a mixture of *L. multiflorum*, *Secale cereale,* and *Vicia villosa* was seeded. Aboveground biomass was sampled before cover crop termination. The cover crop was also removed in four control areas of 4 m^2 per field to separate the physical suppressive effect of the green mulch from the chemical effect that may be provided by the compounds released during cover crop fermentation. In the fields CR and LF1, flooding and rice seeding occurred the same day as cover crop termination. In LF2, rice was seeded approximately 10 days after cover crop termination and field flooding. Throughout the growing season, weed density was assessed monthly, along with rice density, growth stage, and SPAD index. At the end of the season, rice was manually harvested in the control areas and in four other 4 m^2 squares to assess rice yield. The mesocosm study was conducted in the Department of Agricultural, Forest and Food Sciences in Grugliasco. Three bins were left with bare soil as a control, six bins were seeded with *V. sativa*, and nine bins were seeded with *L. multiflorum*. The termination technique was either shredding or crimping for both cover crops, but for *L. multiflorum,* green manure was tested also as an additional treatment.

The aboveground biomass of the cover crops was sampled before their termination, then rice was seeded and the bins were flooded. As in the field trials, weed density, rice density, rice growth stage, and SPAD index were regularly assessed. Additionally, DOM, N, and P concentrations and greenhouse gas emissions were measured. In both the field and the mesocosm trials, submersion water was sampled every three days until rice rooting.

The fields LF1 and LF2 had a higher cover crop biomass compared to the CR field. In all fields, weed density was reduced by the dead mulch compared to the control areas by 50% and 26% in CR and LF1, respectively, and by 57% in LF2. However, the overall weed density in CR and LF1 fields was higher than in LF2. Consequently, rice density was higher in the latter where yield was not affected by the technique. Only in CR was the yield in the control area 35% lower than in the

rest of the field. Preliminary analysis on flooding water showed the presence of organic acids, such as acetic acid, which may be involved in inhibiting seed germination. In the mesocosm trial, weed density was reduced by 90% in all cover crop treatments compared to the control and the green manure treatment, due to the high amount of biomass produced. As a result, rice density was higher in all treatments with cover crops, especially in the shredded vetch treatment, and yields were from 58% to 66% higher than the control. Overall, DOM, N, and P concentrations were higher in the mesocosms with cover crops. Greenhouse gas emissions were higher than control treatment due to the large amount of biomass produced by the cover crops; moreover, emissions from *L. multiflorum* treatment were higher compared to those from *V. villosa* treatment.

This study showed that the use of a dead mulch can be a valuable tool to keep weed density within a reasonable range for organic farmers facing weed management challenges. However, further studies are required to understand the role of the compounds that are released during the cover crop biomass fermentation in reducing weed emergence.

Clearfield® and Provisia® Rice Systems - Complementary Technologies and Stewardship Measures

Hardimon, F. and Mankin, L.

Clearfield rice technology has been important to rice growers for the past 20 years to help control grass (red rice and weedy rice) and broadleaf weed species. The Clearfield Production System has provided economical weed control options to growers throughout the rice production areas in the U.S. Delta and other areas of the world. With time, high usage, and evolution, the system has been stressed with outcross issues that have led to difficulties with imi-resistant red rice and weedy rice in many geographies.

The Provisia Rice System was introduced in 2019 to be a complementary technology to use in rotation with the Clearfield Production System. Provisia is highly effective to help manage red and weedy rice types. Stewardship of this technology is especially important to sustain both technologies for the future. Efforts have been ramped up in the past two years to educate researchers and growers on the best management practices associated with the Provisia Rice System.

Stewardship of the Provisia Rice System is essential to the future of rice production in the U.S. Delta. Both technologies will be reviewed in the presentation and weed control options as well as technical expertise will be shared.

Sedges and Cattails Control with Florpyrauxifen-benzyl as Affected by Application Timing in California Water-Seeded Rice

Inci, D. and Al-Khatib, K.

Cyperus difformis L. (CYPDI), smallflower umbrella sedge, and *Schoenoplectiella mucronata* (L.) J.Jung & H.K.Choi (SCPMU), ricefield bulrush, are the most troublesome sedges in California rice. *Typha latifolia* L. (TYHLA), common cattail, is an aquatic plant growing up to three meters that inherently infests irrigation and drainage canals, ditches, lakes, marshes, ponds, rivers, and streams. Unlike its natural habitat, TYHLA has recently begun to infest drill-seeded rice fields in California's Sacramento-San Joaquin Delta region. Three fields of research were conducted during the 2021-2023 growing seasons to elucidate rice, CYPDI, SCPMU, and TYHLA responses to florpyrauxifen-benzyl (FPB), a novel synthetic-auxin herbicide when applied at different growth stages. In the first study, FPB was applied at 40 g ai/ha to 1-leaf, 10, 15, 20, and 25 cm height CYPDI and SCPMU. In the second study, FPB was applied at 40 and 80 g ai/ha after the rice panicle initiation. In the third study, FPB was applied at 40 g ai/ha, FPB at 40 g ai/ha plus triclopyr at 420 g ae/ha, and FPB at 80 g ai/ha for a range of TYHLA from 2 to 3 leaves up to two-meters-tall. FPB at the 1-leaf stage was the most effective treatment for CYPDI at 28 DAT with 98% control. In the second study, the highest necrosis, 32%, was observed at 7 DAT of FPB at 80 g ai/ha, but rice recovered at 42 DAT. FPB at 80 g ai/ha was the most effective treatment, with 96% CYPDI control at 42 DAT. In the third study, all FPB treatments achieved 100% control regardless of TYHLA growth stages. FPB foliar applications have an excellent potential to control sedges at early growth stages. This research provides critical information to rice producers in Northern California on when FPB applications are most beneficial for controlling CYPDI, SCPMU, and TYHLA weeds.

Phenotypic Traits Associated with Weed Competitiveness for Aerobic Rice Production System in Australia

Opena, J., Eam, S., Vinarao, R., Gong, W., and Mitchell, J.

Aerobic rice production has been proposed as a water saving strategy that can be used by the Australian rice industry to achieve its target of 1.5 t/ML water productivity by 2026. However, weeds are a major constraint in maintaining productivity in aerobic rice production. Rice genotypes with the ability to outcompete weeds can be integrated with other weed management strategies to realize water productivity gains in aerobic rice production. Previous studies in South and Southeast Asian tropical environments have shown that the weed competitiveness and/or suppressive abilities of rice cultivars in aerobic rice production was associated with early vigor (EV) traits. To date, genotypic variation of phenotypic traits associated with weed competitiveness such as EV in aerobic rice production in Australia remain undocumented. Therefore, field studies were undertaken to assess the genotypic variation of early vigor traits and investigate the effects of root architecture on EV in aerobic rice production. Significant genotypic variation in EV traits [EV score, plant height, leaf area index (LAI), and total above ground biomass] were identified. A number of genotypes achieved consistently high scores or measures across several EV traits (EV score, LAI, and total aboveground biomass). The EV score had strong positive correlation with

LAI and moderate positive correlation with plant height and total aboveground biomass. Genotypes with higher leaf area had higher total aboveground biomass. A significant positive relationship existed between rooting depth and leaf area. The narrow deep-rooted genotypes outperformed the wide shallow-rooted genotype across the EV traits. Future studies on the performance of the identified promising genotypes with narrow deep-roots and enhanced early vigor traits on their weed suppressive abilities in aerobic rice areas needs to be conducted.

Patch Spraying Compared to Broadcast Application for False Seedbed Termination in Rice

Vidotto, F., Papandrea, G., Bennani, Z., Romani, M., Cadei, E., Miniotti, E., and Fogliatto, S.

The use of remote sensing techniques to detect weeds, combined with spot application of herbicides, helps provide effective weed control and economic and environmental benefits. These technologies contribute to meet the "Farm to Fork" requirement of the European Green Deal which requires a drastic reduction in pesticide use in the near future. In rice, weeds can be controlled in pre-planting by using the false seedbed technique, which can reduce weed density during rice growth by depleting the weed seed bank prior to rice planting.

A two-year study was conducted in Italy to compare patch spraying of glyphosate in comparison with broadcast spraying for weed termination in the false seedbed technique. Six adjacent fields of approximately 14 hectares were split in half and managed differently, with half the field receiving a broadcast application of glyphosate and the other half receiving a patch application according to a prescription map created after acquiring UAV multispectral and RGB images. The drone flew at an altitude of 70 m when equipped with the multispectral camera, while at 50 m when carrying the RGB camera; the ground resolution of 10 cm and the use of a ground control point to increase the georeferencing accuracy. Weed cover was also assessed from the ground by selecting 10 areas of about 6 m^2 in each field with different levels of infestation (high, medium, low, and none). Weed density was also assessed by counting the weed seedlings present for each species in three 50×50 cm frames per each infested area. Prescription maps were created using NDVI, which showed a consistent correlation with ground weed assessments. Spraying was carried out in the field areas where NDVI exceeded 0.2, as this value corresponded to bare soil; the untreated areas were set to be no more than 50% of the total field area. Spraying was carried out in May with a 24 m boom sprayer, split in 24 sections of one meter each.

Both the broadcast and patch sprayed field areas showed low weed infestation in the following rice crop, mainly constituted by weedy rice (*Oryza sativa*), demonstrating the high efficacy of both spraying techniques. A reduction in glyphosate use was also obtained in patch-sprayed areas, reaching 50% in the areas where infestation was particularly low and localized to few parts of the field. Patch spraying appears to be a promising technique for the termination of the false seedbed, helping to reduce herbicide use while keeping effective weed control. Therefore, remote sensing can be a useful tool for sustainable weed management.

STUDENT ORAL PRESENTATIONS – CULTURE AND SOIL SCIENCE

Introduction of Year-Long Fallow to Continuous Rice Affects Greenhouse Gas Emissions

Zhang, Z., Fenster, T., and Linquist, B.

Rice production in California follows a norm of mono-cropping, where fields are consistently in rice cultivation without rotations or fallows. However, due to the effects of climate change, drought events are occurring with increased frequency in the region, forcing the fallowing of fields when there are water restrictions. With a heightened emphasis on maintaining production levels while reducing greenhouse gas (GHG) emissions, it is pivotal to investigate changes in GHG emissions when a year-long fallow is introduced to continuous rice. A 3-year field trial was set up to evaluate the differences in GHG emissions between fallow rice and continuous rice systems. Gas samples were sampled weekly during the growing season utilizing a static chamber setup. Collected samples were analyzed for methane (CH4) and nitrous oxide (N2O) concentration using gas chromatography, which were then used to estimate seasonal emission levels. The field experiment in 2021 showed that fallow rice had 45% reduced GHG emissions compared to continuous rice while the 2022 experiment showed no differences in emissions between the two systems. We are currently analyzing the third year of experimental data. In addition to the GHG emission data, the mechanistic rationale of differences in emissions was investigated by analyzing soils for particulate organic matter (POM) through physical fractionation (data analysis in progress). Overall, we hypothesize that fallow rice will have reduced GHG emissions and POM levels due to increased aerobic decomposition of soil organic matter and reduced residue incorporation. These results will be important empirical verifications of GHG emissions from the two systems and serve as geo-specific emission inventories for estimations of environmental footprint as the California rice industry continues to strive for climate-smart production.

Linking Potential Climatic Impact of Greenhouse Gas Emission with Organic-Amended Soil in Rice Paddy

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

Oxic-anoxic interface in rice paddy offers a unique ecosystem to study its biochemical processes. It selects for distinct soil microbiomes that are beneficial for the ecological functions; however, this ecosystem has always been pronounced as a significant source for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions, the deleterious gases causing global warming and ozone depletion. Here, we investigated the effects of different N rates of organic soil amendments on soil microbial biomass and the changes of greenhouse gas (GHG) emissions in rice ecosystem impacting global warming potential (GWP) and greenhouse gas intensity (GHGI). Organic managements in rice paddy resulted in varied soil microbial biomass, CO_2 and CH_4 emissions, GWP, and GHGI. Greater microbial biomass in rice paddy was associated with the application of chicken litter pellet (CLP) at 150 kg N ha^{-1} during rice heading stage to harvest. Paddy soils amended with NatureSafe® (NS) at 50 kg N ha^{-1} were found to emit significantly less

CO_2 and CH_4 compared to other organic soil amendments applied at 150 kg N ha^{-1}. Moreover, our organic managements in rice paddy indicated potential higher rate of N_2O consumption than its production. The accumulations of CO_2 and CH_4 emission during the rice growing season were estimated to significantly impact GWP and GHGI.

Influence of Sampling Depth on Carbon-Based Soil Health Indicators in Rice-Soybean Rotation

French, K.S., Drescher, G.L., Roberts, T.L., Smartt, A.D., Smith, D.A., Ortel, C.C., Hoegenauer, K.A., Bessa de Lima, G.H., Mengez, G.A.L, McLain, T.D., Vickmark, H.E., and Prado, M.P.R.

To understand and diagnose problems within crop production systems, indicators of soil health can better inform producers and scientists about potential solutions within mid-south row crop production systems. Fertilizer-phosphorus (P) and potassium (K) rate trials were established in 2007 at the Rice Research and Extension Center near Stuttgart, AR, on a Dewitt silt loam. The trials are a randomized complete block design with six blocks and five fertilizer rates (0, 45, 90, 135, 180 kg P_2O_5, or K_2O ha^{-1}) applied as triple super phosphate (TSP; 0-46-0) and muriate of potash (MOP; 0-0-60) at preplant. Rice (*Oryza sativa* L.) and soybean (*Glycine max)* are rotated within these four trials every year. Only the two fertilizer-P and fertilizer-K rate trial data on rice (with previous crop of soybean) will be presented. Individual plots were 4.6-m wide and 7.6-m long with 19-cm row spacings. These trials have been under no-tillage management practice since 2007 and were managed as direct-seeded, delayed-flood rice. The mean soil-test P (0- to 10-cm depth) among all the fertilizer-P rates ranged from 8 to 113 mg L^{-1} with a mean pH of 5.5. The mean soil-test K (0- to 10-cm depth) among all the fertilizer-K treatments ranged from 59 to 124 mg L-1 K, with a soil pH of 5.7.

Soil health indicators that are carbon-based were examined after soil samples were collected at the beginning of June 2023. Soil samples were taken from the 0-5 cm, 5-10 cm, and 10-15 cm depths from three fertilizer-P and -K rates (0, 45, 90 kg P_2O_5, or K_2O ha^{-1}) and three replicates. The indicators studied include soil organic matter (SOM), carbon dioxide respiration, β-glucosidase enzyme activity, active carbon, and Comprehensive Assessment of Soil Health (CASH) score. Overall, soil health indicator values decreased in magnitude with increasing sampling depth. In both long-term fertilizer-P and -K trials, soil health indexes were not affected by fertilizer-P and -K rate treatments. In the long-term fertilizer-P and fertilizer-K trial, sampling depth had a statistically significant effect ($\alpha = 0.05$) on all selected indicators, including SOM, carbon dioxide respiration, β-glucosidase, active carbon, and CASH Score. All indicator values, except for SOM, taken from soil samples in the 0-5-cm depth were significantly different from the deeper 5-10 and 10-15 cm samples. In the long-term fertilizer-P trial, each soil depth layer was statistically different from each other when considering SOM indicator. The results of this research are critical to rice and soybean producers that sample their soil for routine and soil health analysis. The depth of soil collected when taking field samples can easily be misjudged, but these results support carefully testing the soil at specific depths to obtain the most informed and sensitive soil health indicator values.

Developing Improved Nutrient Management in Rice and Rice-Based Production Systems through Silicon Enrichment in Soil

Radam, E. and Tubana, B.

Rice (*Oryza sativa*) is a staple food for a significant portion of the global population. Improving the production management of this grain is essential for food security. Silicon (Si), though not classified as an essential plant nutrient, has been increasingly recognized for its beneficial effects on various crops, including rice. This study explores the impact of integrating Si in the nutrient management of rice and would lead to the optimization and improvement of the productivity of rice-soybean and rice-crawfish production systems in Louisiana. This study involves the application of Si in two production systems (rice-soybean and rice-crawfish). For each production system, the Si fertilization was established in two blocks: 1) farmer's standard practice or FP, and 2) under a set of best management practices or BMPs. Si-amended plots (3 m x 15 m) were established in both crop rotation fields in Kaplan, LA. The Si source is a byproduct of iron and steel (Plant Tuff®) production with total Si content of 4%. The Si byproduct was applied at 2 ton/ac at preflood. Provisia (PVLO3) line was planted in rice-soybean field and Jasmine cultivar in rice-crawfish field. Both fields received 78 kg P/ha and 100 kg K/ha. After the harvest of the main crop, the rice plants were grown again for ratoon cropping, a common practice of Louisiana rice producers.

There was an evident difference in production potential between the two rice rotation systems in Louisiana during the first production season. Variety was a factor separating the average grain yield in rice-soybean and rice-crawfish by >2,600 kg/ha. In the rice-soybean field, the harvest of the BMP field was highest (12,378 kg/ha), close to the harvest of the field enriched with Si (11,459 kg/ha). The Si-treated field was about 2,000 kg/ha higher than at the FP field (9,490 kg/ha). Si-treated field had a yield of 7,068 kg/ha, comparable to the BMP (7,212 kg/ha) and the FP field (7,442 kg/ha). In the rice-crawfish field FP field attained the highest grain yield (8,963 kg/ha) but similar to the field enriched with Si (8,607 kg/ha). The ratoon crop had lower yield than the main crop with BMP field yielding the highest at 6,186 kg/ha followed by Si-treated field (5,264 kg/ha) then the FP (4,020 kg/ha).

The inclusion of Si in the rice fertilizer program through the application of Si-rich byproducts can raise the level of productivity in these rice rotation systems through improved soil fertility and the capability of the plant to withstand biotic and abiotic stresses that affect the production performance of the crop. The outcomes from this research will provide information about the mechanisms and practical applications of silicon enrichment thus, farmers and researchers can contribute to the development of resilient and productive rice cultivation systems especially in Louisiana and other areas of the same ecosystem.

Rice Response to Zinc Sources

McLain, T.D., Roberts, T.L., Drescher, G.L., Smith, D.A., Smartt, A.D., Hoegenauer, K.A., Ortel, C.C., Vickmark, H.E., and Bessa de Lima, G.H.

Zinc (Zn) is the most common micronutrient deficiency found in rice (*Oryza sativa* L.) production and deemed the third most important factor limiting rice yields. New Zn fertilization sources have been introduced and promoted for rice management, but there is limited research confirming their effectiveness. A study was developed in Eastern Arkansas, in the Mississippi river alluvial plain, on a calcareous Calhoun silt loam to compare different Zn management fertilization sources to the standard practice and current recommendation of applying 11.2 kg Zn ha^{-1} as granular Zn sulfate (ZnSO4) preplant incorporated. Comparisons of the treatments focus on the effects on tissue-Zn concentration, grain yields, and soil-test Zn levels over time. To achieve the objective, the following Zn treatments were implemented: i) non-treated control, ii) granular ZnSO4 applied at 3.36 kg Zn ha^{-1}, iii) granular ZnSO4 applied at 11.2 kg Zn ha^{-1}, iv) Zn EDTA applied at 1.12 kg Zn ha^{-1}, v) F-420G applied at 11.2 kg Zn ha^{-1}, vi) F-420G Exp applied at 11.2 kg Zn ha^{-1}, vii) MicroEssential's (MESZ) applied at 1.12 kg Zn ha^{-1}, viii) MESZ applied at 1.12 kg Zn ha^{-1} in combination with ZnSO4 applied at 2.24 kg Zn ha^{-1}, ix) Muriate of potash (MOP) applied at 101 kg ha^{-1} coated with Wolf Trax Zn DDP at 1.23 kg Zn ha^{-1}, and x) MOP applied at 101 kg ha^{-1} coated with Yaravita Procote Zn at 1.23 kg Zn ha^{-1}. All Zn treatments were applied prior to planting and incorporated, except for Zn-EDTA which was applied as a foliar spray at the V2 growth stage. Results indicate that there were significant differences in rice tissue-Zn concentration at the V5 growth stage, as the standard practice, treatment iii, and the foliar applied Zn-EDTA, had concentrations statistically higher than all others. Other treatments exhibited concentrations similar to that of the non-treated control. Grain yields of the treated plots were statistically higher than that of the non-treated control. Yields of granular sources, preplant incorporated, were higher than all others except the foliar-applied Zn EDTA, which yielded statistically similar. Yield data also indicates that micronutrient coatings do not provide enough Zn to correct deficiency in soils with low-Zn levels. The data implies that granular sources should be applied at the recommended rate to supply the crop with adequate Zn and build up soil-test Zn levels. Foliar applied Zn EDTA will correct a deficiency if the deficiency is discovered after the crop is established; however, due to previous research, it is not expected to build up soil-test Zn as the granular sources would.

Nutrient Uptake, Partitioning, and Accumulation of Modern Rice Cultivars in Eastern Arkansas

Bessa de Lima, G.H., Roberts, T.L., Drescher, G.L., Hardke, J.T., Ortel, C.C., Hoegenauer, K.A., Smartt, A., McLain, T.D., and French, K.S.

Over the past three decades, the number of rice cultivars has tremendously increased for farmers. However, there has been no study to evaluate how this increase in cultivars is affected by nutrient management. To address this gap, a study was conducted to assess nutrient uptake, partitioning, and accumulation in four different rice cultivars commonly grown in the Arkansas delta region. The trials were established in 2022 at the Rohwer and Pine Tree Research Stations using a randomized complete block design, 4x2 factorial arrangement. The main factors were cultivar (RT

7521 FP, CLL 16, Titan, and Diamond) by fertility regime (optimal and above optimal). For nutrient uptake, partitioning, and biomass accumulation evaluation, samples were taken at the V3, V5/6, 2 weeks post flood, 4 weeks post flood, 50% heading, and maturity growth stages. Differences ($P < 0.05$) in biomass and nutrient uptake among the treatments were observed due to fertilization rate and cultivar effect, respectively. The results of this research provide meaningful information on how the commonly used rice cultivars perform and how farmers can use the information to make fertilizer recommendations.

Long-Term Cover Crop Effects on Soil Health in Eastern Arkansas Rice Production

Vickmark, H.E., Roberts, T.L., Drescher, G.L., Smith, D.A., Smartt, A.D., Hoegenauer, K.A., Brye, K.R., Ramos do Prado, M.P., and McLain, T.

A cover crop is any non-cash crop planted in addition to the primary cash crops grown by a producer and are often used to reduce erosion, stabilize soil aggregates, increase infiltration, and reduce disease, weed, and insect pressure. While some Arkansas rice (*Oryza sativa* L.) producers already include cover cropping in their production system, many overlook the benefits of cover cropping due to the added seed costs and labor associated with cover crops. Our study aims to investigate rice response to the addition of cover crops during the off-season in eastern Arkansas.

A randomized complete block design was established with three replications of seven treatment combinations: 1) control treatment with conventional tillage, continuous rice, and no other additions, 2) no-tillage (NT), no cover crop, and plant residues burned after harvest, 3) NT, no cover crop, and non-burned plant residues, 4) NT, black-seeded oats (*Avena sativa*) and Austrian winter pea (*Pisum sativum*) cover crop blend, and non-burned plant residues, 5) NT, legume only cover crop, and non-burned plant residues, 6) NT, black-seeded oats only as the cover crop, and non-burned plant residues, and 7) NT, black-seeded oats only as the cover crop, non-burned plant residues, and an addition of a single application of 5,589 kg ha^{-1} of biochar mechanically incorporated prior to plot establishment. Cover crop samples were collected from a 0.36 m^2 area immediately prior to rice planting and analyzed for biomass and nutrient concentrations. Rice, cultivar RT7521 FP, was planted at a rate of 35 kg seed ha^{-1} directly into cover crop residue using a NT drill in May of 2023. Samples of rice from each plot were collected at 50% and maturity from 1 m of a bordered row and analyzed for biomass and nutrient concentrations, with grain analysis separate from leaves and stalks at the maturity sample timing. Rice harvest occurred in October of 2023, and measurements of plot area, grain weight, and grain moisture were collected from each plot to provide a final rough rice yield and harvest index.

The data obtained in this research has shown that after one year, there were no significant differences in rice biomass or rice yield across treatments. However, average rice yield was numerically greater in the legume-only cover crop treatment (treatment 5) when compared to all other treatments, which could be attributed to the N accumulation attributes associated with leguminous cover crops. It can be expected that this yield increase will become significant over time, but additional years of data are required to support this conclusion.
The results of this research are an important step in the effort to influence Arkansas rice producers to implement cover cropping during the off-season and improve their overall soil health.

Life after the Flood: An Automated, Low-Water-Use Rice Production System

Oakley, G.R., Spencer, G.D., Gholson, D.M., and Krutz, L.J.

Groundwater resources are being depleted by irrigation practices in the mid-southern United States. This study was conducted to determine whether automated technologies and low-water-use techniques can be coupled to reduce water use in the drill-seeded, delayed flood rice (*Oryza sativa* L.) production system. The effects of autonomously managing the intermittent flood depth on water use, grain yield, and rice milling quality were investigated at Shaw, MS, on a Sharkey clay (very-fine, smetitic, thermic Chromic Epiaquerts). Automating an intermittent flood decreased the volume of water applied 23.5% when compared to a continuous flood. Rice grain yield did not differ between a continuous and intermittent flood; however, a 4% yield reduction was observed in the bottom paddy relative to the top and middle portions of the field. Intermittent flooding did not affect the quantity of whole milled rice kernels. Chalk content in rice grown under an intermittent flood production system decreased as distance from the top of the field increased, while chalk content in a continuous flood was similar across the field. Implementing automation with intermittent flood management appears to be an effective strategy to reduce irrigation water applied while having no effect on rice grain yield and quality.

Pure-Line and Hybrid Rice Yield Responses to Potassium Fertilization

Prado, M.P.R., Drescher, G.L., Roberts, T.L., Smartt, A.D., Smith, D.A., Hoegenauer, K., Vickmark, H.E., and Mengez, G.A.L.

Potassium (K) plays a key role in successful rice (*Oryza sativa L.*) production grown in the direct-seeded, delayed-flood cultivation system common in the U.S. Mid-South. Substantial yield reductions can occur in soils with limited exchangeable K availability. The main objective of this research was to compare yield responses of pure-line and hybrid rice cultivars to K fertilization in trials where various fertilizer-K rates (0, 45, 90, 135, and 179 kg K_2O ha^{-1}) have been applied annually for several years. Both cultivars responded positively to K fertilization with Very Low (<61) Mehlich-3 K in the no-fertilizer-K control plots. Without K application, for 2022 the pure-line (Diamond) produced 67% of the maximum yield with K fertilization, while the hybrid (RT 7321 FP) produced 53%. For 2023, Diamond in the non-fertilized control produced 81% of the maximum yield with K fertilization, while the hybrid (RT 7421 FP) produced 56% when compared to the highest-yielding treatment fertilized with K. Overall, the grain yields from the control plots were significantly less from the hybrid than from pure-line for both years. Grain yields of the hybrid cultivar were lower than expected for 2022, likely due to lodging, which was substantially less in the 2023 trials. Both factors and the interaction were significant for 2023 and presented maximum yields with the application of 90 kg K_2O ha^{-1}. Results of this study suggest these hybrids may be more responsive to K fertilizer than pure-line cultivars, but recent trials observed another hybrid (RT Gemini 214 CL) to be less responsive. Based on inconsistent responses of hybrid rice to K fertilization and the fact that earlier studies predominantly evaluated pure-line cultivars, it is important to continue studying the response of hybrid rice to K fertilization for potential adjustments to K fertilizer recommendations and to build a database for proper interpretation of tissue data.

STUDENT ORAL PRESENTATIONS – PLANT PROTECTION/BREEDING AND GENOMICS

Seed Endophytic Bacteria: Potential Protection of Rice against Seedling Blight Pathogens

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

Seedling blight is an important seedling disease in rice in the southern United States. Seedling blight poses a notable threat to dry-seeded rice, which is the predominant rice production method in the southern United States, leading to substantial stand losses. *Rhizoctonia solani* is among the most important pathogens that cause seedling blight. While fungicide seed treatments are commonly relied upon by growers' control, organic rice farmers face considerable challenges due to no availability of effective seed treatment options. Biocontrol agents hold promise as a sustainable solution for managing seedling blight. Even traditional approaches could benefit from integrating biocontrol agents with synthetic fungicides since they can improve efficacy and reduce environmental impact. The microbial communities within seeds have been recognized for their role in promoting seed germination and enhancing resilience to various stresses, including both biotic and abiotic factors. Moreover, these seed microbial populations serve as a natural defense mechanism against various soilborne and seedborne pathogens. Endophytic bacteria residing within seeds, particularly those with anti-fungal properties, offer a stable biocontrol option for safeguarding seedlings. This study aimed at identifying potential biocontrol agents against seedling blight pathogens, with a focus on exploring naturally occurring endophytic bacteria within rice seeds.

Seed endophytic bacteria were isolated from rice seeds grown in both organic and conventional farming systems using culture-based methods. Subsequently, the 16S rRNA of all cultured bacteria was amplified and sequenced to facilitate their identification. These bacteria were grouped based on their sequence similarity, with those exhibiting >97% similarity categorized as potentially the same "species." Representative isolates from each group were selected for screening for their antagonistic activities. *In vitro* tests were conducted to assess the antagonistic effects of selected bacterial isolates against three seedling blight pathogens: *R. solani* AG11, *R. solani* AG4, and *Marimus graminum*. Bacterial isolates demonstrating antagonistic activity were further evaluated both greenhouse and field conditions against *R. solani* AG11 and *R. solani* AG4, the two most prevalent pathogens causing seedling blight. Cruiser Maxx Rice, the standard commercial fungicide seed treatment, served as the positive control.

A total of 85 endophytic bacteria were isolated from rice seeds, and subsequent analysis of the 16S rRNA sequence homology classified them into 10 genera and 31 unique "species." Among these endophytic bacteria, *Bacillus* sp. ST24, *Burkholderia* sp. OR5, and *Pantoea* sp. ST25 exhibited antagonistic activities against all three seedling blight pathogens. However, *Burkholderia* sp. OR5 was found to hinder seed germination. In greenhouse trials, seeds treated with *Bacillus* sp. ST24 or *Pantoea* sp. ST25 significantly reduced the diseases caused by *R. solani* AG4 and *R. solani* AG11, achieving efficacy levels similar to the Cruiser Maxx treatment. In field conditions, seed treatment with *Bacillus* sp. ST24 or *Pantoea* sp. ST25 mitigated stand loss caused by *R. solani* AG11 and *R. solani* AG4, although the efficacy did not reach the levels observed with the Cruiser

Maxx treatment in terms of stand loss. Despite being in the early stage, these results highlight the potential of utilizing naturally inhabiting seed endophytic bacteria as biocontrol agents for managing seedling blight pathogens in rice.

Influence of Insect Pest Infestations in the Main and Ratoon Crops on Rice Yields in Louisiana

Wilson, B.E., Gambino, C.E., Musgrove, T.R.T., Villegas, J.M., and Landry, K.J.

Rice cultivation in the southernmost U.S. regions, often cultivate a secondary, or "ratoon," crop post-primary harvest. This ratoon crop is typically managed for low production costs owing to reduced inputs of labor, fertilizer, and pesticides to maximize income during the same cropping year. Managed for cost-effectiveness, the ratoon crop faces vulnerability to insect pests, notably the rice water weevil (*Lissorhoptrus oryzophilus* Kuschel), causing potential yield losses of up to 30%. Insecticidal seed treatments, primarily Chlorantraniliprole, for *L. oryzophilus* control, have shown sustained efficacy beyond the initial two months post-planting, presenting potential breakthroughs for managing the Mexican rice borer *(Eoreuma loftini*). Three-year field trials were conducted at the H. Rouse Caffey Rice Research Station in Crowley, LA. Plots were arranged in a randomized complete box design with four blocks, one replicate per block. The objectives of this study were to determine the effects of *L. oryzophilus* and *E. loftini* management in the main and ratoon crops on rice yields. The objectives were (1) assess whether *L. oryzophilus* control in the main crop augments ratoon yields, (2) evaluate the impact of *L. oryzophilus* control specifically in the ratoon crop on ensuing yields, and (3) examine the consequences of protecting ratoon rice from *E. loftini* on the total of rice yield. The ratoon yields were two-fold greater in seed treatment plots in 2021, but not in 2022. Higher weevil densities were observed in untreated and Chlorantraniliprole ratoon plots. Both stem borer infestations and main crop yields were significantly affected.

Effect of Silicon Uptake Capacity and Herbivory on Silicon Accumulation in Rice at Local and Systemic Levels

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

Silicon (Si) is known to play a vital role in protecting rice plants against biotic and abiotic stresses. However, it is unclear whether herbivory induces Si accumulation in rice, as it does in other plants, and how the silicon uptake capacity of rice affects this accumulation. Therefore, a study was conducted to investigate the impact of herbivory on Si accumulation and to determine whether the Si uptake capacity of rice affects this accumulation. The experiment involved using *Spodoptera frugiperda* Smith, the fall armyworm, as an insect herbivore, and three Si transporter mutants with varying levels of Si uptake (one with over 95% deficiency in Si uptake, another with around 55% deficiency in Si uptake, and the third with uptake similar to wild-type) and compared them to the wild-type rice cultivar Nipponbare. The study used a 4*3*2 factorial design with four levels of rice genotype, three levels of Si fertilizer, and two levels of herbivory. Si quantification at local as well as systemic levels and biomass measurements were taken in this experiment. The initial

results of the study indicate that a higher uptake of Si increased the biomass content of rice. The results of this study can be used to improve plant resilience through sustainable agriculture by understanding the relationship between herbivory, Si uptake capacity of rice genotypes, and Si accumulation.

Mid-South Rice Stink Bug Management

Lytle, M.J., Cook, D.R., Crow, W.D., Bond, J.A., Gore, J.,
Catchot, A.L., Towles, T.B, and Bateman, N.R.

Throughout rice, *Oryza sativa* L., production across the Mississippi Delta and Mid-South, the rice stink bug, *Oebalus pugnax* F., is a key late-season insect pest. Historically, Mississippi rice producers have relied on pyrethroids to effectively manage rice stink bug due to the cost effectiveness of insecticides within the chemistry. Rice stink bug has the potential to cause direct yield loss due to kernel development being restricted as well as profit losses resulting from decreases in grain quality (e.g., peck) and subsequent milling damage. There are currently five insecticides labeled in Mississippi for control of stink bug. These are dinotefuran (Tenchu), gamma-cyhalothrin (Declare), lambda-cyhalothrin (Warrior II), malathion (Malathion 57 EC, Malathion 5EC), and zeta-cypermethrin (Mustang Maxx). Failed pyrethroid applications in recent years have been reported across a number of Mississippi rice acres, potentially indicating a reduction in efficacy and ultimately resistance development. From 2021-2023, laboratory bioassay experiments were conducted at Mississippi State University's Delta Research and Extension Center in Stoneville, MS. The study was comprised of liquid scintillation vials each treated with technical grade lambda-cyhalothrin at various concentrations, and an untreated control. Technical grade lambda-cyhalothrin was diluted in acetone and 0.5 milliliter was pipetted into each vial. The vials were placed onto a commercial hot dog roller with the heating element disabled and allowed to roll until the acetone had evaporated, leaving only the appropriate lambda-cyhalothrin concentration in each vial. Lambda-cyhalothrin was chosen as a representative of the pyrethroid class due to the popularity with Mississippi rice producers. Rice stink bug populations were collected throughout the Mississippi Delta and one rice stink bug was placed per treated vial. Mortality ratings were taken 24 hours following infestation. Historical data from Mississippi in 2012 produced a baseline LC_{50} of 0.16 µg/ml. This was used to calculate resistance ratios. During 2021, the mean LC_{50} was 0.40 µg/ml, with resistance ratios of 1.3 to 48. During 2020, 5 µg/ml and 10 µg/ml were the highest concentrations tested. These resulted in <50% mortality and resistance ratios of >18. During 2023, the highest concentrations tested were 50 and 100 µg/ml. In all cases but one, these concentrations failed to produce >50% mortality. This resulted in resistance ratios of 310 to >625. The 2024 data collection and analysis are ongoing. Percent mortality data suggests that many populations of rice stink bug exhibit increased tolerance to pyrethroids at previously lethal doses. These results indicate a reduction in pyrethroid efficacy and a need for further evaluation of acceptable insecticides for rice stink bug control in the Mid-South. The loss of an economical insecticide may be challenging for Mississippi rice producers to protect yields with an already limited number of chemical options for rice stink bug control.

Enhancing the Sustainability of Insect Pest Management in Furrow-Irrigated Rice, *Oryza sativa* L.

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

Rice, *Oryza sativa* L, is one of the most widely cultivated cereal grains in Louisiana. Approximately 176,000 hectares were planted in 2023 across the northeast and southwest regions of the state, which represent the Delta and Gulf Coast rice production regions, respectively. Most of these hectares are grown under flood irrigation. Recently, alternative irrigation practices like furrow-irrigated rice (FIR) have become popular in rice production across the mid-south with approximately 14,000 hectares grown in Louisiana in 2023.

Agronomic practices can have a significant impact on arthropod pest management in agroecosystems. Classic examples include till vs no-till, cover crops, and manipulating planting dates. In flood-irrigated rice, insecticidal seed treatments (ISTs) are the most effective means to control the most economically significant pest of rice, the rice water weevil (RWW) (*Lissorhoptrus oryzophilus*) (Family: Curculionidae). However, RWW is not likely to become a major pest of FIR because flood irrigation is critical to RWW development. Despite this, ISTs are widely deployed on FIR hectares across the Mid-south. This is largely driven by the emergence of the rice billbug (*Sphenophorus pertinax*) (Family: Curculionidae) as the key weevil pest in FIR. However, the efficacy of seed treatments against billbugs is unknown. Therefore, all ISTs labelled for rice were tested over multiple years, site-locations, and irrigated conditions assessing their impact on RWW/billbug larval densities and rough rice yield. Larval densities of RWW and billbugs were quantified per soil core and m^2, respectively. At harvest maturity, rice was harvested with a whole-plot combine and yields were adjusted to 12% grain moisture. Data was subjected to a generalized linear mixed model and means were separated using Tukey's HSD when significance was found (α=0.05).

RWW larval numbers were very low (<1 per soil core) across all sites/years. Seed treatments did not affect billbug densities nor did they improve yield relative to controls. Additionally, economic returns for seed treatments were inconclusive, even when pest pressure varied significantly across sites/years. Leaving economic returns aside, we conclude that widespread use of ISTs in FIR is unjustified because ISTs are ineffective against key pests of FIR and yields were not consistently improved.

Is There Common QTL Controlling Cold and Heat Tolerance at the Reproductive Stages?

Nguyen, T., Vinarao, R., Wood, S., Proud, C., Fukai, S., and Mitchell, J.

The Riverina region of Southern New South Wales is the primary area for rice production in Australia. This region has a high likelihood of exposure to both low (below 15°C) and high (above 35°C) temperatures during the reproductive stage, leading to spikelet sterility and yield reduction. Additionally, growers in the Riverina are under increasing pressure to improve water productivity with aerobic production considered as a water-saving method that may sustain Australian rice

production. Therefore, it is crucial to identify rice genotypes that can tolerate both low and high temperature events at the reproductive stages, especially when shifting to aerobic production.

Two experiments involving 196 recombinant inbred line (RILs) of an F6 population derived from a cross between IRAT109 and Norin PL8 were used to identify low and high temperature tolerant quantitative trait loci (QTL) during the reproductive stage. Experiments were conducted in temperature-controlled glasshouse facilities for low and high temperature exposure. In the low temperature experiment, RILs were grown in low temperature condition (24/15°C) from maximum tillering to maturity. In the high (38/22°C) temperature experiment, all plants were grown in control condition (28/22°C), except for 7 days of exposure at the flowering stage. All plants were phenotyped for spikelet sterility (SS). IRAT109 was identified as a genotype tolerant to both low and high temperature, while Norin PL8 was a known low temperature tolerant donor and found to be susceptible to high temperature at the reproductive stage.

QTL analysis revealed that *qYMCT3* and *qYMCT10* located on chromosomes 3 and 10, respectively, were associated with SS in the long-term low temperature condition, while a region on chromosome 6 was related to low SS after exposure to high temperature at the flowering stage. For both *qYMCT3* and *qYMCT10*, introgression of the allele from Norin PL8 (BB) conferred lower SS by more than 10%. In the high temperature experiment, the introgression of IRAT109 (AA) allele resulted in about 15% lower SS. Additionally, a number of genotypes have been found to harbor favorable alleles of all QTL identified with low SS in both low and high temperature conditions. This study successfully identified individuals within a population and genomic regions associated with both low and high temperature tolerance, demonstrating the possibility of pyramiding low and high temperature tolerance within a single line. Further research is required to explore the low temperature tolerance of this population at the specific development stages of young microspore and flowering for low temperature tolerance and then validate these QTL in alternative genetic backgrounds.

Genotypic Characterization of Blast in U.S. Rice and Identification of a Novel Broad Spectrum Resistance Gene

Manangkil, J.M., Angira, B., Oliveira-Garcia, E., Fritsche-Neto, R., and Famoso, A.N.

Rice blast, caused by a fungal pathogen, *Magnaporthe oryzae*, is a highly destructive rice disease that significantly reduces rice yields on a global scale. Numerous rice blast resistant genes have been discovered and integrated into breeding programs. However, pathogens evolve over time, leading to the potential adaptation of certain races that can overcome these resistant genes (R genes). Therefore, exploring new sources of resistance to breed varieties with a broad spectrum of resistance is continuously needed. Incorporating new sources of resistance from exotic germplasm is possible, however, this can lead to the introduction of undesirable traits and can take many years to incorporate into a commercial variety. Thus, it is ideal to exploit resistance genes that are already present in the elite germplasm pool when possible. This study aimed to characterize the resistance of U.S. rice germplasm to four different blast races and to explore whether any additional large-effect, broad-spectrum genes are present in Southern U.S. long-grain breeding germplasm.

A panel of 258 lines, representing the Southern U.S. long-grain rice breeding program, was evaluated with four blast races (IB1, IB17, IB49, and IE1K) under controlled conditions. The panel was sequenced at 5x genome coverage, and 326,329 SNPs were used to conduct a Genome-Wide Association Study (GWAS). The panel exhibited a broad phenotypic distribution and GWAS identified the previously known blast resistance genes in the germplasm. In total, 21 significant loci distributed across chromosomes were identified within different blast races. Specifically, eight markers associated with resistance against IB1, five against IB17, seven against IB49, and four against IE1K. The most significant locus detected was identified on Chr. 4, conferring resistance to three races (IB1, IB49, and IE1K). Subsequent validation of this GWAS locus was conducted in a bi-parental breeding population segregating for the Chr. 4 locus and the known *Pita* gene on Chr. 12. To conduct the validation, four genotypic groups (20 lines each) consisting of four combinations of the Chr. 4 and Pita alleles (Res/Res, Res/Sus, Sus/Res, and Sus/Sus) were phenotyped separately with IB1, IB49, and IE1K. This validation confirmed that the Chr. 4 locus confers resistance to each of the races. Subsequent characterization of the Chr. 4 locus across four races (IA45, IB45, IB54, and IG1) demonstrated broad-spectrum resistance, with the locus conferring resistance to all but one race (IB54). The discovery and validation of this broad-spectrum resistance gene within the elite breeding germplasm will facilitate immediate impact into variety development and characterization activities. Future work will focus on fine-mapping and developing a SNP marker for routine breeding applications.

Exploring Salt-Tolerant Germplasm: Alleviating Saltwater Intrusion and Weed Management Issues in Rice in South Carolina in Partial Saltwater Agroecosystem

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White, S.A., Cutulle, M.A., and Ward B.

Climate change is causing sea levels to rise and increasing saltwater intrusion. Saltwater intrusion threatens coastal rice production, particularly in South Carolina (SC), where current rice cultivars are highly salt-sensitive. Additionally, weed infestation has been a major factor contributing to yield losses in organic rice production, particularly in partial saltwater agroecosystems. Addressing this challenge requires a thorough understanding of the effects of salinity on lowland rice cultivars and weed interactions to ensure profitability and effective weed control in organic production systems. Preliminary experiments, conducted collaboratively by Clemson University researchers with USDA-ARS Dale Bumpers National Rice Research Center (DBNRRC) consultation, resulted in the creation of a diverse panel comprising of 12 rice cultivars/germplasm.

This panel underwent salt tolerance screening in Clemson University greenhouses. In brief, we screened rice germplasm under various seawater concentrations (0, 0.375, 0.75, 1.5, and 3%) in weed-free and competition conditions. The results revealed a significant impact of a 3% seawater concentration on rice plants, causing a two- to three-time reduction in biomass and up to a five-time decrease in yields under weed competition. When comparing the seawater effects on weed growth, we observed a reduction in barnyard grass growth, while hemp sesbania exhibited no significant impact at the 3% seawater concentration. M202 and Doble Carolina exhibited the highest salt tolerance and photosynthesis rate compared to the Carolina Gold and Santee Gold local genotypes. The cultivars demonstrating superior performance under these conditions were

subjected to further testing in organic research plots, incorporating supplemental irrigation with tidal ocean water. The field experiment was designed to validate the outcomes of the greenhouse studies and to assess the salinity tolerance of six rice genotypes (Carolina Gold, Santee Gold, Doble Carolina, M202, Jupiter, and JN100) under different seawater concentrations (0, 1.5, 3, 6, and 12%), both in weed-free and weed-competition scenarios. Tidal water was collected from the adjacent marsh using a gasoline pump in a 4,000-gallon-capacity reservoir/pool. Then, tidal and freshwater volumes were applied by monitoring respective electrical conductivity (EC) in different treatment plots. The findings validated our greenhouse observations, demonstrating that M202, Doble Carolina, and JN100 showed the highest salt tolerance as evidenced by their lower reduction in root length, root fresh weight, shoot length, plant biomass, and chlorophyll content compared to Carolina Gold and Santee Gold. These resilient genotypes showed higher photosynthesis rates, lower membrane damage, and reduced tissue Na/K ratios, highlighting their ability to cope with high soil salinity conditions.

Additionally, weed competition reduced the rice plant height, number of tillers, panicles, dry root, and shoot weight across the entire salinity gradient. Salinity significantly reduced weed growth, resulting in a three- to five-time decrease in weeding time at 6% seawater and eight- to 10-time decrease at 12% seawater compared to the control condition without seawater (0%). This study's findings contribute to our understanding of the responses of SC rice cultivars to saltwater intrusion and weed competition. Eventually, the most promising cultivars identified are being incorporated into a breeding program to integrate salt-tolerant genes into historically significant SC rice cultivars such as Carolina Gold. Based on our findings, growing salt-tolerant rice in a saltwater agroecosystem will likely improve the competition between rice and weeds and reduce hand-weeding time. The outcomes of this research are foundational to successfully increasing rice production in SC in a saltwater agroecosystem.

STUDENT ORAL PRESENTATIONS – WEED SCIENCE/POST HARVEST

Fall-Applied Residual Herbicides Targeting Glyphosate-Resistant Italian Ryegrass in a Delayed Flood Rice System

Dodd, J.

Italian ryegrass (*Lolium perenne* ssp. *multiflorum*) is one of the most troublesome weeds of rice in Mississippi. Residue remaining following control measures is often present at the time of rice seeding, and this can compromise planting efficiency. The most effective and economical management strategy to control Italian ryegrass is fall-applied residual herbicides; however, the most effective products are not labeled for use in the fall prior to rice seeding. Two separate field studies were conducted in 2021-22 and 2022-23 in Stoneville, Mississippi, to evaluate fall-applied treatments of group 15 herbicides with and without flumioxazin for control of glyphosate-resistant (GR) Italian ryegrass (Herbicide Mixture Study) and to determine the effect of adding a residual herbicide to a sequential clethodim treatment following fall-applied residual treatment (Sequential Application Study).

The experimental design of the Herbicide Mixture Study was a randomized complete block with a two-factor factorial arrangement of treatments and four replications. Factor A was flumioxazin rates of 0 and 72 g ai ha^{-1}. Factor B was Group 15 herbicide and included no group 15 herbicide, acetochlor at 1,266 g ai ha^{-1}, dimethenamid-P at 841 g ai ha^{-1}, *S*-metolachlor at 1,424 g ai ha^{-1}, and pyroxasulfone at 240 g ai ha^{-1}. The Sequential Application Study utilized a randomized complete block with a two-factor factorial arrangement of treatments and four replications. Factor A was fall treatment and included no fall treatment, dimethenamid-P at 842 g ha^{-1}, and acetochlor at 1,267 g ha^{-1}. Factor B was sequential herbicide treatment and included no sequential treatment, clethodim at 140 g ai ha^{-1}, clethodim at 140 g ha^{-1} plus *S*-metolachlor at 1,424 g ha^{-1}, and clethodim at 140 g ha^{-1} plus flumioxazin at 72 g ha^{-1}. Data were subjected to ANOVA and estimates of least squared means were utilized for mean separation ($p \leq 0.05$).

Dimethenamid-P, pyroxasulfone, and *S*-metolachlor alone provided ≥ 94% control of GR Italian ryegrass 21 d after treatment (DAT) in the Herbicide Mixture Study. The addition of flumioxazin to dimethenamid-P, pyroxasulfone, and *S*-metolachlor did not improve control 130 DAT. In the Sequential Application Study, GR Italian ryegrass control was ≥ 96% with treatments containing dimethenamid-P at 70 d after fall application. When no fall treatment was utilized, the addition of flumioxazin to clethodim POST increased control ≥ 14% compared with clethodim alone.

Fall-applied residual herbicides are a necessary component of programs for control of GR Italian ryegrass in Mississippi. Treatments with fall-applied dimethenamid-P performed better than acetochlor except when fall-applied acetochlor was followed by a sequential application of clethodim plus *S*-metolachlor. Poor control with acetochlor might be related to its ME formulation compared with dimethenamid-P being an emulsifiable concentrate (EC).

Influence of Fall-Applied Residual Herbicides on Rice Growth and Yield

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

Seventy of 82 counties in Mississippi contain populations of glyphosate-resistant (GR) Italian ryegrass (*Lolium perenne* ssp. *multiflorum*). Italian ryegrass residue remaining at planting can impede planting practices, contribute to competition between crop seedlings and established GR Italian ryegrass, and hinder herbicide programs due to inadequate coverage. Mississippi State University recommends fall applications of residual herbicides for control of GR Italian ryegrass. Recommended residual herbicides include clomazone, pyroxasulfone, *s*-metolachlor, and trifluralin. Problematically, only clomazone is labeled for fall application prior to planting rice. Therefore, research was conducted in Stoneville, MS, to evaluate the effect of fall-applied residual herbicides on rice growth and yield.

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

Clomazone, dimethenamid-P, and flumioxazin injured rice ≤11% 28 DAE. Acetochlor delayed rice maturity 2 d when compared to clomazone, dimethenamid-P, and flumioxazin. Rice density was reduced ≥4 plants m^{-2} with fall-applied acetochlor. Rough rice yields were reduced 20% with fall-applied acetochlor alone.

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

Evaluation of Tetflupyrolimet Application Methods for Annual Grass Control

Stoker, S.B., Webster, L.C., Hains, M.P., and Carr, W.B.

Tetflupyrolimet is a pyrimidine biosynthesis inhibitor via inhibition of dihydroorotate dehydrogenase synthesis. Tetflupyrolimet is a novel herbicide undergoing development by FMC®. This herbicide expresses selective action against various grass species commonly found in rice (*Oryza sativa* L.) production. Tetflupyrolimet will be classified as a group 28 herbicide by the Herbicide Resistance Action Committee.

A study was conducted in 2023 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, to evaluate tetflupyrolimet applied as a spray and impregnated on fertilizer. Plot size was 1.5 by 5.2 m and all plots were seeded with 'PVL03' at 78.4 kg ha^{-1}. This study was a two-factor factorial with a randomized complete block design with four replications. Due to a nondisclosure agreement, the rates of tetflupyrolimet cannot be disclosed and will be represented by low 'a' or high 'b.' Factor A consisted of herbicides applied prior to emergence either impregnated on fertilizer or sprayed. Factor B consisted of tetflupyrolimet at 'a' or 'b,' clomazone at 225 or 313 g ai ha^{-1}, tetflupyrolimet at 'a' plus clomazone at 225 g ha^{-1}, or tetflupyrolimet at 'b' plus clomazone at 313 g ha^{-1}. All sprayed herbicide applications were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Herbicide impregnation treatments were applied using a starter fertilizer of 0-23-30 (N-P_2O_5-K_2O) at 280 kg ha^{-1}. Visual evaluations of percent control for barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster] were observed at 14, 21, and 35 days after treatment (DAT). Rough rice yields were obtained and adjusted to 12% moisture content.

At 14 DAT, barnyardgrass control of 89 to 97% was observed when tetflupyrolimet was mixed with clomazone regardless of rate when applied as a spray. At 21 DAT, barnyardgrass control of 91% was observed when tetflupyrolimet was applied at 'b' plus clomazone at 313 g ha^{-1} implementing a spray application. At 36 DAT, 83 to 84% control of barnyardgrass was observed when tetflupyrolimet was applied, regardless of application method, at 'b' plus clomazone at 313 g ha^{-1}. Treatments applied via fertilizer impregnation resulted in a slower release of herbicides, causing weaker early season control when compared to spray applications. Preliminary results suggest that impregnating tetflupyrolimet on starter fertilizer can be used in Louisiana rice production.

The Evaluation of DodhylexTM in Mississippi Rice Production

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

Synthetic herbicides' utility as weed killers is threatened by the widespread evolution of resistance to most herbicide mode of actions (MOA). Barnyardgrass, which can significantly reduce rice yield, has limited control options due to its evolved resistance to many herbicides. Additionally, there have been no reports on herbicides with a novel MOA for nearly 30 years. However, FMC Corporation recently discovered tetflupyrolimet, known as the Dodhylex™ active. This new MOA

has been classified as WSSA & HRAC Group 28, which inhibits dihydroorotate dehydrogenase. Multiple studies were conducted in 2023 to evaluate tetflupyrolimet for midsouthern United States (U.S.) rice production at the Delta Research and Extension Center in Stoneville. The first study determined barnyardgrass control and rice tolerance with tetflupyrolimet and clomazone in 13 different stand alone and/or combination treatments. The second study evaluated tolerance of four midsouthern U.S. row crops (cotton, soybeans, grain sorghum, and corn) to low rates of tetflupyrolimet and clomazone. These low rates, designed to simulate drift, were applied immediately following planting and at the V4 crop stage. Visual weed control and crop injury ratings were taken after applications and yield data was collected at crop maturity. Results indicate increased residual barnyardgrass control with the addition of tetflupyrolimet to clomazone. In the second study, common midsouthern U.S. crops have shown no injury related to tetflupyrolimet symptomology and yields were not decreased. The discovery of tetflupyrolimet is an important one and appears to provide a safe option for residual barnyardgrass control in Mississippi rice production.

Evaluation of Annual Grass Control Using Mixtures of Tetflupyrolimet and Clomazone

Hains, M.A., Webster, L.C., Williams, J.A., Carr, W.B., Stoker, S.B., and Vallee, L.N.

Tetflupyrolimet, a novel herbicide being developed by FMC®, hinders *de novo* pyrimidine biosynthesis by inhibiting dihydroorotate dehydrogenase. Tetflupyrolimet is selective for grass control in rice (*Oryza sativa* L.) and is the first herbicide in the new Herbicide Resistance Action Committee Group 28. A study was conducted in 2023 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, to evaluate different rates of tetflupyrolimet and clomazone applied alone and in mixtures for preemergence grass control in rice. Plot size was 3-m by 9.14-m with 16-19.5 cm drill-seeded rows of 'PVL03' at 78.4 kg ha^{-1}. This study was a randomized complete block design with five sequentially increasing rates of tetflupyrolimet applied alone (a, b, c, d, and e), five rates of clomazone applied alone at 125 g ai ha^{-1}, 188 g ai ha^{-1}, 250 g ai ha^{-1}, 313 g ai ha^{-1}, and 375 g ai ha^{-1}, and five applications of mixtures of tetflupyrolimet and clomazone with corresponding increasing rates. A nontreated check was added for comparison. Because tetflupyrolimet is still being developed, usage rates of tetflupyrolimet are to remain confidential and denoted as rates "a," "b," "c," "d," and "e," where the lowest rate correlates to the first letter in alphabetical order and the highest rate correlates to the last letter. Uniform stand treatments of halosulfuron plus prosulfuron at 105 g ai ha^{-1} and quizalofop at 1,086 g ai ha^{-1} were applied at the two- to three-leaf and panicle initiation rice growth stages, respectively. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations of percent control for this study included barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster] at 21 and 56 days after treatment (DAT). Visual evaluations of percent control were also recorded for Amazon sprangletop [*Leptochloa panicoides* (J. Presl) Hitchc.] at 63 DAT. Rough rice yields were obtained and adjusted to 12% moisture.

At 21 DAT, barnyardgrass was controlled 70 to 77% when tetflupyrolimet and clomazone were applied alone at "a" and 125 g ha^{-1}, respectively; however, when tetflupyrolimet at "a" and clomazone at 125 g ha^{-1} were mixed, 87% control of barnyardgrass was observed. At 56 DAT, 72

to 83% control of barnyardgrass was observed when tetflupyrolimet at "c" and clomazone at 250 g ha^{-1} were applied separately, while 93% control was observed from tetflupyrolimet plus clomazone at the rates of "c" and 250 g ha^{-1} respectively. Comparable results were observed for broadleaf signalgrass at 21 and 56 DAT. Tetflupyrolimet control of Amazon sprangletop at 63 DAT ranged from 68 to 95% across all rates, while clomazone achieved 25 to 62% control across all rates. The mixtures of clomazone and tetflupyrolimet controlled Amazon sprangletop 78 to 95% across all rates. These results suggest that using a preemergence mixture of clomazone plus tetflupyrolimet significantly increases grass control in rice compared to control observed when each herbicide is applied alone.

Evaluation of Oxyfluorfen in a Furrow-Irrigated ROXY Rice Production System

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

Furrow-irrigated rice (*Oryza sativa* L.) is grown on raised beds with water furrows similar to the traditional irrigation method for row crops in the midsouthern United States. Non-transgenic, herbicide-resistant rice cultivars have been utilized to combat certain weed species such as weedy rice. A new non-transgenic rice has been developed called ROXY, which is resistant to formulations of oxyfluorfen. Utilizing the ROXY rice production system in a furrow-irrigated system could help combat troublesome terrestrial weeds. The ROXY rice production system represents a useful weed control option for rice producers.

To evaluate the performance of oxyfluorfen in furrow-irrigated ROXY rice production system, two concurrent field studies were conducted at the Delta Research and Extension Center in Stoneville, MS, from 2022 to 2023. The first study evaluated residual grass and broadleaf weed control with oxyfluorfen applied delayed-preemergence (DPRE). The experimental design was a randomized complete block with a 3 x 4 factorial arrangement of treatments and four replications. Factor A was oxyfluorfen rates of 0, 700, and 981 g ai ha^{-1}. Factor B was herbicide mixture and included no mixture, clomazone at 560 g ai ha^{-1}, saflufenacil at 50 g ai ha^{-1}, and halosulfuron-methyl plus prosulfuron at 83 g ai ha^{-1}. The second study evaluated residual grass and broadleaf weed control with oxyfluorfen in a full-season herbicide program for furrow-irrigated rice. The experimental design for the second study was a randomized complete block design with a 4 x 4 factorial arrangement of treatments and four replications. Factor A was DPRE treatment and included no DPRE treatment, oxyfluorfen at 1,121 g ha^{-1}, oxyfluorfen 1,121 g ha^{-1} plus clomazone at 560 g ha^{-1}, and clomazone at 560 g ha^{-1} plus saflufenacil at 50 g ha^{-1}. Factor B was postemergence (POST) treatment and included no POST, propanil plus thiobencarb at 6,728 g ha^{-1} applied to rice in the two- to three-leaf stage (EPOST), quinclorac at 421 g ha^{-1} plus halosulfuron-methyl plus prosulfuron at 83 g ha^{-1} plus petroleum oil surfactant at 1% v/v applied to rice in the four-leaf to one-tiller stage (LPOST), and propanil plus thiobencarb EPOST followed by quinclorac plus halosulfuron-methyl plus prosulfuron plus petroleum oil surfactant LPOST. Rice injury and weed control were recorded at 14, 21, 28, and 35 d after first application (DAA). Mean rice height was recorded 28 DAA and at maturity. Data will be subjected to ANOVA using the PROC GLIMMIX procedure in SAS 9.4 with estimates of least square means at 5% significance level were used for mean separation.

In the first study, barnyardgrass control was ≤ 64% across all three mixtures 35 DAA with no oxyfluorfen. When oxyfluorfen was mixed with clomazone, saflufenacil, or halosulfuron plus prosulfuron, barnyardgrass control was ≥ 78%. No differences in barnyardgrass or Palmer amaranth control were observed between the two oxyfluorfen rates. In the second study, oxyfluorfen plus clomazone DPRE only improved barnyardgrass control compared to clomazone plus saflufenacil DPRE at 48 DAA when no POST treatment was applied or when POST treatment was propanil plus thiobencarb EPOST. Oxyfluorfen DPRE did not control Palmer amaranth 48 DAA. However, when oxyfluorfen plus clomazone was followed by propanil plus thiobencarb EPOST, Palmer amaranth control increased 32%. Oxyfluorfen has the potential to be a tool utilized in furrow-irrigated rice but utilizing different herbicide modes of action, and residual chemistries will be necessary in a full-season program.

How Provisia Rice Injury Can Be Influenced by Overcast Weather Before and After a Quizalofop Application

Carr, W.B., Webster, L.C., Stoker, S.B., Arcement, M.P., Valle, L.N., and Williams, J.A.

Crop injury in non-transgenic herbicide-resistant rice (*Oryza Sativa* L.) can be induced by decreased herbicide metabolism as a result of poor growing conditions. In 2023 and previous growing seasons, crop injury has been observed when quizalofop was applied at the labeled rate in Provisia® rice during periods of low solar radiation and low temperatures.

In 2023, at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, a study was conducted to evaluate overcast weather conditions before and after quizalofop applications in Provisia® rice. Shade cloths (The Shade Cloth Store, Mundelein, Illinois 60060) were used in these studies to simulate overcast growing conditions. The experimental design consisted of a three-factor factorial arrangement of treatments with three replications. Factor A (whole plot) consisted of either no shade, shade for a period of 7 days prior to quizalofop application, or shade for a period of 7 days after quizalofop application. Factor B (sub plot) consisted of shade coverage representing overcast weather at 30, 60, or 90%. Factor C (sub sub plot) consisted of either no quizalofop, quizalofop at 120 g ai ha^{-1}, or quizalofop at 240 g ai ha^{-1} at the three- to four-leaf rice growth stage. Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Visual evaluations for crop injury were recorded 14 and 21 days after treatment (DAT). At 14 DAT, crop injury was 2 to 8% following quizalofop applications when no overcast weather was simulated across both rates. When overcast weather was present for a period of 7 days prior to quizalofop applied at 120 g ha^{-1} at 30, 60, and 90% shade, crop injury was observed at 5, 9, and 19%, respectively, and when 240 g ha^{-1} of quizalofop was applied, crop injury was observed at 13, 15, and 26%, respectively. When overcast weather was present for a period of 7 days following quizalofop applied at 120 g ha^{-1} at 30, 60, and 90% shade, crop injury was observed at 7, 16, and 27%, respectively, and when 240 g ha^{-1} of quizalofop was applied, crop injury was observed at 11, 19, and 34%, respectively. This research indicates that overcast growing conditions are playing a role in crop injury in the Provisia® rice production system.

Impacts of Drying and Storage Approaches on Physiological Characteristics of Seed Rice

Olaoni, S.O., Luthra, K., and Atungulu, G.G.

Improper drying, causing the fissuring of rice kernels, may influence the overall physiological health of the seed. Previous research has shown that drying seed rice above the temperature of 43°C may damage and adversely affect its viability. Given the presence of several rice varieties and cultivars, this study becomes necessary. To investigate this, two long-grain hybrid rice cultivars harvested at high, medium, and low moisture content (MC) were utilized. On-field fissure intensity of the kernel was observed using an X-ray machine. The samples were then dried to 12.5% MC on a wet basis at temperatures of 40°C, 50°C, and 60°C) and relative humidities of 25 and 50%. Subsequently, the fissure intensity of the treated samples was carefully examined, and the remaining samples were stored for a duration of one year in three-month intervals. Following every three months, samples needed were removed, and the seed germination and vigor of each treatment were measured and quantified.

The research has shown that samples dried and germinated in the first month immediately after harvest exhibited lower seed germination compared to subsequent months (3, 6, 9, and 12 months). This was a result of the dormancy effect, which prohibited the seeds from germinating. Results from three months supported this claim since seed germination increased to about 90% and continued a similar trend until 12 months. In addition, the temperature and RH explored had no adverse impact on the seed germination and vigor of the seed. Reports on new approaches to break the dormancy of the seed as soon as needed have been proposed and will potentially be presented. This investigation quantifies the importance of rice drying and storage conditions for seed rice physiological health while offering valuable insights for optimizing seed preservation in the seed industry and ensuring high crop yields.

Investigating Parboiling Traits of Contemporary Rice Cultivars

Ameyaw Owusu, E., Luthra, K., and Atungulu, G.G.

The head rice yield (HRY) holds crucial importance for rice processors dealing with parboiled rice. Prior studies suggest that achieving the maximum head rice yields during rice parboiling may not require extensive starch gelatinization, with 40% starch gelatinization being sufficient to correlate with maximum head rice yield. Presently, several contemporary rice cultivars that exhibit distinct starch compositions and characteristics, different from those previously studied, are in use. These changes necessitate investigations into the degrees of gelatinization needed to achieve the maximum head rice yields for these contemporary cultivars during parboiling. The objectives of this study were therefore to (1) determine the degree of gelatinization that correlates with the maximum head rice yield (HRY) for contemporary rice cultivars during parboiling and (2) determine processing parameters that lead to optimal quality (Color, Texture) for contemporary rice cultivars during parboiling. This study utilized 26 different rice cultivars harvested in 2023 from various regions in Arkansas. The cultivars were parboiled using a partially automated parboiling unit within the University of Arkansas Rice Processing Program (UARPP). The soaking temperature applied was slightly below the onset gelatinization temperature for each cultivar, and

the soaking duration was set at the minimum time necessary to achieve complete hydration of the rice. Steaming temperatures of 100°C and 110°C were applied for 4, 10, and 20 minutes. The results for the long-grain cultivar (PVL03) exhibited a range of starch gelatinization degrees, ranging from 58.8% to 100%, depending on the parboiling treatment applied. The optimal degree of starch gelatinization, corresponding to the maximum HRY, was identified to be 75%, at a HRY of 70.9%. The parboiling process parameters, involving soaking at 72°C for 3 hours and steaming at 110°C for 10 minutes, demonstrated optimal conditions for achieving the best quality of parboiled rice. Under these parameters, the resulting characteristics included a hardness of 11,955.3 g, adhesiveness of -36.8 g, (*L) color of 36.7, (*b) color of 26.8, and a HRY of 70.3%. The obtained results prove highly advantageous for rice processors, assisting them in identifying the optimal parameters required to achieve the desired quality of parboiled rice while conserving energy efficiently.

Instantization Potential and Product Quality Attributes in Hybrid and Pureline Rice Cultivars

Ouma, F., Luthra, K., and Atungulu, G.

Instant rice has gained popularity due to its convenience, yet the instant rice processing industry is still faced with challenges in producing high-quality products with respect to their physical and textural properties. While the impact of hybrid and pureline rice cultivars on instant rice quality remains an underexplored domain, this study aimed to investigate the instantization potential of various long-grain (hybrid and pureline) and medium-grain rice cultivars by determining their cooking characteristics and quality attributes. Factors studied included cooking duration, instantized rice water activity, bulk density, color, rehydration ratio, volume increase ratio, and texture. Rice of each studied cultivar category, with 12.5% moisture content (wet basis), milled to 0.4% surface lipid content, was cooked in an excess rice-water ratio (1:20). The optimal cooking duration for the rice was determined using the glass plate method. The cooked rice samples were then dried using a hot air oven (stepwise approach) at 230°C, 220°C, 210°C and 200°C for 1, 1, 1, and 3 minutes, respectively. Afterwards, the rice was gently dried in a controlled chamber (25°C, 55% relative humidity) until the moisture content was 12% (w.b.). Results showed differences in cooking duration and water removal characteristics across the rice cultivars. The long-grain rice RT7523 cultivar had a longer cooking duration of 29 minutes compared to the other counterpart long-grain rice cultivars XP782, RT7331, and PVLO3, of 24 minutes. Furthermore, the moisture removal percentages after hot air oven treatment for the RT7331 and XP782 cultivars were 23.62% and 26.49%, respectively. These results to be presented could potentially help processors identify rice cultivars for instant rice products with desirable physicochemical and textural attributes.

POSTER SESSION

Breeding and Genomics - Posters

Genome-Wide Association Study (GWAS) to Identify Candidate Genes Associated with Milling Quality and Appearance Quality Traits Useful in a U.S. Rice Applied Breeding Program

Borjas, A., Sha, X., Samuel, F., Murphy, M., and De Guzman, C.

Milling and appearance characteristics of rice seeds are important parameters that determine the grain quality of rice varieties. Identification of genomic regions targeting grain quality traits is crucial to identifying genes and implementing marker-assisted breeding for high-quality variety development program. Here, a genome-wide association study (GWAS) using 128 genotypes and 1,342 SNP was performed to identify marker-trait associations for total rice yield (TRY), head rice yield (HRY), chalk impact, seed length, seed width, seed thickness, milling degree, grain whiteness, and grain transparency. Significant SNPs were associated with the nine grain quality traits. Among them, 81 SNPs explained >10% of the phenotypic variation on various traits. Our findings confirmed previously reported QTLs. Additionally, novel regions were identified for all the investigated traits except HRY. These novel regions were identified for TRY on chromosomes 2, 7, and 12, seed length on chromosomes 4 and 11, seed width on chromosome 11, and seed thickness on chromosomes 4, 6, 7, 8, and 10. This is the first genome-wide association study to report genomic regions linked to the degree of milling, grain transparency, and grain whiteness of rice. Overall, this study offered genetic insights into enhancing key grain quality traits by identifying significantly associated SNPs. Future validation of these genomic regions will benefit their implementation in applied rice breeding programs.

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

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

Plant breeding programs require extensive and meticulous data management. The incorporation of advanced breeding methodologies into large-scale variety development programs has increased the need to store and repeatedly retrieve historical data. Cataloguing, retrieval, and analysis of data can be cumbersome and prone to errors when performed by hand or in numerous spreadsheets. By integrating the use of Breedbase (a comprehensive breeding management and analysis software) into our rice breeding program, we have more efficiently created trials, crosses, seed lots, and field books, stored and analyzed phenotypic and genotypic data, linked accessions to their respective metadata, and searched for and downloaded large amounts of data. Breedbase was developed at Cornell University and is the same platform used to develop the rice marker and sequence database “Ricebase. Breedbase is customizable and able to record additional properties/metadata, images, documents, spreadsheets, etc. that may be pertinent to an accession.

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

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

20Y4033, A Promising New Fragrant Calrose

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

Rice aroma commands a premium price in the market. The USA, being the 4th or 5th rice exporting country in the world, is a net importer of rice. More than 60% of imported rice to the United States are Basmati and Jasmine rice to cater the Asian demand for aromatic rice. At the California Rice Experiment Station, a rice cultivar with an experimental line ID as 20Y4033 is being considered for variety release in January 2025 as a new class of Calrose with subtle popcorn or floral fragrance. The line was developed by crossing an M-206 mutant with an aromatic long grain A-202, followed by two consecutive backcrossing to M-206. Genetically, 20Y4033 is 87.5% M-206 and 12.5% A-202. Agronomically, 20Y4033 closely resembles M-206. It is semidwarf, with non-pubescent leaves and grain hull, and has similar seedling vigor like M-206. On average, plant height of 20Y4033 is 101 cm and it reaches 50% to heading at 87 days, which is a day earlier than M-206. In terms of cold tolerance, 20Y4033 has similar high resistance to cold induced-panicle blanking. Moreover, 20Y4033 is expected to be susceptible to blast and stem rot like M-206. Based on three years of statewide yield testing, 20Y4033 has an average yield of 10.61 ton/ha or 8,585 lb/acre. The milling yield of 20Y4033 on average is 62% head rice, 71% total at 18-22% MC. Sensory evaluations by individuals and rice marketing companies indicated the excellent grain appearance of 20Y4033 uncooked and cooked rice. Unlike Basmati or Jasmine with overwhelming aroma during and after cooking, the floral or popcorn aroma of 20Y4033 is very subtle during cooking and nearly gone in cooked rice. Nevertheless, the signature eating qualities (soft, fluffy, moist, and smooth texture) of Calrose rice are preserved in 20Y4033. The addition of fragrance in 20Y4033 enhanced the flavor and overall taste of rice. Considering the unique subtle fragrance of 20Y4033 as compared to conventional Calrose, the 20Y4033 will be required to have identity preservation once released to the growers.

18Y2070, An Improved High Yielding California Risotto Rice

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

To accommodate the Arborio rice niche market in the United States, the California Rice Experiment Station developed and released a rice germplasm designated as 89Y235 in 1994. After 30 years of germplasm improvement and multiple cross-breeding of Italian Arborio, Carnaroli, and Faro to M-201 and other California breeding lines, a very high yielding promising risotto rice with experimental ID as 18Y2070 was developed. 18Y2070 has the signature bold kernel and white belly typical of risotto rice varieties. Based on five years of multi-location statewide yield testing, 18Y2070 had an average yield of 10.68 ton/ha (8,647 lb/acre), which is 12% yield higher than 89Y235 and 100% yield advantage over Arborio rice. 18Y2070 is a semidwarf rice with a plant height of 103 cm. The leaves and grain hull of 18Y2070 are glabrous or smooth. It has seedling vigor similar to 89Y235 but still less than the seedling vigor of Arborio. Plants of 18Y2070 are lodging resistant and reach 50% to heading at 89 days. With natural chalky or white belly grains typical to risotto rice, 18Y2070 is preferably harvested at 18-22% MC to obtain an average milling yield of 51% head rice, 66% total. Based on external blind and open evaluations by chefs and culinary experts, 18Y2070 is acceptable to the Arborio-type market based on grain appearance, aroma, texture, and taste ideal to risotto cooking. With yield advantage, grain quality, cooking, and eating qualities desirable for risotto rice, 18Y2070 will be proposed for variety release in January 2025.

Gene Editing of UDP-Glucose Pyrophosphorylase 3 (UGP3) Confers Oxyfluorfen Tolerance in Rice

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

Weeds are the number one constraint to rice production in California. However, rice growers are limited to a few number of registered herbicides for use in rice. To provide options that will help control weeds in rice, the California Rice Experiment Station (RES) started a mutation breeding study to create a novel herbicide-resistant rice using ethyl methanesulfonate (EMS). After several spraying and screening of mutated rice seeds against various herbicides, nine rice lines were found highly tolerant to oxyfluorfen and named as ROXY lines. A tolerant line was then crossed to medium and long grains. The gene responsible for the trait was fine mapped and narrowed down to a mutation in *UDP-Glucose Pyrophosphorylase 3 (UGP3*) gene. The nucleotide deletion resulted in a frameshift mutation and a shorter predicted protein. Here in this study, the *CRISPR-Cas9* system was utilized to validate the functional association of *UGP3* mutation to oxyfluorfen tolerance in rice. A *CRISPR-Cas9* gene construct containing two guide RNAs targeting *UGP3* was designed and used in rice transformation of Calmochi-203, a waxy or glutinous short-grain rice released by RES. Putative gene-edited Calmochi-203 rice was recovered and was advanced to T_2 generation. Oxyfluorfen treatment of gene-edited Calmochi-203 seedlings showed enhanced shoot and root growth consistent with the tolerance of ROXY® lines. Furthermore, gene sequencing of

UGP3 target site in gene-edited rice confirmed the presence of mutations introduced by *CRISPR-Cas9* that resulted in recovery of the herbicide tolerance trait. This study therefore illustrated the functional involvement of *UGP3* to oxyfluorfen tolerance. Furthermore, the use of *CRISPR-Cas9* system was proven useful in introducing targeted nucleotide mutation and gain of a new trait in rice.

Frost and Recovery: Unraveling Extrachromosomal Circular DNA Diversity in Rice under Genotoxicity and Cold Stress

Katouzi, M. and Bucher, E.

Oryza sativa is one of the most studied crops in genomics. Genetic changes caused by abiotic stress, such as cold, have been extensively researched, but there are still hidden layers that warrant further investigation. One such aspect is the impact of abiotic stress on the diversity of extrachromosomal circular DNA (eccDNA). eccDNA is a form of DNA that is not included in chromosomes and that can have various origins. Transposable elements (TEs) are one of these sources. Stresses, in general, can modify the activity of TEs and as a consequence the diversity and production of eccDNAs.

This study aims to evaluate the impact of genotoxic drugs and cold stress on eccDNA accumulation in rice (Nipponbare). To accomplish this, we examined the effects of a combination of drugs and cold stress during treatment and following recovery from the treatment. DNA of the plants was then extracted and eccDNAs were amplified for mobilome sequencing.

The results showed that the diversity of eccDNAs varied depending on the condition. The effect of combining genotoxic drugs and cold stress was evident in both the accumulation and diversity of eccDNAs derived from TEs. Interestingly, we identified condition-specific eccDNAs suggesting a specific response to the treatments. Recovery after cold stress emerged as a key factor in the production of eccDNA containing complete TEs. The sampling time did not affect the production of eccDNAs containing complete TEs under normal conditions; however, it could influence the production of eccDNAs.

This study provides novel insights into the interplay between genotoxicity, abiotic stress, and the complex mechanisms that support genomic stability. By investigating how these factors influence the activity of TEs and the subsequent production and diversity of eccDNAs, we found first indications that eccDNAs may contribute to genetic variation. Moreover, the identification of specific loci involved in eccDNA production under stress conditions increased our understanding of epigenetic regulation in this process. It also sheds light on potential targets for future research aimed at better understanding genome dynamics in rice.

Our study highlights the significance of examining complex interactions within the broader genomic landscape. It emphasizes moving beyond the traditional focus solely on chromosomes and genomes to gain a comprehensive understanding of how stress can impact the genome.

Analysis of the Blast Resistance Gene in Korean Rice Cultivars

Lee, H-S., Lee, S.Y., Chung, H., Ha, S-K., Lee, G., Lee, C-M., and Jeung, J-U.

Globally, rice blast disease is a major factor contributing to the reduction in rice yields in rice cultivation areas. The rice blast pathogen, *Magnaporthe oryzae*, is a fungus that can infect the entire plant from the seedling stage to mature stage throughout the rice growth period. While methods such as recommended nitrogen fertilizer application and fungicide treatment can be used for disease control, breeding resistant varieties is the most effective and economical way. However, these resistant varieties also undergo the breakdown due to rapid pathogen evolution. In the case of Korea, there was a widespread outbreak from 1978 to 1980 due to the cultivation of a similar genetic background rice (Tongil type) and rapid pathogen differentiation. In this study, the association analysis of the blast resistance degree and genotype using 27 DNA markers previously reported of blast resistance in 300 Korean rice varieties developed since 1979 was conducted. Blast resistance was determined using the 0–9 scoring system (a scale 0=no lesions to 9=dead leaves) from IRRI in the nursery test of the experimental field in Wanju, South Korea, for three years from 2018 to 2021. The results revealed that Tongil-type varieties showed strong resistance compared to Japonica varieties, and early maturing varieties exhibited stronger resistance than the mid-late or medium maturing varieties. The association analysis revealed that the resistance of early maturing type was strongly associated with *Pi40* gene marker, while all Tongil-type varieties exhibited resistance genotype at the *Pi20* gene markers. These results suggest that blast resistance in Korean rice cultivars may be primarily influenced by the *Pi40* in early maturing type and the *Pi20* gene in Tongil-type. The *Pi40* gene in the early maturing type is known to be closely linked with heading data gene, *Hd1*. Since most of Korea's major rice cultivars are susceptible to rice blast, we have developed an elite mid-late maturing type line with the *Pi40* gene through Marker-Assisted Backcrossing (MAB). This breeding line exhibited resistance against all 30 representative blast isolates collected in Korea. These results will be beneficial for breeding of blast resistance rice in Korea. The research was funded by the Rural Development Administration (RDA) of South Korea, grant number PJ017269.

Genetic Improvement of Low-Temperature Stress Tolerant Rice Varieties for High Elevation Areas

Manangkil, O.E., Padolina, T.F., Pautin, L.R., and Braceros, R.C

Unstable rice production in the high elevation areas in the Philippines can be attributed to lack of improved cultivars adapted to low temperature, low solar radiation, higher relative humidity, nutritional disorders like zinc and nitrogen deficiency, and biotic stresses such as blast disease. This necessitates the long-term objective of improving the yield potential of the indigenous germplasm in the area. The main rice crop during the dry season from January to June requires cool temperature tolerance below 17ºC while in the wet season. From July to December, the production areas are fallowed due to lack of suitable varieties with higher tolerance at temperatures lower than 17ºC in the reproductive stage. These areas with higher elevation, usually at $\geq$1,000 meters above sea level (mASL), are more challenging and mostly with low or no yields at all.

Based on these premises, the breeding objectives concentrated to satisfy season and elevation specific adaptation.

Shuttle breeding following the conventional method was employed. The local cultivars and breeding materials were crossed to known cold tolerant donor germplasm and shuttled and selected under the natural cold stress in Benguet and Ifugao provinces. Other traits such as early flowering, medium tall stature, intermediate to non-shattering, resistance to pests, with good grain quality, and a yield of at least or more than 4.0 tons/ha were targeted.

Before the 1980s, selection from the International Cold Tolerance Nursery by the International Rice Research Institute (IRRI) generated the variety RPKn2 with moderate cool tolerance and only adapted in low elevation areas in the Ifugao province (≤500 mASL). Under the formal breeding program of Philippine Rice Research Institute, from 1995 to 2001, six modern rice varieties were released with season-specific adaptation. From 2011, breeding for cool temperature was revitalized when the Philippines became a member of the Temperate Rice Research Consortium (TRRC) coordinated by IRRI. Better cold tolerant donor germplasm was accessed for the program. In 2019, four varieties were commercially released by the National Seed Industry Council (NSIC) as NSIC Rc 560 (Cordillera 1), NSIC Rc 562 (Cordillera 2), NSIC Rc 564(Cordillera 3), and NSIC Rc 566 (Cordillera 4). These varieties possessed higher yield potential, better grain quality, moderate seedling cold tolerance, resistant to field blast resistance, and good grain and eating quality.

Currently, donor germplasm generated from modern biotechnology with known genes for cold tolerance, blast resistance, grain quality, and other yield-enhancing traits are now being used in improving our elite breeding lines such as PR42484-B-17-1, PR43682-B-1-5, PR52619-B-B-1, and PR52662-B-3-1 to generate better varieties for the cool climatic zones in the country. Moreover, local collaborations have been strengthened to expand dissemination of cool tolerant varieties in areas other than the Cordilleras. Equally, with international cooperation, sharing of donor germplasm, protocols, research information, and use of facilities for screening and evaluation paved better opportunities for the development of suitable varieties.

Multi-Environment Stability Analysis of California Rice Varieties

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

Developing new rice varieties with high and stable yields across different environments is challenging due to genotype-by-environment interaction influence. The objectives of this study were 1) to evaluate the consistency of correlation between grain yield and stability indices in multi-environment yield trials of commercial rice (*Oryza sativa* L.) varieties and 2) to identify suitable stability indices for selecting rice genotypes. Grain yield data from the University of California Cooperative Extension (UCCE) statewide (SW) yield trials (2020-2023) of 19 commercially grown rice varieties (medium, long, and short) developed and released by California Cooperative Rice Research Foundation, Inc. at the Rice Experiment Station (RES) was used in this study. The trials were conducted at nine locations: Colusa, Glenn, North Butte, South Butte, San Joaquin, Yuba, Yolo, Sutter, and Biggs in California. All trials were laid in a randomized complete block design with either three or four replicates per location. Each trial was managed according to the

host farmer's field management practices. A total of 10 stability indices were used to evaluate stability and to compare the stability indices, correlation coefficients between methods were estimated. Most of the stability indices studied were positively correlated. Positive correlations were also observed between grain yield (YLD) and AMMI-based stability indices. Based on the current results, stability indices including harmonic mean of the relative performance of the genotypic values and superiority indexes for all, favorable and unfavorable environments can be used because they had high and positive correlations with grain yield.

16Y2028, An Improved Low Amylose Short-Grain Rice

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

In 2006, the California Cooperative Rice Research Foundation Inc. released the first low amylose short-grain rice variety, Calamylow-201 (CA-201), developed for a specialty market. It is an induced mutant of Calhikari-201, a premium quality short-grain rice. However, CA-201 is low yielding; as such, there was a need to develop an improved variety to address this limitation. Low amylose short-grain rice is primarily used for making rice products that remain fresh under chilled or refrigerated conditions. An experimental line,16Y2028, is an improved low amylose short-grain rice developed at the Rice Experiment Station through pedigree breeding. It is a very high yielding, glabrous, early maturing, and cold tolerant short-grain rice. From 2019 to 2023 statewide yield trials, line 16Y2028 significantly outyielded the check variety, CA-201, in all test locations. On average, line 16Y2028 yielded 10.14 t/ha compared to 7.62 t/ha for the check variety, thus a yield advantage of 33%. It reached days to 50% heading 86 days after planting, it had good seedling vigor of 4.9 on a scale of 1-5, 1 being poor and 5 being excellent, and it is cold tolerant. When harvested at 18-20% moisture content, 16Y2028 had an average milling yield of 59% head rice and 70% total rice. In addition, its kernels are longer, wider and heavier than the check variety. Grain quality attributes of 16Y2028, including grain appearance, cooking and eating qualities are similar to CA-201.

Impact of ENSO phases on Uruguayan rice productivity.

Pérez-de-Vida, F.B.

The occurrence of climate variations known as ENSO phases are caused by anomalies in ocean surface temperature in the so-called Niño 3.4 region in the Central Equatorial Pacific. These anomalies are officially used by NOAA (U.S. National Oceanic and Atmospheric Administration) to define whether there is a probability of occurrence of a La Niña, El Niño or neutral phase with global impact. In Uruguay, South America, the impact of climatic variations associated with ENSO phases on agricultural and pasture production is well known. In rice cultivation, although 100% irrigated, this impact is significant on a commercial scale (Roel et al 2020), associated with variations in the level of rainfall in spring and summer that can mean delays in the optimal planting date and variable levels of solar radiation. This report, meanwhile, analyzes its impact on rice yield in evaluation trials of INIA's rice breeding program in a series of 10 harvests (2013/14 to 2022/23).

A regression analysis that includes physical yield data of five check varieties and the temperature anomalies of the Pacific Ocean (regions 3 and 4) allows us to identify a significant association between the environmental conditions and the yields obtained in cultivar evaluation experiments of the INIA genetic breeding project. Overall, for the data set, a loss in rice yield potential of 613 kg/ha would be expected for every 1 Celsius degree change in surface ocean temperature.

The planting date is a significant factor in reducing the negative impact of temperature deviations in Pacific conditions. The loss of yield potential doubles in late sowing (1st half of November, -0.882 t/ha) in relation to early October plantings (-398 kg/ha). On the other hand, including as sources of variation the categorization according to ENSO phases and the cultivars included in the study, both factors are highly significant. The yields obtained under La Niña seasons were significantly more productive (10.99 t/ha) than those of Neutral or El Niño seasons (10.02 t/ha). In the case of an El Niño higher intensity (temperature deviation +2.5°C), the yield obtained is significantly lower (8.84 t/ha). In the experimental conditions in which these results were obtained, the high temperatures and radiation in La Niña seasons would explain the higher yields. Under commercial conditions for which similar results are expected, for example, the last three harvests (2020/21 to 2022/23) with average yields above 9 t/ha – the greater probability of early plantings and harvests with fewer losses or delays due to lower rainfall incidences would be added as determining factors of high productivity.

The environmental conditions generated by the climatic variations associated with the ENSO phases, which have a territorial scope for all rice-growing regions in the country, have a significant impact on the productivity obtained in trials to evaluate the yield of rice cultivars. A variation in yield potential of approximately 600 kg/ha is expected for every +1 °C variation in ocean surface temperature in the Central Equatorial Pacific. The phases of ocean warming imply a reduction in yield that is maximized to the extent that the crop is planted in periods that are not optimal (October for the eastern region of the country). The results indicate that a significant factor in the country's current production levels in the three immediately past harvests was the occurrence of "La Niña," which, together with improved cultural practices and high productivity new varieties, have allowed the national average to exceed 9 t/ha.

Screening for Kernel Smut Resistance in Diverse Rice Germplasm

Prodhan, Z.H., Samonte, S.O.P.B., Sanchez, D.L., and Elec, V.H.

Kernel smut, a devastating grain disease of rice, is attributed to *Tilletia horrida* Tak., also known as *Neovossia barclayana* Bref. This fungus invades rice flowers and colonizes internal organs via mycelia, which ultimately generates large quantities of teliospores appearing as black powdery masses. Teliospores are the predominant stage of *T. horrida* during the winter dormancy and can survive for over one year in the soil and at least three years on the surface of host seeds. During the initial stage of infection, the floral organ tissue remains intact and does not exhibit any noticeable disease symptoms. However, the teliospores only become visible during the yellow maturity stage of rice and have already caused a significant reduction in rice grain yield at this stage. Hence, the selection and development of resistant rice cultivars could be the only way to mitigate the damage caused by the kernel smut. Until now, no cultivar has been identified with

high levels of resistance. This study aims to detect and screen for kernel smut resistance donors in diverse rice germplasm collected at the Texas A&M AgriLife Research Center, Beaumont, Texas.

The transcriptome analysis revealed an elevated expression of stress-responsive genes, transcription factors, and a potential kernel smut resistance gene in resistant rice lines. In addition, a simple and rapid technique has been developed based on the partial sequences of the internal transcribed spacer (ITS) DNA region to identify *T. horrida* in rice seeds.

The targeted gene sequencing and amplification of a 503-bp fragment using custom-designed primers will be applied for the identification of rice lines with different levels of resistance, intermediate, and susceptible to kernel smut. The selected rice lines could be applied to kernel smut resistance breeding programs, and the PCR-based diagnostic technique can be used to detect and identify kernel smut infected rice samples.

Development of Low Glycemic Index Rice at Texas A&M AgriLife Research

Samonte, S.O.P.B., Sanchez, D.L., Ponce, K.S., Prodhan, Md. Z. H.,
Elec, V. H., Talukder, S.K., and Wilson, L.T.

High amylose rice, which has a lower glycemic index than conventional rice, is a healthy alternative for consumption by the 31 million people in the United States who have diabetes, obesity, and colon diseases. Rice types based on amylose concentration are waxy (0 to 2%), very low (2 to 12%), low (12 to 20%), intermediate (20 to 25%), and high (>25%). Texas A&M AgriLife Research initiated its Specialty Rice Breeding Program in 2022, with the development of high-amylose rice cultivars as one of its breeding objectives.

In 2023, replicated yield trials were conducted in Beaumont and Victoria, Texas, to evaluate 65 high amylose rice entries and check cultivars. The rice entries were evaluated for agronomic, grain quality, taste, and genetic markers for amylose concentration, stress tolerance, and chalkiness. Texas inbred line 'TIL22043' was the top entry selected from these yield trials. Compared to check cultivar Preisdio, TIL22043 was higher in grain yield (25% more), taller by 12 cm, with longer grain length (6.67 vs. 6.19 mm) but similar width, and comparably low chalky grain percentage (5.3 and 6.9%, respectively). Both Presidio and TIL22043 headed at 79 days after germination and did not lodge. Amylose concentrations based on iodine colorimetric analyses were 20% for Presidio and 36% for TIL22043. Genetically, TIL22043 has the alleles for high amylose, blast resistance (*Pi54* and *Pii*), anaerobic germination (*qAG1* and *qAG3*), and low chalkiness (*qPGWC8*). Furthermore, it performed satisfactorily in taste tests evaluating aroma, whiteness, glossiness, appearance, chewiness, taste, and softness.

With its good phenotype (high amylose concentration, high yield, good grain quality, early maturity) and genotype (stress-resistant and low chalkiness), TIL22043 is our top low glycemic index (high amylose) rice line being evaluated for its potential for cultivar release.

Marker-Assisted Selection of Aromatic Breeding Lines at Texas A&M AgriLife Research

Sanchez, D.L., Samonte, S.O.P.B., Ponce, K.S., Prodhan, Z.H., and Elec, V.H.

Rice imports in the United States are on an upward trend and will continue to do so with the increasing consumer demand for aromatic jasmine and basmati varieties. U.S.-grown aromatic rice makes up less than 1% of the market share. The Specialty Rice Breeding Program was established at Texas A&M AgriLife Research in 2022, which aims to develop competitive jasmine-type and basmati-type rice cultivars adapted to US field conditions.

During the 2023 season, 660 aromatic F3-F10 lines were planted panicle-to-row in the field at Texas A&M AgriLife Research Center at Beaumont. Two weeks after the heading date of the check variety Presidio, these breeding lines were screened for heading date (not later than seven days after Presidio's heading date), intermediate plant height, high tillering, and none to minimal disease incidence. After phenotypic selection, leaf samples from selected 138 lines were sent to AgriPlex Genomics for genotyping. Nineteen of these lines were identified to possess both the *fgr* and *sd1* genes, which confer aroma and semidwarf height, respectively. Nine of these 19 lines possess one blast resistance gene, and six have two blast resistance genes. Eighteen of the selected lines possess the *CRSP2.1* gene for narrow brown spot resistance. Eighteen of the 19 lines have the *GS3* allele for long grain, while one has the medium-grain allele. Six of these lines have the *Waxy* haplotype for low amylose content, one for intermediate amylose, and 12 for very high amylose. Eight lines have low to intermediate gelatinization temperatures, and 11 have high gelatinization temperatures. Marker-assisted selection for grain elongation, an important grain quality trait in basmati rice, is ongoing.

Seeds of the selected aromatic lines are currently being increased in the winter nursery in Puerto Rico and will be evaluated in preliminary yield trials at Beaumont, TX, in 2024. Marker-assisted selection was an effective tool for selecting desirable agronomic, stress resistance, and grain quality traits.

Improving Rice Hybrids and Their Parental Lines Using Molecular Markers for Temperate Conditions

Sattari, M.

Rice is one of the most important cereal grains and, after wheat, is the staple food source for Iranian families. The total area under rice cultivation is about 0.7 million hectares with an annual rice paddy production of more than 3.6 million tons. Since the rice demand and supply in Iran are not evenly balanced, the country imports around 0.8-1 million tons of rice for domestic consumption. Despite the increase of average rice production from 2.5 to 5 t/ha during past 40 years, considerable progress has been achieved in developing high-yielding varieties (HYVs) with release of several new high quality inbred and hybrid rice cultivars with more than 7 and 9 t/ha, respectively. Hybrid rice technology is one of the options to achieve increased production per unit of area. Hybrid rice varieties produce 20 to 30 percent more yields than those of improved or HYVs with the same growth duration. Wide-scale adoption of hybrid rice to sustain the rice production levels in Iran

has been now well developed. Daylam (IR58025A/IR42686R), the first aromatic and good cooking quality rice hybrid with an average yield of 9.0 t/ha over 900 ha was released after extensive on-farm trials in Iran. All research-related aspects from seed to consumer's plate has been carried out and standardized. Serious efforts were made by screening the testcrosses for potential maintainers and restorers in local Iranian germplasm using IR62829A and IR58025A. Many of the Iranian germplasm were found to be usable maintainers which further encouraged the breeders to develop their own cytoplasmic male sterile (CMS) lines. The hybrid rice seed production efficiency was increased and demonstrated to produce as high as 3.4 t/ha. Ensuring the genetic purity of hybrid seed is a prerequisite for successful production of hybrid rice. Hybrid seed is often contaminated by crosses derived from pollen from other varieties or the occurrence of selfing resulting from the impurity of male-sterile parental lines.

The objectives of this study were to characterize newly developed CMS lines and to identify informative microsatellite markers (SSR) capable to distinguish hybrid rice parental lines and their utilization in seed purity assessment. In this research, 18 Iranian and exotic CMS lines of different cytoplasmic sources and their maintainers (B) and one Thermo-sensitive Genic Male Sterile (TGMS) line, TG51, were tested under a randomized complete block design. The use of molecular markers based on PCR have been investigated to assess their purity.

The results showed significant differences in plant height, flag leaf length, flag leaf width, fertile tiller number, floret length and width, panicle length, the exit status of the panicle, percentage of allogamy, total number, and panicle fertility percentage. Mean comparison of traits showed that selection and prioritization of the superior lines according to fertility percentage, panicle exsertion, percentage of allogamy, and floret number traits related to Fajr A and Neda A and IR58025 A. Due to proper height, panicle length, number of florets, and upper percentage of allogamy in the Dasht B, these lines were introduced to improve the seed production program. Molecular tests based on PCR using four markers for purity of the seed parent, CMS and the distinction between male-sterile and maintainer lines were performed. Combination of CMS and RG136 markers and RMT6 marker could distinguish between the lines of CMS-WA and no efficiency of other male sterility sources. Results showed that the bands of drrcms marker distinction cytoplasmic male sterility lines between different sources of WA, DISSI, and Gambiaca produce different monomorphic fragments for each of the male sterile and B lines. Therefore, these markers can be used for genetic purity and possible infection test of the seed parent and suitable alternative for the time-consuming Grow-Out-Test (GOT).

Phenotypic Responses of California Advanced Breeding Lines to Heat Stress During Reproductive Stage

Sharma, N., Martin, J., De Leon, T.B., Maulana, F., Zaunbrecher, G., and Harrell, D.

In 2022, the rice growing area of North Sacramento Valley experienced an unusual heatwave that coincided with the grain filling of rice. The heat stress resulted in increased grain chalkiness in the majority of California rice varieties. The elevated number of chalky kernels lowered the overall grain quality of Calrose varieties from U.S. No. 1 to U.S. No. 2 or higher. To overcome the impact of future weather-related grain quality decline, the Rice Experiment Station breeding program

started looking at ways to mitigate the problem. A literature search indicated there are few rice varieties that are tolerant to heat stress. Therefore, rice genetic improvement for heat stress is possible. Nevertheless, before embarking on rice breeding work, it is imperative to understand the level of heat tolerance or heat sensitivity existing in our breeding lines and rice germplasm. Since grain quality is a complex trait, it is essential to identify heat-tolerant lines in our gene pool before introducing new germplasm in the breeding pipeline. In this study, we characterized our advanced breeding lines for heat stress in the greenhouse. After 100% panicle emergence, the greenhouse temperature was set to a high night temperature of 28°C for 12 hours and a day temperature of 22°C. The treatment continued until harvest, and the grain qualities of harvested seeds were evaluated using the Vibe scanner. Based on chalky kernel and other grain attributes, our breeding lines are all sensitive to heat stress. The medium-grain and short-grain lines were more sensitive with chalkiness that ranges from 9.5% - 81.0% and 4.0% - 83.9% chalkiness, respectively. Among the three grain types, the long-grain lines (1.7% - 76.0% chalkiness) exhibited some level of tolerance to heat stress. The long-grain advanced lines: 19Y1018, 20Y1009, and 20Y1010 showed lower percentage of chalky kernel compared to the corresponding lines in the control treatment. For medium grains, M-105 showed a lower percentage of chalky kernel compared to M-105 in the control. Overall, the California rice breeding program needs to be improved for heat stress tolerance. Furthermore, donors for heat stress tolerance will be sourced outside the California rice gene pool.

Epicuticular Wax-Deficient Mutants of Rice

Tai, T.H., Butterfield, T.S., Bernaola, L., Stout, M., Shim, K.C., and Liebscher, A.V.

Epicuticular waxes are the outermost protective barrier of land plants, working together with other parts of the plant cuticle to prevent unregulated water loss and provide protection against external environmental stresses. As such, the biosynthesis and accumulation of these waxes have an important role to play in climate resiliency.

A hallmark of wax-deficient rice mutants is the adhesion of water on their leaf surfaces. Using this simple screen, over a dozen mutants were identified from a population derived from chemical seed mutagenesis of the southern long grain Sabine. Three of these mutants (SAB 6-1A, 7-17A, and 11-39A) exhibited significantly reduced wax content (quantitatively and qualitatively) compared to wildtype Sabine and showed reduced resistance to rice water weevil and fall armyworm.

While almost all the Sabine mutants detected had a “wet leaf” or glossy appearance, one mutant SAB 1558 presented a distinct phenotype consisting of the adherence of small, discrete water droplets. Scanning electron microscopy confirmed that this mutant exhibited more and larger epicuticular wax crystals than the others. The wax content and composition of SAB 1558 is being characterized and the effect of this novel phenotype on physiological functions is being undertaken. Identification of the underlying mutations for SAB 6-1A, 7-17A, 11-39A, and 1558 using bulked segregant sequencing-based approaches is underway.

Understanding the function of epicuticular waxes in rice may lead to discoveries impacting resiliency against climate-driven changes to rice production areas.

Identification and Characterization of Rice Endosperm Mutants

Tai, T.H., Shim, K.C., Kim, H., Yoon, M., Chun, A., and Liebscher, A.V.

Rice (*Oryza sativa* L.) is unique among major cereal crops as the vast majority is used directly for human consumption in the form of whole milled kernels. As such, rice starch provides the bulk of the daily calorie intake for billions of people worldwide. Major differences in local, regional, or social-cultural preferences require the development of a wide array of grain quality characteristics to meet the needs of diverse consumers.

Reverse and forward genetic approaches were applied to identify mutants of interest from populations derived from chemical mutagenesis of the japonica varieties Nipponbare and Kitaake. Targeting of Induced Local Lesions in Genomes (TILLING) by sequencing and targeted sequencing by exon capture have been employed to identify mutations in starch synthesis-related genes, and corresponding rice lines harboring those mutations are being characterized for changes in physico-chemical grain traits and other properties. Forward screens based on visual evaluation of grains and physico-chemical assays (e.g., iodine staining, alkali digestion) have resulted in the identification of additional rice mutants with altered endosperms. These mutants are currently being used for genetic studies to identify the underlying mutations and developed as genetic resources for grain quality studies and non-table rice uses.

Identification and characterization of grain mutants will provide useful resources for understanding and improving rice grain quality in response to climate-driven challenges. Novel mutants may also lead to the development of new products or alternative uses.

Identification and Characterization of Metalloid Uptake Mutants in Rice

Tai, T.H., Kim, H., Magee, S.C., Shim, K.C., and Liebscher A.V.

Germanium (Ge) is a metalloid element with chemical properties similar to those of silicon (Si). In Si accumulators like rice (*Oryza sativa* L.), low concentrations of Ge (μM) can result in toxicity which manifests itself in the form of necrotic lesions, leading to chlorosis and possible mortality. This attribute of Ge has been employed to great effect in the identification of 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 Ge response phenotypes. Six mutant lines were isolated, four of which were more Ge tolerant and two that were more Ge sensitive 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 GeO2, 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 $P \leq 0.01$). Further characterization of the response of KDS-557B and Kitaake to Ge is underway.

The mutants identified here will be useful resources for understanding the interaction of metalloid elements and plants in the environment.

Overexpression of the Transcription Factor *HYR* in Rice Improves Grain Yield and Grain Quality under Drought and High Temperature Stress Conditions

Thomas, J., Riaz, A., Dwiningsi, Y., Kumar, A., Gupta, C., and Pereira, A.

The photosynthetic activity of the rice crop is directly correlated with the grain yield and needs to be increased in order to meet the global food demand. Climate change triggers environmental stresses, including drought and high-temperature stress, which negatively affect photosynthesis and limits grain yield. This research was conducted in a greenhouse, at the Fayetteville Campus of the University of Arkansas's Division of Agriculture.

The research result confirms that the *HYR* (Higher Yield Rice) transcription factor gene regulates photosynthetic carbon metabolism (PCM). Overexpression of *HYR* (Os03g02650) in rice lines enhances photosynthetic capacity and contributes to higher grain yield under normal conditions as well as drought and high-temperature stress conditions. Since *HYR* is involved in regulating PCM and response to environmental stress signals, this study reveals the genetic regulations of the drought and temperature responses. The transcriptome-based association approach was undertaken to investigate the correlation between genetically regulated gene expression and complex abiotic stress responses to grain yield and quality. The expression of *HYR* was strongly affected by circadian rhythm. Our results suggest the changes in *HYR* gene expression during day and night cycle may be an essential target for optimizing PCM and yield under drought and high-temperature stress. In this study, *HYR* lines of IR-64 *HYR* and Vandana *HYR* showed higher filled grain per panicle number under normal and environmental stress conditions than WT. Most of the *HYR* lines produced higher filled grain per panicle number under control and environmental stress conditions with longer, wider, heavier, and less chalkiness than WT. Alteration of the root anatomy components of the *HYR* lines, increasing in metaxylem number and aerenchyma area, and also decreasing in metaxylem size and cortical cell file number under normal and environmental stress conditions showed a significant positive correlation with grain yield and grain quality characteristics.

This research shows that engineering of a master-regulator the *HYR* gene in IR-64 showed 30-40% less reduction in grain yield under drought, high nighttime temperature, and high daytime temperature stress, increasing photosynthesis, showing the role of hub genes in controlling plasticity or robustness in plants under abiotic stress.

Implementation of KASP at the California Rice Experiment Station

Zaunbrecher, G.M., Yeltatzie, G.B., and Harrell, D.L.

For the past 15 years, most rice genetic labs used simple sequence repeats (SSRs) for marker-assisted selection (MAS) due to the relatively large SSR databases available. Single nucleotide polymorphisms (SNPs) are superior to SSRs in identifying genetic variations due to their abundance in the genome. In addition, some SNPs can cause functional effects within a gene. Until recently, SNP databases have been limited by inefficient sequencing technology and access to proper bioinformatic software. Improved next generation sequencing and new analytical software have allowed for comparisons of full genome sequences of many rice varieties, leading to the identification and validation of 100s fold more SNPs than previously discovered. With this unprecedented access to SNP data many, labs began the transition to SNP analysis for MAS. Kompetative allele specific PCR (KASP), a proprietary technology of LGC genomics, is one of the SNP analysis platforms that many genetic labs have implemented into their MAS programs.

The Genetics Lab at the California Rice Research Station has historically used SSR MAS in assisting the breeders in identifying the genotypic variation or purity of rice lines developed for the unique growing conditions in California. Recently, the transition to a SNP analysis platform has begun in the lab with the purchase of specialized equipment. In addition to the equipment, the development of a new marker library able to distinguish subtle differences between related germplasm is currently underway.

With the development of specific marker libraries for each grain type and specialty rice, the Genetics Lab will be able to provide the breeders with a significantly higher data throughput which will allow for faster and more economical variety development, greatly benefitting the California rice growers.

Culture and Soil Science – Posters

Irrigation and Phosphorous Fertilization Managements to Minimize Rice Grain Arsenic Content

Campos, F., Roel, A., Carracelas, G., Verger, M., Huertas, R., and Perdomo, C.

This research project was focused in minimizing inorganic arsenic levels in polished rice grain while maintaining crop yield and water productivity of the most planted *Indica* cultivar in Uruguay, INIA Merin. Two experiments were conducted during seasons 2018-2019 and 2019-2020. A split-plot experimental design with three blocks was used to test five irrigation treatments applied in main plots and two phosphorous fertilization treatments were applied in subplots. Irrigation treatments consisted of a control traditional continuous flooded (CF) and four alternative irrigation techniques (AIT) with one or two drying events during the crop cycle. Phosphorous fertilization treatments were an unfertilized control with 0 kg P_2O_5 ha^{-1} and the traditional fertilization practice commonly used in commercial farms of 50 kg P_2O_5 ha^{-1}. Accumulated inorganic arsenic in grain was below international maximum levels in all analyzed samples, with an average value of 0.084 mg kg^{-1}. Alternative irrigation treatment with two drying events, implemented at panicle initiation and full flowering stages, was the most effective irrigation treatment in reducing inorganic arsenic accumulation in grain, without either affecting grain yield or water use. Cadmium rice grain levels that can potentially increase under this irrigation treatment were also well below international maximum levels. This irrigation technique could be considered as an alternative management to the traditional CF in order to reach minimal inorganic arsenic accumulation in grain to either attend special quality standards or specific market requirements.

Potential Seeding Rate Alterations to Maximize Profitability in Furrow-Irrigated Rice

Chlapecka, J.L., Rhodes, L.N., and Hunt, C.M.

Furrow-irrigated rice has become a prominent production system in the Mid-Southern United States since 2017, making up close to 20% of Arkansas' and 33% of Missouri's production. The typical recommended seeding rates of 107-118 seeds m^{-2} for hybrids and 269-323 seeds m^{-2} for varieties are currently being utilized across the majority of these furrow-irrigated rice systems; however, these seeding rates were defined in the direct-seeded, delayed-flood production system. Due to varying seedbed preparation and significantly less moisture in upper portions of the field, it is fair to believe that the optimum seeding rate could differ from that of delayed-flood rice. Trials were initiated in 2022 and continued into 2023 at a total of five site-years to determine the optimum seeding rate for furrow-irrigated rice. Four replications of one hybrid and three varieties were included in three zones within the field: top, non-flooded; middle, muddy; and bottom, flooded environments. Across both years, increasing seeding rate in the non-flooded portions of the field

led to increased grain yield in the majority of cultivars, while no rate response was detected in the flooded portion of the field all the way to the lowest seeding rate of 43 seeds m^{-2} for hybrids and 107 seeds m^{-2} for varieties. Results suggest that it's likely not profitable to increase the overall seeding rate of the field, but variable rate seeding technology has the potential to place seed where it could be most beneficial by shifting additional seed toward the upper, drier end of the field.

Resilient Rice of the Future for Latin America and Caribe

Cordero-Lara, K., Bonell, M., Mejías, I., Brito, D., Quinteros, C., Marano, R., Graterol, E., Witkowski, K., and Barrera, F.

This research seeks to increase the productivity of rice cultivation using SRI, improving productive conditions, sustainability, profitability, and food security in family agriculture systems of Chile, Venezuela, Panama, and Argentina. Addressing the increasing consumer demand for more sustainably-produced food that considers the conservation of natural resources and has a lower environmental impact.

Implementing and scaling a set of specific management practices for each region allows for greater adaptation of rice to climate change. The research is executed with the support of FONTAGRO and leadership of INIA Chile, with the co-execution of IDIAP of Panama and INTA Argentina and in partnership with IICA, FLAR, UNER, UNL, and FUNDARROZ from Venezuela. This research aims to establish a technical cooperation platform between Argentina, Chile, Panama, and Venezuela, with the support of other institutions such as research centers, producer associations, and international cooperation agencies. The goal has been to disseminate and share knowledge and experience generated in countries where the SRI methodology has already been adapted, validated, and used, in order to facilitate scaling at the commercial level. In addition, the research would support the adoption and validation process in those countries where SRI has not yet been validated, to increase the productivity and sustainability of rice cultivation in the region.

Results using SRI have achieved between a 20 to 100% increase in yield due to agronomic improvements, including more roots, stems, spikes, and full grains, less lodging, and greater resilience to the effects of climate change such as droughts and extreme winds. The system contributes to reducing water use by 10 to 40% during the production cycle. This allows for better soil quality, higher microbial activity, and a reduction in methane emissions (up to 60%). SRI reduces the seed required by up to 90% and agrochemical use by 20 to 50%. Even more important are the socio-economic impacts, which include an increase in profits for family farming producers by reducing costs and increasing yields. The system contributes to achieving the goals of national plans and policies on climate change, water resource management, food production, and poverty reduction.

Within-Field Study of Rice Crop Behavior Variability Using Remote Sensing in Arkansas

Fita, D., Simeón, R., Castiñeira-Ibáñez, S., Tarrazó-Serrano, D., Uris, A., Arizo, P., Franch, B., Moreno García, B., Runkle, B.R.K., Reba, M.L., Isbell, M., Rubio, C., and San Bautista, A.

Crop management and monitoring techniques are continuously changing in agricultural systems, especially in rice production. The use of satellite imagery has been a promising tool since its development, but its applicability for yield enhancement is still a challenge. In recent years, high spatial resolution space missions such as the 10 m pixel, Sentinel-2 mission have enabled a focus on agricultural applications. Sentinel-2 spectral bands help distinguish photosynthetic activity via differences between the low reflectance in the visible region (red, blue, and green) and the high reflectance in the infrared region (NIR). In the present work, Sentinel-2 imagery was used to evaluate rice growth in a rice field (32 ha) located in Arkansas (US) for four years (2019-2022). The main goal of the work was to study the correlation between remote sensing data and marketable yield measured by yield monitors. The results from this study would allow the applicability of Sentinel-2 data for yield improvement via crop management.

A descriptive analysis was carried out. First, the time series of the Normalized Difference Vegetation Index (NDVI), calculated as the normalized difference between NIR and red reflectance, was analyzed. This time series showed the phenology of each year and was used as a reference for data applicability. Second, multiple linear regression models between all Sentinel-2 bands at 10 and 20 m resolution and the yield values measured by the yield monitor were obtained, for all cloud-free dates from planting to harvest. The coefficient of determination R^2 was used to evaluate the model performance in explaining variability of the in-field yield measurements. During the vegetative stage, the R^2 was low, while in the reproductive and ripening stages, this value increased, reaching a maximum of 0.75. The R^2 values in the four years studied were irregular for all days analyzed, thus making it difficult to obtain a yield estimation via satellite at the within-field level. Panicle Differentiation (PD) was identified as the critical moment in the increase of R^2, however, the values remained unstable and highly dependent on the year. To deepen this response, crop monitoring using additional remote sensing data was proposed. The NDVI saturation date and the previous date (end of tillering), located in the middle of the NDVI increase slope, were compared. Two moments were analyzed in detail (48 - 61 DAP and 68 - 76 DAP, year-dependent intervals, where DAP=Days After Planting). For the interval 48 - 61 DAP (end of tillering, ET), the NDVI median value was calculated and the pixels were divided into two groups according to this value (high and low NDVI areas). The results showed uncertainty for the use of NDVI to yield estimation, since the yield of the area with low NDVI was equal or superior to the area with high NDVI. Analyzing the NDVI within-field variability, high Coefficient of Variation (CV) values in 2020 and 2022 were obtained, showing a huge spatial anomaly (CV=25.60%) at 48 - 61 DAP. However, the yield within-field variability was lower (CV=11.04%) compared with NDVI, indicating that it is possible to improve crop management after the ET. In addition, NDVI values at ET and PD were compared with NIR values. The correlation between NIR and NDVI was weak at the ET stage due to the high CV. This weak NIR – NDVI correlation may indicate anomalous crop growth (or irregular crop management).

In conclusion, the NDVI saturation (NDVI values of 0.90) happened at the PD stage and also was the best stage to estimate total yield with remote sensing data. Therefore, proposing changes in rice cultural practices before this date may be crucial to improve yield and reduce initial within-field variability. The low correlation between initial plant growth and yield could be explained by considering all crop production inputs (weather, weeds, soil, water, pests, etc.), and in the future, these causes could be analyzed via remote sensing. For example, a high NDVI could be caused by excessive weed growth, and for this reason, the variability would be large, causing a weak NIR – NDVI correlation. The variability in the vegetative index registered by Sentinel-2 could indicate an anomalous crop correlation with production inputs and could be used for decision making when there is still time to modify some agriculture inputs (fertilizers or pesticides).

Evaluation of Rice Varieties and Water Management Practices on Greenhouse Gas Emissions

Kongchum, M., Fluitt, J., Leonards, J., and Breaux, M.

Greenhouse gas emissions from rice fields can be influenced by several factors. Alternative water management practices have decreased greenhouse gas emissions in various studies from different locations. Rice variety is one of the major factors controlling the emissions. A field experiment was conducted in 2023 at the Louisiana State University Agricultural Center – H. Rouse Caffey Rice Research Station, near Crowley, Louisiana, to evaluate the effect of water management practices and rice varieties on methane (CH_4) and nitrous oxide (N_2O) emissions. Three rice varieties (CLL17, RT7521FP, and Titan) were drilled in Crowley silt loam soil under two different water management practices; delayed flooding (DF) and furrow irrigated systems (FIR). Nitrogen fertilizer in the form of urea was applied at the rate of 168 kg N ha^{-1} one time before permanent flooding in delayed flood system and before applying irrigation water in the FIR system (at 4- to 5- leaf stage). The CH_4 and N_2O fluxes were measured using a custom-made diffusion chamber. A 15-mL gas sample was withdrawn from the septum at the top of the chamber using a 20-mL gas-tight syringe at intervals of 0, 30, and 60 minutes, twice a week from the first day of irrigation until harvesting. The gas samples were analyzed for CH_4 and N_2O using a gas chromatography (Shimadzu 2010 *plus*) equipped with FID (Flame Ionization Detector) and ECD (Electron Capture Detection). The data was converted from parts per million by volume (ppmv) to mass per unit volume (mg m^{-3}).

The emission of CH_4 was highest in the RT7521 FP variety, but it was not statistically different from the CLL17 and Titan variety in the same water management practice. The average CH_4 emissions over the three rice varieties was 180 kg CH_4 ha^{-1} in the delayed flood system and 30 kg CH_4 ha^{-1} in the FIR system. In contrast, the emission of N_2O in the FIR system (3,860 g N_2O ha^{-1}) was higher compared to the DF system (369 g N_2O ha^{-1}). In addition, the emission of N_2O was significantly higher in the Titan (6,764 g N_2O ha^{-1}) followed by CLL17 (3,242 g N_2O ha^{-1}) and RT7521 FP (1,575 g N_2O ha^{-1}) in the FIR system. However, there were no differences for the N_2O emissions in the DF system, which were 265, 478, and 364 g N_2O ha^{-1} from CLL17, RT7521 FP, and Titan, respectively.

Geospatial Machine Learning and On-Farm Data for Improved Agronomy

Macedo, I., Pittelkow, C.M., Terra, J.A., Castillo, J., and Roel, A.

New agronomic research methods are needed to complement traditional experiments to better understand yield variations. Approximately 2,100 georeferenced farmers' rice fields, covering approximately 60,000 ha per year (40% of total rice area) across four cropping seasons (2018-2021) in the three main rice regions of Uruguay were used in this study. The objective was to quantify the relative importance of soil properties and management variables as well its spatial variation using geospatial machine learning. The database contains a list of variables related to rice yield, management, and field conditions. Soil types and soil properties data were obtained and linked with each field. Our application of geospatial machine learning using geographically weighted random forest models showed that crop management decisions influenced rice yield more than variation in soil properties, highlighting the potential for improved agronomy to boost crop production by 1.4-1.8 Mg ha-1 across regions. Seeding date, variety, P rate, and K rate were the most important variables controlling yield but with significant variation across fields. The findings of this study will provide a better understanding of the main management practices explaining yield under real farming conditions. This study's results will allow identifying priorities for research and extension.

Silicon Fertilization in Rice: Benefits and Application Guidelines in Louisiana Rice Production Systems

Nicchio, B., Tubana, B., Cruz, J., Wooiklee, P., and Babu, T.

Rice (*Oryza sativa*) is a silicon accumulator with an average removal rate of about 500 kg/ha, surpassing nitrogen which is a primary essential nutrient. Silicon is abundant in the soil, but with continuous farming and slow-release from silica/silicate containing minerals in the soil, the plant-available silicon level may fall below rice demand. Field and greenhouse studies were conducted to establish the silicon fertilization guidelines for Louisiana rice production systems. Specific objectives were designed to: (a) identify the suitable extraction procedure for soil silicon that plant takes up, (b) determine the critical silicon level in the soil for rice, (c) evaluate different sources of silicon, and (d) develop approach(es) other than fertilization to increase soluble silicon in the soil.

To estimate plant-available silicon rice soils, the 0.5 M acetic acid extraction procedure showed to be suitable in Louisiana. The critical soil silicon level is set at 45 mg/kg, thus soil with test values below this level is prompted to receive one to two tons/ha of silicon fertilizer. Soil-applied silicon is better than foliar fed with sources including industry byproducts (7-12% total silicon content). The high liming potential of these industry byproducts limits its use in high pH soil. However, microorganism-assisted solubilization of silica/silicate can potentially improve the supply of plant-available silicon in the soil. One strain of bacteria thriving in Louisiana soils was identified capable of solubilizing silica/silicate in the soil and can release plant growth promoting compound.

The high demand of rice for silicon calls for effective field practices to increase availability of silicon in soils. The outcomes from this research are vital to assist rice producers in incorporating silicon fertilization in their current fertilizer program.

Greenhouse Gas Emissions from the Rice-Soybean Rotation in Lowlands of Southern Brazil

Scivittaro, W.B., Vasconcelos, E.E., Buznello, G., Oliveira, R.M.D.,
Peglow, L.U., Rosso, R.G., and Bayer, C.

The introduction of rainfed species, as soybeans, in rotation with irrigated rice constitutes a promising alternative to increase the sustainability of lowland production systems of Southern Brazil. Besides the inherent benefits of crop diversification, the decrease in the period of anoxic environment influences crop yield and interferes in the dynamics of soil carbon and nitrogen and, consequently, in greenhouse gas emissions potential. The aim of this study was to evaluate methane (CH_4) and nitrous oxide (N_2O) emissions and global warming potential (*p*GWP) of conformations of the soybean/irrigated rice rotation in lowlands of Southern Brazil.

A field trail was carried out in the growing seasons 2019/2020 to 2020/2021 in a Typic Albaqualf, in Capão do Leão, State of Rio Grande do Sul, Brazil. The 2:1 conformations (soybean/soybean/rice and rice/rice/soybean) and 1:1 conformations of the rotation soybean/ irrigated rice (soybean/rice/soybean and rice/soybean/rice) were evaluated. Measurements of CH_4 and N_2O fluxes were performed using static chambers with three replications. The measurements were conducted at least once a week throughout rice and soybean-growing seasons. In order to compare the effect of crop rotations on seasonal GHG emissions, the data from the 2021/2022 growing season were considered, which depict a complete cycle of the 2:1 and 1:1 soybean-irrigated rice conformations. We also compared the sum of CH_4 and N_2O seasonal emissions and *p*GWP of the rotation conformations over the three seasons.

Soybean rotation reduced CH_4 emissions and increased N_2O emissions from the soil; the reduction of CH_4 emissions was more significant than the increase in N_2O emissions. This effect was greater for the soybean-soybean-rice conformation than for the rice-soybean-rice conformation. Methane contributed with almost all (>95%) of the global warming potential of the irrigated rice, while nitrous oxide was the main component of the soybean global warming potential (>90%). The conformations involving two successive (30,231 kg CO_2eq) or intercalary irrigated rice crops (28,153 kg CO_2eq) provided higher *p*GWP than those comprising two soybean crops, being 10,436 and 11,772 kg CO_2eq, respectively, for soybean-rice-soybean and soybean-soybean-rice.

Seasonal CH_4 emissions and global warming potential are associated with the cultivated species, irrigated rice or soybeans but also with the cropping sequence. Methane emissions and the global warming potential of irrigated rice are reduced when grown in succession to soybeans, compared to two successive irrigated rice crops. Therefore, crop rotation constitutes a promising strategy to mitigate greenhouse gas in the lowlands of Southern Brazil.

Organic Rice Ratoon Production in the Southern United States

Vernon, J.D., Weathington, M., Bera, T., Yang, Y., Dou, F., Wilson, L.T., and Zhou, X.

The organic ratoon rice production in Texas and other Southern United States is a sustainable farming approach that emphasizes soil health and organic inputs, avoiding synthetic agrochemicals. Despite a significant increase in U.S. organic rice acreage since 1995, mainly in Texas and California, existing production falls short of meeting market demand. Leveraging improved ratoon cropping presents an opportunity to mitigate dependence on imports, benefiting U.S. rice farmers economically. This project aims to establish resilient organic ratoon rice production systems in the Southern United States by integrating cover crops, organic soil amendments, and rice varieties to augment crop productivity, economic returns, and soil health.

A field trial was conducted at The Texas A&M AgriLife Research Center near Beaumont, Texas, USA, focusing on two rice varieties (inbred - Presidio and hybrid - XP753) and two cover crop treatments (alfalfa hay and winter fallow). Five nitrogen (N) rates were applied to the ratoon crop, with treatments replicated four times. Alfalfa hay was used to mimic the leguminous cover crop effect due to unsuccessful attempts to establish cover crops in the fall of 2022. Rice planting occurred on March 31, with a permanent flood established on April 25. Nitrogen treatment was applied on May 4, and the main crop was harvested on July 27-28. The ratoon crop was harvested on October 25, with grain weight measured and moisture content assessed to calculate ratoon rice yield.

Significant variations in ratoon rice yield were observed based on cover crop treatments and rice varieties. The hybrid variety XP753 demonstrated a 96% higher yield compared to the inbred variety Presidio, while the cultivation of a cover crop (alfalfa hay) resulted in a 32% higher yield than winter fallow. Although no significant impact of N rates on ratoon rice yield was observed, a trend of increasing yield with increasing N rates up to 90 lb/acre suggests an optimal N rate near 90 lb/acre. Further analysis revealed that with a cover crop, the hybrid variety XP753 demonstrated a 22% increase in yield, while the inbred variety Presidio exhibited a significant 59% yield enhancement compared to winter fallow. In conclusion, the findings from this field trial underscore the importance of integrating cover crops, organic soil amendments, and suitable rice varieties to enhance the productivity of organic ratoon rice production systems in the Southern United States.

Plant Protection (Entomology & Pathology) – Posters

An Alert System for Controlling Blast Epidemics in Italy

Biloni, M., Mazzini, N., Masserano, G., Spanna, F., Silvestri, S., and Rodolfi, M.

In Italy, an alert system for controlling rice blast epidemics is ongoing since 2009. The system is based on three techniques: a simulation model, a mycological analysis with microscope, and field observations. The system evolved to include a larger area and to satisfy an increasing number of rice farmers. The project is part of a PPP (public private partnership).

The system has been fine calibrated to give fast information to the farmers that, in case, might enter the fields to spray fungicide. Two times per week a message is sent directly to the mobile of the registered farmers. The message describes the risk of blast infection in seven areas. Each farmer may check the area where the farm is located. The information provided is not stating if or not to apply a fungicide but is trying to give support to the farmer-taken decision. The scale adopted to describe the blast risk is going from 0 to 3 where 0 corresponds to no risk at all and 3, the full risk. The values 1 and 2 are linked to intermediate conditions which should be evaluated by the farmers: if the grown variety is susceptible to blast and the soil conditions are blast-prone, it is better to spray fungicide at value 1 otherwise better to wait to value 2.

The system helped the farmers to adopt a more sustainable approach using chemicals for rice farming. For this reason, the Piedmont Region decided to continue to finance the project also in 2024.

Effect of Stem Rot on Yield of Rice and Monitoring Guidelines

Espino, L. and Brim-DeForest, W.

Stem rot is a common disease of rice in California. When severe, the disease can produce panicle blanking and lodging, reducing yields and interfering with harvest. Stem rot lesions appear on tillers at the water level midseason and are most noticeable when fields are drained for harvest. Lesions may not be detected because they remain under the canopy.

In 11 fungicide trials conducted between 2017 and 2022, rice yield decreased an average of 328 kg/ha for every unit increase in the stem rot severity scale (0-4), or 3.2% of the predicted maximum yield. To determine the severity level of a field, tiller samples taken at drain time need to be examined carefully and rated. Rating tillers is time consuming and may not be appropriate for management decision making. Alternatively, managers can use the incidence of the disease to infer the severity level of the field. Data from the fungicide trials show that stem rot incidence and severity are linearly related, with severity increasing with incidence until severity reaches level 2. At level 2 or higher, stem rot incidence is 100%. The information managers obtain from monitoring for stem rot at drain time can be used to plan management actions the following season.

Rising Resistance: Alpha-Cypermethrin and the Future of Rice Bloodworm Control in Australia

Hoskins, J. and Stevens, M.

Rice bloodworms (Diptera: Chironomidae) pose a significant threat to rice crops grown in Australia. The use of alpha-cypermethrin, a synthetic pyrethroid insecticide, has been a primary strategy for controlling these pests. Recently, resistance to alpha-cypermethrin in rice bloodworm populations in Australia has been observed, and this has raised concerns about the future use of this chemical as a control measure. To assess the extent of resistance and its prevalence, we conducted laboratory bioassays using rice bloodworm strains collected from New South Wales and Victoria. Bioassays demonstrated a decrease in the efficacy of alpha-cypermethrin for all strains of bloodworm, with LC50 values far exceeding established historical thresholds. Our results show widespread resistance to alpha-cypermethrin is occurring in rice bloodworm and indicate the reliance on this chemical as a primary control measure is becoming increasingly unsustainable.

Exploring QTLs for Developing Durable Resistance to Bacterial Panicle Blight in Rice

Ontoy, J.C., Cortes, J.D., and Ham, J.H.

The absence of stable resistance to bacterial panicle blight (BPB) in rice presents a significant dilemma and problem for rice growers across the world. BPB is recognized as an emerging disease in rice, and its prevalence and severity are believed to be influenced by global warming. BPB exhibited similarities to abiotic stress, particularly in the context of the excessive accumulation of reactive oxygen species (ROS) in rice plants, and this phenomenon has a wide range of effects on rice physiology which ultimately resulting in poor grain quality and reduced yield.

Due to a limited pool of resistance varieties available, Jupiter, a medium-grain rice with moderate resistance to BPB, has been used as a donor of resistance for both genetics study and breeding. We developed two mapping populations by crossing the donor to two susceptible Louisiana rice varieties, Trenasse (a long-grain variety) and Bengal (a medium-grain variety). Phenotypic data, comprised of disease score index and days to heading, were collected from multiple-year of field trials at the H. Rouse Caffey Rice Research Station in Rayne, Louisiana, while their genotypic information was acquired through Kompetitive allele specific PCR (KASP) assay and genotyping-by-sequencing (GBS). From this study, we identified two QTLs closely adjacent to each other, qBPB3.1 and qBPB3.2. They were located at a known broad-spectrum resistance (BSR) hotspot in the short arm of chromosome 3. We also performed transcriptome profiling to characterize the mechanism behind the resistance of Jupiter to BPB. The analysis revealed the involvement of an array of regulatory genes, some of which were also found in BSR hotspot in chromosome 3, reinforcing the notion of quantitative nature of BPB resistance and the importance of that hotspot in regulating the defense-stress mechanism. Currently, we are making efforts to introgress the two BPB-associated QTLs on chromosome 3, along with an additional BPB-associated QTL on chromosome 1 from an indica variety Kele, to BPB-susceptible U.S. varieties through marker-

assisted pyramiding. The resistance against BPB will be assessed in rice lines containing all the three BPB-associated QTLs when they are obtained.
This research aims not only to develop BPB-resistant rice but also to enhance our understanding of the similarities between the effects of BPB and abiotic stress. This knowledge can offer insights into the development of novel strategies to mitigate the impact of both biotic and abiotic stressors, ultimately fostering resilience in rice.

Monitoring Fungicide Resistance of Sheath Blight in Arkansas Rice Fields

Ronning, B., Stalter, J., Belmar, S., Bedoya, J., Rojas, A., and Nicolli, C.

Sheath blight, caused by the fungus *Rhizoctonia solani* AG1-IA, presents a significant challenge to rice cultivation, often resulting in substantial yield losses when susceptible cultivars are grown without adequate disease control measures. Azoxystrobin, a broad-spectrum fungicide belonging to the strobilurin group, has shown promise in managing this disease. However, concerns have arisen regarding its efficacy, with growers reporting issues in the previous season. Given the importance of responsible fungicide use to prevent resistance and environmental damage, our primary initiative aims to map sheath blight resistance to commonly used fungicides in rice fields, particularly focusing on azoxystrobin. During the 2023 season, plant samples were collected from 12 counties in Arkansas, and a total of 17 isolates were obtained and subjected to genetic testing to confirm their identity as *R. solani*. Sensitivity testing of the fungi to the fungicide azoxystrobin was conducted using a culture medium supplemented with concentrations of 10 ppm, 1 ppm, 0.1 ppm, 0.01 ppm, and 0.001 ppm of the fungicide, along with an untreated control. The plates were then incubated at 25°C for four days, with daily measurements to assess isolate growth rates. After four days, the effective dose to reduce 50% of the mycelia growth (EC50) was estimated based on the final measurements. Three isolates (PP058, PP064, and PP071) collected from Jefferson, Miller, and Arkansas counties displayed lower sensitivity to the fungicide in vitro. In contrast, the remaining isolates exhibited sensitivity and effectively controlled mycelial growth compared to the control, with the isolates from Clay and Lafayette counties the most sensitive to the fungicide originated. In the 2024 season, we will sample rice fields in Arkansas to continue mapping and monitoring disease response to fungicides. These data are crucial for understanding sheath blight resistance in Arkansas.

Post Harvest (Economics and Quality) – Poster

Economic Analysis of Current and Future Rice Varieties in Mississippi Considering Milling Quality and Yield

Martin, S.W., Bond J.A., and Bowman, H.D.

Rice, *Oryza sativa L.*, producers are focused on returns per hectare. Yield is a vital part of the return equation as is value or price per hundredweight. Often from a producer's perspective, milling quality which affects value/price is not considered. However, milling quality/yield is extremely important to those buying rough rice as well as those selling milled rice as a final product. United States rice routinely has to compete for market share in terms of quality and milling yield.

This paper attempts to provide insight on expected returns per hectare to Mississippi and other U.S. rice producers considering currently available varieties and varieties that will be available for growers in the near future based on Mississippi variety trial data.

Results suggest that growers will select varieties providing the highest total rice yield per hectare to maximum farm income. While buyers and marketers of U.S.-grown rice are extremely concerned with milling/quality, without a system or contract in place to reward growers for selecting varieties that mill better at the expense of less total rice yield per hectare, adoption of these type varieties will be limited.

Weed Science - Posters

Pre-Emergent Herbicides Activity in Ryegrass Straw Direct Drilled Rice

Andres, A., Martins, M.B., Schreiber, F., and Scherer, A.

Rio Grande do Sul State (RS) is responsible for more than 70% of Brazilian's rice production, which is mainly sown after many soil tillage operations. Rice areas in Southern Brazil are commonly leased from cattle breeders, these areas normally overwinter without any cultivation with a pasture crop. Ryegrass is the most common pasture producing high forage yields. Rice producers start burning down the pastures with glyphosate, usually 30 days before sowing, allowing for direct drilling of the crop. The ryegrass coverage can affect the performance of pre-emergent herbicides and, therefore, weed control. The objective of this study was to evaluate the performance of four pre-emergent herbicides to two different volumes of ryegrass soil coverage.

The study was conducted in two cropping seasons at the Terras Baixas Experimental Station, a unit of the Embrapa Temperate Agriculture, near Capão do Leão, RS, Brazil. A randomized block design with four replications was used to distribute herbicide treatments in each ryegrass coverage volumes (0.9 and 1.5 ton/ha), which were allocated in strips. The herbicides tested were clomazone (288 $g_{a.i.}$/ha), imazapyr + imazapic (73.5 + 24.5 $g_{a.i.}$/ha), pendimethalin (1,592 $g_{a.i.}$/ha) and penoxsulam (72 $g_{a.i.}$/ha). Ryegrass was burned down with glyphosate (1,440 $g_{a.i.}$/ha) 15 days before sowing. All herbicide treatments were combined with glyphosate (1,440 $g_{a.i.}$/ha) to control already emerged weeds, allowing to evaluate only the effect of the treatments. Evaluated variables were barnyardgrass (*Echinochloa crus-galli*) control 28 days after spraying (DAS) and at pre-harvest, and rice grain yield. Data collected was compared between herbicides, ryegrass residue volumes, and crop season.

Barnyardgrass control 28 DAS was affected by herbicide, ryegrass residue volume, and crop season. All four herbicides provided a higher control during the second season. This is related to greater rain accumulation (70.2 mm) after spraying the treatments in comparison to the first season (6.6 mm). Pendimethalin was the only herbicide affected by the increase of soil coverage in both seasons. Rice grain yield was affected by herbicide, ryegrass soil coverage, and crop season. Higher crop yield was obtained in the second season, as a consequence of better barnyardgrass control. Pre-emergent herbicide effect on rice grain yield was verified only during the first season, in which poor barnyardgrass control with pendimethalin reduced productivity (4.9 ton/ha), while other treatments had grain yields around 8 ton/ha.

This study provides valuable insights to growers and advisors in RS, allowing them to choose and recommend the best pre-emergent herbicide to control barnyardgrass in direct drilled areas, which are increasing over the years. These results also bring a new perspective on herbicide behavior on rice production in Brazil, with opportunities to carry more specific studies on these aspects.

Soybean Rotations Reduce Weedy Rice and Barnyardgrass Seedbank

Andres, A., Martins, M.B., Kohls, I., and Matos, A.B.

The Clearfield® System (CL) was made available in Brazil starting with the 2002/2003 crop season, providing the first efficient method to chemically control weedy rice. Farmer adoption was massive, and until recently, CL rice cultivars were planted on more than 80% of all the cultivated area in the Rio Grande do Sul state. This system was a success, making it possible to grow rice on fields that were highly infested with weedy-rice and therefore were not profitable anymore. Despite that, a few years later, weedy-rice developed resistance to imidazolinone herbicides, probably because of the gene-flow caused by cross-fertilization between cultivated rice and weedy-rice. Other factors that contributed to the loss of this technology were mild limits of weedy-rice seeds in cultivated rice seed lots, continuous use of imidazolinone herbicides, and lack of crop rotation. Therefore, farmers and advisors had to find other ways to control weedy-rice and other ALS-resistant weeds. The main option was the introduction of crop rotations, especially soybeans. This crop brings to the system other herbicides with different modes of action that can be used for pre- or post-emergence control of resistant weeds. Thus, the objective of this research was to evaluate the effect of soybean rotation with rice on weedy-rice and barnyardgrass seedbank.

The study was conducted on a farmer's property in Arroio Grande city, Rio Grande do Sul, Brazil during the 2016/2017, 2017/2018, and 2018/2019 crop seasons. The treatments corresponded to three fields with different crop sequences: a three-year succession of CL rice (R-R-R), a one-year rotation between CL rice and soybeans (R-S-R) and a two-year rotation of CL rice with soybeans (R-S-S). Seedbank was evaluated after the 2019 crop harvest using a cylindric soil auger (10 x 10 cm, 785.4 cm^3) collecting 20 samples per field. Soil samples were then washed with running water through three sieves (10, 18, and 20 mesh). Weedy-rice and barnyardgrass seeds of each sample were counted and then the number of seeds in the volume of one hectare was calculated (10 cm). Means of each treatment were then compared through Tukey test.

Results showed that the three-year succession of CL rice (R-R-R) kept the weedy-rice and barnyardgrass seedbanks higher than the other two treatments. After the 2019 rice harvest, 268 million weedy-rice seeds and 87 million barnyardgrass seeds/ha were found, highlighting the high infestation observed in fields with ALS-resistant weeds. The one-year rotation of CL rice with soybeans (R-S-R), commonly known as "ping-pong," provided a decrease of both species seedbank, reducing weedy-rice seed number by 80% (55 million seeds/ha) and barnyardgrass by 46% (47 million seeds/ha). For weedy-rice seedbank reduction, no difference was verified between the one-year rotation and the two-year rotation of CL rice with soybeans (R-S-S). The latter provided an 85% decrease in weedy rice seedbank (38 million seeds/ha). On the other hand, the two-year rotation of CL rice with soybeans (R-S-S) had a greater impact on barnyardgrass seedbank than the one-year rotation, reducing its seedbank by 80% (5 million seeds/ha).

This research is important because it provides strong evidence that a three-year succession of soybeans might be needed to reduce weedy-rice and barnyardgrass seedbank to an adequate level of infestation in order to use CL rice again or to use new ACCase-tolerant rice technologies. This is important to avoid reinfestation and especially gene-flow between weedy-rice and cultivated rice. One of the most positive points of soybean adoption are the many pre-emergent herbicides

that were never used in rice, e.g., s-metolachlor, sulfentrazone, flumioxazin, pyroxasulfone, metribuzin, and diuron. In post-emergence, glyphosate is widely used, but many ACCase herbicides can be used, such as clethodim, haloxyfop, and fluazifop. That way, farmers have two to three opportunities to control weedy-rice and barnyardgrass during soybean cultivation, using different herbicides modes of action. Furthermore, the addition of soybeans to the production system brings other advantages like increased soil fertility, biological nitrogen fixation, more profitable growing seasons, and diversification of income.

Spectral Analysis for Weed Identification in Rice Fields

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Site Specific Weed Management (SSWM) has been largely recognized as a methodology to reduce herbicide use for a more sustainable weed management. Local application of herbicides, aided by weed mapping via remote sensing, may allow the reduction of herbicides without impact on yield production. However, in a context of minimizing the use of herbicides, a more knowledgeable approach is required, notably the identification of weed species via remote sensing. In this study, we assess weed recognition in rice fields through hyperspectral data and spectral signatures. Specifically, we focus on weed species growing on the levees as they offer the possibility of homogeneous patches, thus facilitating the recognition in hyperspectral scans.

Three paddy fields were selected in the region of Piedmont and were scanned via drone flights with hyperspectral imaging. The most prevalent and dispersed species were targeted in pure pixel by ensuring the scanning of patches that only included one species at a time. In each species-patch, the GPS location was marked, and the spectral signature of the topmost leaf was recorded through a spectroradiometer, allowing to match the known weed species with their spectral signatures and the corresponding drone scan. On the other hand, the collected spectral signatures were analysed via clustering and indices in order to discern the most relevant spectral range for species differentiation, notably Normalized Difference Vegetation Index (NDVI) and Green-Red Vegetation Index (GRVI), Photochemical Reflectance Index (PRI), Difference Vegetation Index (DVI), Enhanced Vegetation Index (EVI), and Red/Green (RG). Further analyses of the spectral signatures are on-going through Principal Component Analysis (PCA) and cluster analysis.

The study covered the spectral signature of seven weed species (*Amaranthus retroflexus*, *Chenopodium album*, *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Persicaria lapathifolia*, *Polygonum* spp., and *Potentilla reptans*) in addition to spectral signatures of rice plants (*Oryza sativa*) at each location. The statistical analysis of the indices resulted in the categorization of species into homogeneous groups, notably, *Chenopodium album* and *Digitaria sanguinalis* according to GRVI or *C. album* and *O. sativa* according to NDVI and RG. Furthermore, the analysis of PRI allowed for the distinction between *O. sativa* and *E. crus-galli*.

This study substantiates the potential of spectral analysis for the distinction between weed species, especially through the development of distinctive indices after cluster analysis. However, further studies are still required to facilitate the early detection and distinction of weed species and to overcome the challenge of overlap of different species inside the field.

Control of Grasses with Tetflupyrolimet in California Water-Seeded Rice

Inci, D., Lombardi, M.A., and Al-Khatib, K.

The spread of herbicide-resistant weeds is considered a significant problem for rice production in California, where novel herbicides are necessary. Tetflupyrolimet is a new rice herbicide, a novel dihydroorotate dehydrogenase (DHODH) inhibiting mode of action with superior activity on grass species. Three field studies were conducted at the California Rice Experiment Station during the 2022 and 2023 growing seasons. The research objectives were 1) to determine watergrass, *Echinochloa* spp. P.Beauv. (1ECHG), and bearded sprangletop, *Leptochloa fusca* (L.) Kunth ssp. *fascicularis* (Lam.) N. Snow (LEFFA) control with tetflupyrolimet; 2) characterize the effects of tetflupyrolimet combined with other herbicides on weed control and rice; and 3) determine the responses of rice varieties to tetflupyrolimet. In the first study, tetflupyrolimet was applied at preemergence (PRE) or the 1- to 2-leaf stage of rice (POST) at 0.1, 0.125, or 0.15 kg ai ha^{-1}, followed by carfentrazone. Tetflupyrolimet provided ≥ 99% control of 1ECHG and 100% LEFFA control regardless of the rate or application timing while showing no rice injury or yield reduction. In the second study, tetflupyrolimet was applied PRE or POST at 0.1 or 0.15 kg ai ha^{-1}, followed by commonly used California rice herbicides. Tetflupyrolimet provided ≥ 98% control of 1ECHG, significantly higher than the grower standard treatment, and ≥97% control of LEFFA. Tetflupyrolimet did not display synergistic or antagonistic effects in any herbicide tank-mix combinations. In the third study, tetflupyrolimet was applied PRE or POST at 0.125, 0.15, 0.25, or 0.3 kg ai ha^{-1}, followed by carfentrazone on 'M-105,' 'M-206,' 'M-209,' 'M-211,' 'L-208,' and 'CM-203' rice cultivars. Tetflupyrolimet did not cause any crop injury. In conclusion, tetflupyrolimet provided excellent control of 1ECHG and LEFFA without causing rice injury or yield reductions, regardless of rice variety, when applied alone or combined with commonly used sedge and broadleaf herbicides in California water-seeded rice.

Evolution of Rice Weed Management Strategies in Italy in the Period 2013-2023 in Relation to Sowing Technique, Availability of Herbicides, and Herbicide-Tolerant Varieties

Saluzzo, E., Baino, M., Legnani, C., and Ferrero, A.

In the 2023 cropping season, rice had been cultivated on an area of 210,239 ha, mainly located in the provinces of Pavia, Vercelli, Novara, and Milan and provided a production of over 1,300,000 tons of paddy rice, about 60% of which exported to other EU and third countries. All Italian rice is direct sown, on both dry and water flooded soil (about 65% and 35%, respectively), and mostly continuous cropping. In these conditions weed flora is mainly represented by species such as Oryza sativa var. sylvatica, Cyperaceae, Echinochloa spp., Alisma spp., Heteranthera spp., Digitaria sanguinalis, Panicum dichotomiflorum, Ammannia coccinea, and Murdannia keisak. Since the last

15 years, Italian rice-growing has been characterized by a decreasing availability of authorized herbicides after the withdrawal from the market of widely used products such as Propanil, Quinclorac, Bentazon, Oxadiazon, Azimsulfuron, Bispyribac-sodium against the introduction of Rinskor™, and Napropamide. To cope with the increasing problems of managing difficult-to-control weeds (such as Echinochloa spp. and Oryza sativa var. sylvatica), the same period has also seen a growing spread of herbicide-tolerant rice varieties and hybrids, represented in particular by Clearfield® (Imazamox-tolerant), Provisia® (Cycloxydim-tolerant), and FullPage® (Imazamox-tolerant), introduced from 2006, 2019, and 2022, respectively. In this context, Innova-tech, a private research and test facility organization, carried out a survey aimed to assess over the period 2013-2023 the evolution of rice management strategies based on the type of sowing technique, the use of herbicide-tolerant varieties, and the spread of difficult-to-control weeds. The survey was carried out, through interviews and on-site visits in more than 400 rice farms, representing about 20% of total Italian rice area. With reference to the main results, the study showed the following. 1) Over the period 2013-2023, the sowing of herbicide-tolerant varieties varied from 36% to 61% of the total rice cultivated area. 2) From 2013 onwards, when herbicide-tolerant varieties were already available, the area affected by weeds that escaped treatments remained overall stable but with a significant increase of infestation degree of Oryza sativa var. sylvatica. 3) The sowing technique of Imazamox-tolerant varieties changed over the years, from 23% in dry sowing in 2013, to 72% in 2023. Dry sowing combined with the adoption of herbicide-tolerant varieties has made it possible to effectively control Oryza sativa var. sylvatica, Echinochloa spp., Cyperaceae species, and Alisma spp. 4) From 2013 to 2019 with the increasing adoption of dry sowing, the total surface of weeds that escaped treatment remained stable over time. In contrast, with water sowing, uncontrolled weeds tended to increase. 5) In 2019, the introduction of Rinskor™, which is effective against typical water-sowing weeds, has solved many problems of weeds which previously escaped in traditional sowing, such as Alisma spp., Echinochloa spp., and Cyperus difformis. 6) To make up for the lack of new selective herbicides and weed resistance problems due to the repeated use of herbicide-tolerant varieties, Italian rice growers increased the application of the stale seedbed, both in dry and water sowing, achieving good weed control of Oryza sativa var. sylvatica and Echinochloa spp., provided that short-cycle rice varieties are sown.

Student Posters

Developing a High-Throughput Phenotyping Pipeline to Estimate Yield and Plant Height in Rice

Borges, B.R.C., Silva, A.V., Borges, K.L.R., Famoso, A., and Fritsche-Neto, R.

Phenotyping large populations poses a challenge for breeders, as traditional methods rely on manual measurements that are laborious, inaccurate, and time-consuming. On the other hand, modern tools such as Unmanned Aerial Vehicles (UAVs) and image-based technologies have revolutionized plant breeding by enabling precise monitoring of key traits. Visible light imaging captured by RGB (Red, Green, and Blue) sensors is widely used for high-throughput phenotyping due to its speed, cost-effectiveness, and the ability to simultaneously collect multiple traits throughout the crop cycle. Integrating sophisticated algorithms allows for accurate estimation of target traits, such as grain yield (GY) and plant height (PH), assisting breeders in making selections in early breeding stages when replicates in the field are often lacking. This technology-driven approach enhances the efficiency of the breeding cycle, empowering researchers to make informed decisions and develop resilient, high-yielding rice varieties to address global food security challenges. In this context, we aimed to develop a pipeline for image-based phenotyping and evaluate the robustness of RGB-based vegetation indices to estimate productivity in rice.

During the physiological maturity stage (ripening stage), a UAV Phantom 4 (version 2.0) equipped with an RGB camera with 4K resolution was used to capture images from the Clearfield Preliminary Yield Test (CLPYL) trials in replicated design and planted in 2023 at the LSU Rice Research Station. The collected images were used to reconstruct a high-resolution orthomosaic using Agrisoft Metashape (version 2.0) and QGIS (version 3.32.3). Among many indices described in the literature, we have assessed the following ones: 1) Excess of Green Index (ExGI), 2) Normalized Green-Red Difference Index (NGRDI), and 3) Visible Atmospherically Resistant Index (VARI). Downstream analysis was performed using Software R. Briefly, shapefiles were generated, and masks were applied to remove the soil background from the plots to separate only the pixel area representing the reproductive part, in this case, a surrogate of grain yield. Then, based on the difference of the pixel altitude at canopy and soil level, we estimate the plant height per plot.

All tested vegetation indices were negatively correlated with the target traits, limiting their use for indirect selection. However, the indices helped remove the vegetative part of the plants, enabling the estimation of the plot area corresponding to the panicles (the reproductive part). Subsequently, the panicle area was used to estimate GY as a productivity indicator. The estimated productivity showed a 34% correlation with field GY data. Regarding PH, the correlation was even higher at 61% between estimated values (derived from the images) and field data. The proposed pipeline will be validated in the coming years and applied to other breeding fields at the Rice Research Station. Additionally, using a multispectral camera and ground control points, we expect that higher precision and other indices will boost the prediction accuracies.

Imazethapyr Carryover in Louisiana Rice Varieties

Carr, W.B., Webster, L.C., Stoker, S.B., Arcement, M.P., Valle, L.N., and Williams, J.A.

In rice (*Oryza sativa* L.) production in southern Louisiana, many growers practice a rice and crawfish rotation. Due to the anaerobic conditions associated with crawfish production, imazethapyr that was applied in the previous rice crop can persist longer than when aerobic conditions are present. Over the past couple growing seasons, many growers in southern Louisiana have experienced imazethapyr carryover when rotating from an imazethapyr-resistant (IR) rice and crawfish rotation to a non-IR production system.

In 2023, at the H. Rouse Caffey Rice Research Station in Crowley, Louisiana, three studies were conducted to evaluate imazethapyr carryover in non-IR rice varieties. The studies were set up as randomized complete blocks with three replications. Treatments consisted of either no imazethapyr or imazethapyr at 2, 4, 7, 9, 11, 13, 15, and 17 g ai ha^{-1}. Imazethapyr applications were made prior to seeding the research area which was flushed twice to incorporate the herbicide into the soil profile. Once the soil dried, rice was drill-seeded at 84 kg ha^{-1}, and plot size was 1.5 by 4.3 m^2. Each study evaluated imazethapyr on a different rice variety, with the first being PVL03®, then Cheniere, and Jupiter. Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Evaluations for crop height were recorded 28 days after emergence (DAE). In addition to crop heights, rice plant stand counts were recorded at 28 DAE, and percent heading data was taken at 91 DAE. Rough rice yields were obtained and adjusted to 12% moisture.

At 91 DAE, percent heading data for PVL03 was 82% when no imazethapyr was applied prior to seeding, while PVL03 planted into rates of imazethapyr greater than 11 g ha^{-1} resulted in 70 to 72% heading 91 DAE. In the Cheniere study, percent heading at 91 DAE was 78% in nontreated plots; however, 70 to 73% rice heading was observed when imazethapyr was applied prior to rice seeding at 11, 13, 15, and 17 g ha^{-1}. In the Jupiter study, at 91 DAE, 62% rice heading was observed in the nontreated, while the rest of the imazethapyr-treated plots were less than 50%. This research indicates that imazethapyr carryover plays a role in rice heading timing.

Enhancing Nitrogen Use Efficiency in Rice Rotational Cropping Systems in Louisiana Using Remote Sensor-Based Management Approach

Darnall, C. and Tubana, B.

Optimal nitrogen fertilization can reduce production cost while sustaining yield in rice (*Oryza sativa*). Remote sensing is used for fast and real-time monitoring of rice plant nitrogen health and for deriving a plant need-based recommendation for fertilizer to improve nitrogen use efficiency. Two 20-hectare demonstration trials were established in 2023, one under rice-crawfish and the other rice-soybean rotation system planted with Jasmine CLJ01 and Provisia PVLO3, respectively. Each rotation system was divided into two fields based on nitrogen management: farmers' standard practice (135 kg N/ha after permanent flood + 37 kg/ha at panicle initiation) and sensor-based (135 kg N/ha after permanent flood + recommendation based on sensor reading at panicle initiation). Data on grain yield, plant and soil nitrogen content, and water quality were collected and analyzed.

The sensor-based nitrogen recommendation at panicle initiation was 28 and 12 kg/ha for the rice-soybean and rice-crawfish systems, respectively. Both were lower than the recommendation under farmers' standard practice. Main crop grain yield came back higher in the rice-soybean system using the sensor-based nitrogen recommendation but not in rice-crawfish rotation. The grain produced for every kg of nitrogen applied under farmers' standard practice was 64 kg in rice-soybean and 82 kg in rice-crawfish, whereas the sensor-based recommendation recorded higher values at 72 and 95 kg, respectively. Opposite trend of efficiency was recorded for the following ratoon crop likely due to the higher nitrogen carry over effect in the farmers' standard practice. There were bigger disparities on soil nutrient and water quality parameters between the cropping system than between nitrogen management practices.

The outcomes from this study are vital in the process of scaling up adoption of the sensor-based nitrogen management in rice production on agronomic, environmental, and economic standpoints.

No-Till and Nitrogen Management Strategies: Planting into a Stale-Seedbed of Sacramento Valley's Rice Fields

Godbey, M.

No-till agriculture is gaining traction as a conservation management approach, offering potential advantages such as reduced soil erosion, enhanced soil health, lower production costs, earlier planting, and sustainable long-term crop productivity. While widely adopted in various agricultural contexts, the application of no-till methods in rice farming is not as prevalent. Previous studies have presented inconsistent yields, emphasizing the need for further investigation to understand the limiting factors. Conducting additional research will contribute to a deeper understanding of these constraints, enabling more informed decisions for refining future rice farming practices. This study specifically explores a modified no-tillage system, where field preparation occurs during the fallow summer period. We are assessing the feasibility of directly flooding and air-seeding these stale seedbeds in the following year without additional tillage both on-farm and on-station. This study aims to evaluate and compare nitrogen management practices in no-till and conventional till systems in order to achieve maximum yields. Data were collected from six on-farm sites throughout the Sacramento Valley in 2022 and 2023 and from a replicated trial at the Rice Experiment Station (RES) in 2023. At each of the on-farm sites over these two years, 1-acre portions of the growers' fields were marked off with a no-till area directly adjacent to an area that was conventionally tilled. At the RES, four basins (replications) were managed with the same no-till and conventional treatments as the on-farm trials. Nitrogen rate trials, pest, and weed monitoring areas were set up in each system at all sites. Preliminary data shows that overall, conventionally tilled rice had higher yields than no-till rice, but both system yields reached maximum yield at 175 lb N/acre. Additional findings indicate potential differences in weed and pest pressure between the two systems, with an overall higher percentage of stem rot and aggregate sheath spot, and watergrass, found in conventional till than in no-till. This data will be supported by the yields, weed, and pest pressure data from the RES systems site.

Efficacy of Herbicide Applications Using a Remotely Piloted Aerial Application System for Weed Control in Rice

Kudiabor, R.S., Gurjar, B., Xin-Gen, Z., and Bagavathiannan, M.

Aerial herbicide applications are more convenient than ground applications in rice. In this respect, there is a growing interest in the use of drones. An advantage of using drones over aircraft is the ability to use them in smaller areas and field edges. Research is being conducted to optimize the application parameters for spray drones to achieve maximum coverage and improve weed control efficacy. The objective of this research was to investigate the influence of various drone application parameters for herbicide products and tank mixes for effective weed control in rice. Four herbicide tank mixes and two application methods (drones vs backpack application) were evaluated for weed control at the MPOST and PREFLD growth stages at the David Wintermann Rice Research and Extension Center, Eagle Lake, TX. The study was conducted in a randomized complete block design with four replications. The spray drone was calibrated to spray at an application rate of 18.7 L/ha at a flying speed of 21 km/h and a height of 2.4 m. The drone application had up to 26.7% weed control efficacy compared to 85-100% for backpack application at 28 days after application for all herbicide treatment-timing combinations. Based on the spray card droplet deposition data, drones exhibited a decrease in herbicide deposition (52.71%) and uneven distribution within the plots under current spray parameters compared to backpack application (85.78%). The herbicide treatments applied at MPOST had a significantly higher weed control efficacy than those at PREFLD. There was a higher weed density at the PREFLD timing, which may have led to reduced weed control. The findings highlight field-level variabilities and inconsistencies associated with the current application settings/parameters of commercial drones. More research is ongoing to optimize various parameters, including spray volume, nozzle type, flight speed, among others, for weed control in rice, particularly under high weed densities.

Effect of Silicon Uptake Capacity and Herbivory on Silicon Accumulation in Rice at Local and Systemic Levels

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

Silicon (Si) is known to play a vital role in protecting rice plants against biotic and abiotic stresses. However, it is unclear whether herbivory induces Si accumulation in rice, as it does in other plants, and how the silicon uptake capacity of rice affects this accumulation. Therefore, a study was conducted to investigate the impact of herbivory on Si accumulation and to determine whether the Si uptake capacity of rice affects this accumulation. The experiment involved using *Spodoptera frugiperda* Smith, the fall armyworm, as an insect herbivore, and three Si transporter mutants with varying levels of Si uptake (one with over 95% deficiency in Si uptake, another with around 55% deficiency in Si uptake, and the third with uptake similar to WT) and compared them to the wild-type rice cultivar Nipponbare. The study used a 4*3*2 factorial design with four levels of rice genotype, three levels of Si fertilizer, and two levels of herbivory. Si quantification at local as well

as systemic levels and biomass measurements were taken in this experiment. The initial results of the study indicate that a higher uptake of Si increased the biomass content of rice. The results of this study can be used to improve plant resilience through sustainable agriculture by understanding the relationship between herbivory, Si uptake capacity of rice genotypes, and Si accumulation.

A New SNP Marker Distortion/Error Identification Tool May Improve Data Quality for Downstream Analysis

Gupta, K., Angira, B., Famoso, A., and Fritsche-Neto, R.

Genetic marker analysis is pivotal in unraveling the intricacies of genetic variation, demanding stringent quality control measures to ensure reliable outcomes. In this study, we present an additional quality control tool designed to enhance the precision of marker datasets, extending beyond conventional metrics, such as call rate, missing data, depth, number of alleles, and minor allele frequency (MAF). Specifically, we introduce the contrast between the observed and expected heterozygosity within pre-defined generations complemented with the marker's MAF per se in contrast with the neighbor's values. To exemplify the usefulness of this new approach, we applied it to a well-known rice population.

A novel aspect of this tool involves the calculation of a red flag for heterozygosity by measuring the difference between actual and expected values. A 95% confidence threshold is established to identify significant deviations, and a marker is flagged if the heterozygosity exceeds this threshold. A comprehensive red flag is assigned to a marker only if MAF and heterozygosity exhibit deviations to enhance robustness. This criterion is then applied across diverse populations, including MPA, MPB, MPC, and MPD, all of which are biparental populations at the LSU H. Rouse Caffey Rice Research Station. Markers exhibiting red flags in all populations are systematically discarded, ensuring a stringent filtration process suitable for breeding programs.

To examine the effect on downstream analysis, we used data from 2021 trials, carried out as augmented block design with row numbers and column numbers employed to derive the Best Linear Unbiased Estimates (BLUE) values for two crucial traits: "Days to Heading" and "Yield." Then, Genome-wide association Studies (GWAS) and Genomic Selection (GS) were employed to check for specific changes in marker associations and anticipate a reduction in the selection interval, respectively. These analyses allow us to evaluate the impact of the refined marker dataset on minimizing false positives and enhancing the accuracy of genetic analyses. Overall, this tool brings more robustness to marker quality control and, consequently, to subsequent genomic analysis.

Preemergence Weed Control Using Tetflupyrolimet Mixed with Annual Grass and Broadleaf Herbicides

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Tetflupyrolimet, under development by FMC^{Ò}, is a novel herbicide of aryl pyrrolidinone anilides. By inhibiting dihydroorotate dehydrogenase, tetflupyrolimet interferes with *de novo* pyrimidine biosynthesis. A study was conducted in 2023 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana, to evaluate tetflupyrolimet mixtures to broaden the control spectrum. Plot size was 3-m by 9.14-m with 16-19.5 cm drill-seeded rows of 'PVL03' at 78.4 kg ha^{-1}. This study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of either no herbicide, tetflupyrolimet, clomazone at 313 g ai ha^{-1}, or clomazone at 313 g ai ha^{-1} mixed with tetflupyrolimet. Factor B consisted of either no herbicide, quinclorac at 2,242 g ai ha^{-1}, a prepackaged mixture of halosulfuron plus prosulfuron at 70 g ai ha^{-1}, or saflufenacil at 70 g ai ha^{-1}. Since tetflupyrolimet is still in development, the usage rate will remain confidential. Uniform standard treatments of halosulfuron plus prosulfuron at 105 g ha^{-1} and quizalofop at 1,086 g ai ha^{-1} were applied at two- to three-leaf and panicle initiation rice growth stages, respectively. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations of percent control for this study included barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster] control at 21 and 56 days after treatment (DAT). Visual evaluations of percent control were also recorded for spreading dayflower [*Commelina diffusa* Burm. F.] at 21 DAT. Rough rice yields were obtained and adjusted to 12% moisture.

At 21 DAT, saflufenacil applied alone controlled spreading dayflower 94%, whereas when tetflupyrolimet was mixed with saflufenacil, control decreased to 58%. Barnyardgrass visual evaluations at 56 DAT show a reduction in control when clomazone is mixed with halosulfuron plus prosulfuron or saflufenacil, compared to when tetflupyrolimet is mixed with the same residual herbicides. This study suggests that applying tetflupyrolimet with various preemergence grass and broadleaf herbicides can allow for prolonged control of barnyardgrass. However, these results do indicate a possible antagonistic interaction between saflufenacil and tetflupyrolimet for the control of spreading dayflower.

Parallel Studies Revealed the Responses of Rice Morpho-Physiological Traits, Yield Components, and Nitrogen Use Efficiency under Organic Managements

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Maximizing rice production is critical to feed over half of the world's population and to safeguard food security. However, improper N management poses 'a grand challenge' not only in achieving high-yielding rice production but also ensuring agricultural sustainability. Organic practices have been always regarded as an environmentally sustainable and cost-reduction strategy. However, its contributions to increased rice yields is still questionable. Parallel experiments employing both greenhouse and field studies were conducted to evaluate the effects of organic N fertilization on

rice growth, yield-related traits, and agronomic NUE. N rates of organic soil amendments consisting of CLP and NS were observed to significantly enhance rice morpho-physiological and agronomic traits. The application of NS at 150 kg N ha^{-1} produced the greatest tiller numbers, taller rice plants, and highest chlorophyll and N indexes, aboveground biomass, panicle number, and rice yields in both greenhouse and field tests, except for the NUE that was significantly affected by N rates from organic soil amendments in the greenhouse study. This study indicated that the use of NS at 150 kg N ha^{-1} was the optimal application to promote rice growth, development, and yield under organic management.

Five Decades (1973-2023) of Sheath Blight Chemical Control Studies in Louisiana

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Sheath blight (SB), caused by Rhizoctonia solani AG1-1A, can reduce yields by up to 50-90% and diminish grain quality. Host resistance to this disease is limited. In Louisiana, one of the most effective SB control methods is chemical treatment with foliar fungicides. For over 50 years, the H. Rouse Caffey Rice Research Station at the LSU AgCenter has been conducting trials on the chemical control of SB. Our study aims to qualitatively summarize these efforts.

The first fungicide efficacy study was conducted in 1973, and since then, over 200 trials have been carried out, testing over 400 products either in isolation or in combination. Early studies featured a more diverse number of active ingredients and fungicide groups, including FRAC 1, 2, 3, 6, 7, 16.1, 20, 30, 33, B1, and M5. More recent studies are predominantly limited to fungicide groups of FRAC 3, 7, and 11, namely DMI, SDHI, and QoI, respectively. Fungicide timing studies have also been the subject of many trials. Although some variation between years was identified, better results were generally observed when fungicides were applied before the disease's full establishment. Studies with multiple varieties indicate that better control of sheath blight occurs with the combination of fungicide and varieties with some level of resistance. Treatments without inoculation had, in general, significantly lower disease incidence and severity, which indicates that results without inoculation are more susceptible to disease escape.

Future studies using this historical dataset will be expanded and quantitatively summarized in meta-analytic studies. This data will be utilized in the development and validation of risk assessment models and decision support systems. These tools will assist growers in their decision-making processes and help elucidate key components of disease epidemiology and control.

Developing Improved Nutrient Management in Rice and Rice-Based Production Systems through Silicon Enrichment in Soil

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Rice (*Oryza sativa*) is a staple food for a significant portion of the global population. Improving the production management of this grain is essential for food security. Silicon (Si), though not classified as an essential plant nutrient, has been increasingly recognized for its beneficial effects

on various crops, including rice. This study explores the impact of integrating Si in the nutrient management of rice and would lead to the optimization and improvement of the productivity of rice-soybean and rice-crawfish production systems in Louisiana. This study involves the application of Si in two production systems (rice-soybean and rice-crawfish). For each production system, the Si fertilization was established in two blocks: 1) farmer's standard practice or FP and 2) under a set of best management practices or BMPs. Si-amended plots (3 m x 15 m) were established in both crop rotation fields in Kaplan, LA. The Si source is a byproduct of iron and steel (Plant Tuff®) production with total Si content of 4%. The Si byproduct was applied at 2 ton/ac at preflood. Provisia (PVLO3) line was planted in the rice-soybean field and Jasmine cultivar in the rice-crawfish field. Both fields received 78 kg P/ha and 100 kg K/ha. After the harvest of the main crop, the rice plants were grown again for ratoon cropping, a common practice of Louisiana rice producers.

There was an evident difference in production potential between the two rice rotation systems in Louisiana during the first production season. Variety was a factor separating the average grain yield in rice-soybean and rice-crawfish by >2,600 kg/ha. In the rice-soybean field, the harvest of the BMP field was highest (12,378 kg/ha), close to the harvest of the field enriched with Si (11,459 kg/ha). The Si-treated field was about 2,000 kg/ha higher than at the FP field (9,490 kg/ha). The Si-treated field had a yield of 7,068 kg/ha, comparable to the BMP (7,212 kg/ha) and the FP field (7,442 kg/ha). In the rice-crawfish field, FP field attained the highest grain yield (8,963 kg/ha) but similar to the field enriched with Si (8,607 kg/ha). The ratoon crop had a lower yield than the main crop with BMP field yielding the highest at 6,186 kg/ha followed by Si-treated field (5,264 kg/ha) then the FP (4,020 kg/ha).

The inclusion of Si in the rice fertilizer program through the application of Si-rich byproducts can raise the level of productivity in these rice rotation systems through improved soil fertility and the capability of the plant to withstand biotic and abiotic stresses that affect the production performance of the crop. The outcomes from this research will provide information about the mechanisms and practical applications of silicon enrichment, thus farmers and researchers can contribute to the development of resilient and productive rice cultivation systems, especially in Louisiana and other areas of the same ecosystem.

Mixture Interactions of Propanil and ALS-inhibiting Herbicides for Aquatic Weed Control in Rice (*Oryza sativa* L.)

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Rice (*Oryza sativa* L.) is deemed a prevalent crop in many regions around the world and is considered a pervasive cereal grain crop in southwest Louisiana. Studies were conducted in 2021 and 2022 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana. This research evaluated the interaction of halosulfuron, prosulfuron, and a prepackaged mixture of halosulfuron plus prosulfuron when mixed with propanil. This study was a randomized complete block design with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of propanil, sold under the trade name Stam® at 0 or 3,363 g ai ha^{-1}. Factor B consisted of either no mix partner, halosulfuron at 35 or 53 g ai ha^{-1}, prosulfuron at 20 or 30 g ai ha^{-1}, or a pre-mixture

of halosulfuron plus prosulfuron at 55 or 83 g ai ha^{-1}. Applications were made post-flood at the 5-leaf to 1-tiller rice growth stage and plot size was 1.5 by 5.2 m^2. All applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Visual weed control evaluations were recorded at 14 and 21 days after treatment (DAT), where 0 equals no control and 100 equals plant death. The weed species evaluated were alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.] and grassy arrowhead (*Sagitaria lancifolia* L.). The Blouin's Modified Colby's method was used to determine the presence of synergistic, neutral, and/or antagonistic interactions.

At 14 and 21 DAT, antagonism was observed for alligatorweed control when each herbicide was mixed with propanil. At 14 DAT, an antagonistic interaction was observed for grassy arrowhead control with an observed control of 26% compared with an expected control of 73% when halosulfuron at 53 g ha^{-1} was mixed with propanil. Similarly, at 21 DAT, halosulfuron at 35 and 53 g ha^{-1} was antagonized by propanil for grassy arrowhead control. At 42 DAT, fresh biomass of alligatorweed and grassy arrowhead when treated with halosulfuron mixed with propanil did not differ from nontreated comparisons. Based on these results, acetolactate synthase inhibitors can be antagonized when mixed with propanil for control of aquatic weeds.

Impact of Rice Husk and Dust Diets on *Manduca sexta* Protein Profile, Nutritional Characteristics, and Functional Properties

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Insect farming emerges as a sustainable solution to tackle the global protein shortage, presenting a viable alternative protein source. Recognized for their high protein content, insects are abundant in microelements, various bioactive compounds, and essential amino and fatty acids. Nevertheless, the nutritional composition of insects varies significantly based on factors such as species, developmental stage, environmental conditions, and feed. Our study focused on examining the impact of substituting artificial diet with rice husk and dust (at 10% and 20% levels) on the growth and development of *Manduca sexta* (tobacco hornworm), an agricultural pest in the insect order Lepidoptera often used as lab models. Additionally, our research aims to explore differences in the functional, structural, and nutritional profiles of proteins obtained from *M. sexta* larvae and pupae fed with rice husk and dust, respectively.

In this study, insects were fed the Lepidoptera diet (control) and 10 or 20% rice dust or husk substituted diet for 3 weeks. Harvesting was done at the larvae and pupae stages within 3 weeks. Proximate analysis, in vitro protein digestibility, and amino acid profiling of the two insect groups, will be presented. To gain a comprehensive understanding of the protein profile, behavior, structure, and thermal stability, techniques such as SDS-page electrophoresis, Fourier-transform infrared spectroscopy (FTIR), and differential scanning calorimetry (DSC) are employed.

Preliminary results indicate that caterpillars reared on a husk-added diet exhibited faster growth, increased body mass, and quicker pupation with fewer pupal defects, while the opposite trend was observed in rice dust-fed larvae, especially at higher substitution percentage (20%).

The research findings will provide detailed information on the distinctions and characteristics of the extracted proteins, offering insights into their potential applications as functional ingredients in food, feed or pharmaceutical contexts. Additionally, the research aims to contribute to the valorization of rice by-products, typically treated as waste, by presenting them as a cost-effective and sustainable feed option for insect rearing.

Estimating Change in Soil Health from Baseline after Long-Term Cover Cropping in Rice

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The intensity of severe weather events is increasing, and crop yields have already begun to see yield effects from global climate change. Rice (*Oryza sativa* L.) and the associated management practices release some of the greatest amounts of greenhouse gas emissions compared to any other crop grown in the United States. In an attempt to reduce greenhouse gas emissions, sequester soil carbon (C), and improve soil health, rice producers are beginning to transition to more regenerative agricultural management practices.

The purpose of this study is to investigate the long-term soil health effects of some known regenerative management practices, while also assessing rice yield response, in a zero-grade, flood-irrigated rice production system in eastern Arkansas. Prior to the first rice crop planting, two soil samples were collected from each plot to a depth of 1 m using a Giddings trailer-mounted hydraulic coring machine, and the cores were separated in depth intervals of 0-10, 10-20, 20-40, 40-60, 60-80, and 80-100 cm. Each soil sample for every plot and depth was tested for soil respiration by 24-hour CO_2 measurements, water-soluble C and nitrogen (N), organic matter (OM) concentration via loss-on-ignition, permanganate-oxidizable C, nutrient concentrations via the Mehlich-3-extraction method, as well as soil pH, salinity, bulk density, and cation exchange capacity. In 2023 and for the next several years, three replications of seven treatment combinations will be applied to 6.1 x 30.5 m rice plots: 1) control treatment with conventional tillage, continuous rice, and no other additions; 2) no-tillage (NT), no cover crop, and plant residues burned after harvest; 3) NT, no cover crop, and non-burned plant residues; 4) NT, black-seeded oats (*Avena sativa*) and legume (either hairy vetch [*Vicia villosa*] or Austrian winter pea [*Pisum sativum*]) cover crop blend, and non-burned plant residues; 5) NT, legume only (either hairy vetch or Austrian winter pea) cover crop, and non-burned plant residues; 6) NT, black-seeded oats only as the cover crop, and non-burned plant residues; and 7) NT, black-seeded oats only as the cover crop, non-burned plant residues, and an addition of a single application of 5,589 kg ha^{-1} of biochar mechanically incorporated prior to plot establishment. Cover crop biomass, rice biomass, elemental concentrations of rice, and rough rice yield will be assessed yearly. The deep soil samples and lab analyses will be performed again in spring of 2025 and periodically over the next decade to evaluate differences in soil health and rice yield response over time as an effect of the treatments.

As baseline soil samples were taken before introducing treatments to the study, soil property values remained similar across all plots. It is worth noting that the tests measuring soil C and soil OM,

such as OM via loss on ignition (1.4-2.3%), microbially active C (11.9-37.4%), permanganate-oxidizable C (165.1-349.9 ppm), water soluble organic C (66.7-154.1 ppm), and soil CO_2 respiration (7.5-55.1 ppm), were all greatest at the surface and decreased as sampling depth increased. Although there has yet to be observable significant differences in soil health or rice yield responses thus far due to a "priming effect," it can be hypothesized based on previous studies that soil C (active and non-active), soil respiration, soil organic matter, and rice yield will be greater in cover crop treatments (treatments 4, 5, 6, and 7) in comparison to treatments without cover crops (treatments 1, 2, and 3), and soil N concentrations will be greater in treatments with leguminous cover crops (treatments 4 and 5) in comparison to the rest of the treatments.

The results of this research are critical to understand the practices associated with sequestering soil C, lowering greenhouse gas emissions, and improving overall soil health, without the penalty of a yield reduction, even in a production system as complex as zero-grade and flood-irrigated. It is expected that the conclusions of this research will influence the use of regenerative management practices in rice production across the Mid-south United States.

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