RICE FIELD DAY

Wednesday, August 28, 2019

California Cooperative Rice Research Foundation, Inc.
University of California
United States Department of Agriculture
Cooperating

Rice Experiment Station

P.O. Box 306, Biggs, CA 95917-0306

About the Cover

In 2018, grain yield of 12Y2175 was significantly higher than any of the medium grain check varieties. Days to 50% heading is similar to M-209. In addition to this yield potential, it has premium quality parentage and taste/texture evaluations indicate more premium quality characteristics than Calrose varieties. This line is in seed increase for consideration for release in 2020.

2018 UCCE Statewide Yield Test (All Locations)

ID	YIELD (lb/a)	SV	HDG	LOD	HT (cm)
12Y2175	**10031**	**4.8**	**87**	**21**	**101**
M-209	9241	4.7	87	18	97
M-206	9182	4.8	82	36	101
M-105	9168	4.7	79	41	100
M-210	9159	4.8	82	34	99

ID	%CHALK AREA	%CHALK	WHITE	L	W	L/W
12Y2175	**16**	**0.8**	**138**	**5.9**	**2.7**	**2.2**
M-105	13	0.8	134	5.8	2.6	2.3
M-206	14	0.8	135	5.7	2.6	2.2
M-209	15	1.1	137	5.9	2.5	2.3

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UC Rice Research

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Kevin Goding, Staff Research Associate II
Alex Ceseski, Ph.D. Candidate
Aaron Becerra-Alvarez, Junior Specialist

2019 Rice Field Day Program

7:30—8:30 Registration and Poster Viewing

Posters and Demonstrations

1. Rice Waste Discharge Requirement: Pesticide Monitoring Requirements Under the Order and Compliance Reporting for Growers (California Rice Commission)
2. Rice Pesticide Program: Thiobencarb Monitoring Results and Potential Changes to Management Practices and DPR Permit Conditions (California Rice Commission)
3. Thiobencarb Management Practices & Permit Conditions per DPR Enforcement Compendium and Registrant Stewardship Materials (California Rice Commission)
4. Rice Pesticide Use Matrix: Summarizes Rice Pesticide Use in CA (California Rice Commission)
5. Herbicide Resistance Stewardship Chart and Handout as an IPM Guide to Growers for Herbicide Selection (California Rice Commission)
6. Intrepid 2F Section 18 for Armyworm Control and Progress Toward Registration (California Rice Commission)
7. DPR Brochures and Information of FIFRA Section 24(c) Special Local Need Registrations and Comparison to Section 18 Emergency Exemptions
8. ALS Cross-Resistance and Multiple Resistance in California Accessions of *Cyperus difformis* (A. Ceseski, A. Godar and K. Al-Khatib, UCD)
9. Effects of Planting Depth on Rice Cultivar Response (A. Ceseski and K. Al-Khatib, UCD)
10. Flooding Depth and Burial Effect on Emergence of Five California Weedy Rice Biotypes (L. Galvin, D. Inci, W. Brim-DeForest, M. Mesgaran, K. Al-Khatib, UCD)
11. Survey of Bearded Sprangletop Response to Clomazone in California Rice (K. Driver, K. Al-Khatib and A. Godar, UCD)
12. *Leptochloa acuminata* Flooding Tolerance in California Water Seeded Rice (K. Driver, K. Al-Khatib, UCD)
13. Effect of Fertilizer Application Rates on Nuisance Algal Growth in California Rice (S. Ohadi, J. Madsen and K. Al-Khatib, UCD)
14. Evaluating Different Algaecides for Controlling Early Bloom of the Algae in Flooded Rice (S. Ohadi, A. Godar and K. Al-Khatib, UCD)
15. Management of Tadpole Shrimp with Insecticides (L. Espino and C. Sheppard, UCCE)
16. Insecticide Trials for Armyworm Control (L. Espino, C. Sheppard and I. Grettenberger, UCCE and UCD)
17. California Weedy Rice Surveillance and Rice Production Survey (W. Brim-DeForest, L. Karn, L. Bhagirath and L. Espino, UCCE)

18. Weedy Rice Update: Populations and Distribution in California (W. Brim-DeForest, T. Blank and L. Espino, UCCE and CCIA)
19. Methylmercury Dynamics in Sacramento Valley Rice Fields Receiving Recycled Irrigation Water (L. Salvato, M. Marvin-DiPasquale, J. Fleck, S. McCord and B. Linquist, UCD)
20. Measuring and Modeling Nitrogen Losses from Aqua Ammonia Fertilizer During Dry Down Periods in Conventional California Rice Production Systems (B. Linquist and P. Geoghan, UCD)
21. The Effects of Midseason Drainage on Greenhouse Gas Emissions and Yield in California Rice Systems (H. Perry, D. Carrijo and B. Linquist, UCD)
22. The Effect of Fertilizer Sources and Placements on Ammonia Volatilization Losses from Water-Seeded Rice Systems in Sacramento Valley (T. Chuong and B. Linquist, UCD)
23. Using Drone Technology to Guide Midseason Nitrogen Fertilizer Applications (T. Rehman, B. Linquist, UCD)
24. Identification of Novel Mutations in Genes Involved in Silicon and Arsenic Uptake and Accumulation in Rice (T. Tai and H. Kim, USDA-ARS and UCD)

8:30 - 9:15 a.m. GENERAL SESSION

Welcome by Gary Enos, Chairman, CCRRF

CCRRF Business Meeting

- ROXY™ Report
  Kent McKenzie, RES
- Financial Report,
  Rob Doornbos, Treasurer, CCRRF
- Directors Nomination Committee Report,
  Kent McKenzie, RES
- Rice Research Trust Report,
  Steven Willey, Chairman, RRT
- D. Marlin Brandon Rice Research Fellowship
  Kent McKenzie, RES
- California Rice Research Board Report,
  Jason Bowen, Chairman, CRRB
- California Rice Industry Award Presentation,
  Kurt Meyer, Vice Chairman, CCRRF

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9:20 - 10:45 a.m. MAIN STATION TOUR

Two tours occur simultaneously and repeat.

Blue & Green Groups to Trucks

Rice Breeding Program
(V.C. Andaya, T. De Leon, S. Talukder, RES)

Managing Nitrogen Fertilizer
(B.A. Linquist, UCD)

10:30 - 10:45 a.m. Refreshments – Under Carport

10:45 - Noon Repeat Station Tour with
Red & White Groups

9:20 - 10:45 a.m. HAMILTON ROAD TOUR

Two tours occur simultaneously and repeat.

Red & White Groups to Buses

Weed Control in CA Rice: Evaluation of New Weed Control Methods and Methodologies
(K. Al-Khatib, UCD)

10:30 - 10:45 a.m. Refreshments – Research Building Canopy

10:45 - Noon Repeat Hamilton Road Tour with
Blue & Green Groups

Noon Luncheon Concludes Program

Lunch will be served in the New Research Building with seating at the tables on the lawns under the canopies.

1.0 hour of Continuing Education credit for this 2019 Rice Field Day has been granted from Cal/EPA Department of Pesticide Regulation

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Introduction

By Gary Enos

On behalf of the Board of Directors, staff and UC cooperators, welcome to Rice Field Day 2019. Field Day is our annual opportunity to highlight the research that is underway at the Rice Experiment Station for the California Rice Industry. It is also the annual business meeting for the grower/owners of the California Cooperative Rice Research Foundation.

In 2018, we released foundation seed of M-210 with a new blast resistant gene developed with marker-assisted selection provided by our DNA Lab. Calaroma-201, our first long grain with jasmine cooking quality, was also released. This year, we released S-202; a smooth hull, short grain with very high yield potential.

The RES Rice Breeding Program remains true to its mission and continues to move forward. This has been possible with the continued financial support from the California Rice Research Board as well as the Foundation and the Rice Research Trust and a committed staff. Of special note is the 'under construction RES Genetics Lab' that will expand our capabilities in genetics to support future variety development.

The highlight of the day's activities are the field tours where you are able to hear from the researchers and see the breeding nurseries on the main station as well as weed control research at the Hamilton Road site.

Dr. Virgilio "Butz" Andaya, Director of Plant Breeding, and our new rice breeders Drs. Teresa De Leon, Shyamal Talukder, and Research Scientist Cynthia Andaya will be reporting research and developments in the RES Rice Breeding Program.

Dr. Bruce Linquist, Rice Specialist in Cooperative Extension, will be reporting on UC research from the Systems Research Nursery.

Dr. Kassim Al-Khatib, UC Davis Professor, heads the UC rice weed control project and will be speaking to you on a walking tour of the weed research nursery at the Hamilton Road site.

The Rice Experiment Station remains committed to the production of clean, weed and disease free foundation seed for the California rice growers. We continue work in cooperation with the Foundation Seed and Certification Services and the California Crop Improvement Association. We are now further strengthening our seed program for all RES varieties by licensing all seed growers of our varieties. The certified seed program is an essential part of maintaining genetic purity in our varieties and insuring the highest quality seed is available to the industry, as well as stemming the spread of weedy red rice. The seed program is self-supporting and is not funded by the Rice Research Board.

I would like to acknowledge the many businesses and growers who support Rice Field Day through financial donations, agro chemicals and use of trucks for our tours. This year we have also included equipment displays from several sponsors. This industry support is very important to the success of the Field Day. The supporters are listed in your program and we thank them again for their assistance. Lastly, thanks to all of the RES staff and UC that work very hard to make Rice Field Day successful.

Thank you for attending Rice Field Day and supporting our research programs. If you have any questions about Field Day or the Rice Experiment Station, please take the opportunity to talk with the Director and his staff. There is a great deal of useful information on display today and I invite you to visit the displays and posters as well as taking the field tours.

D. Marlin Brandon Rice Research Fellowship

In 2000, a memorial fellowship was established to provide financial assistance to students pursuing careers in rice production science and technology as a tribute to Dr. D. Marlin Brandon, past Director and Agronomist at the Rice Experiment Station. The California Rice Research Board made a one-time donation to the Rice Research Trust of $52,500 with $2,500 used for the 2000 fellowship. The Rice Research Trust contributed an additional $50,000 and established a fellowship account. Interest from investments on the $100,000 principal is used to provide grants to the D. Marlin Brandon Rice Scholars. Thirty fellowships have been issued from 2000 to 2018.

D. Marlin Brandon Rice Scholars

William Carlson
2000
Nicholas Roncoroni
2001
David P. Cheetham
2002
Jennifer J. Keeling
2002
Kristie J. Pellerin
2003
Michael S. Bosworth
2003
Kristie J. Pellerin
2004
Leslie J. Snyder
2004
Gregory D. Van Dyke
2004
Leslie J. Snyder
2005
Louis G. Boddy
2006
Rebecca S. Bart
2006
Jennifer B. Williams
2007
Mark E. Lundy
2007
Louis G. Boddy
2008
Monika Krupa
2008
Cameron Pittelkow
2009
Charles Joseph Pfyl
2009
Maegen Simmonds
2009
Mark E. Lundy
2010
Cameron Pittelkow
2011
Whitney Brim-DeForest
2011
Matthew Espe
2015
Mathias Marcos
2015
Gabriel T. LaHue
2016
Johnny Campbell
2017
Alex Ceseski
2017
Telha Rehman
2017
Katie Driver
2018
Luke Salvato
2018

ALS CROSS-RESISTANCE AND MULTIPLE RESISTANCE IN CALIFORNIA ACCESSIONS OF *CYPERUS DIFFORMIS*

❖ A. Ceseski, A. Godar and K. Al-Khatib, UCD

Control of smallflower umbrella sedge (*Cyperus difformis* L.) in California rice has relied heavily on acetolactase synthase (ALS) inhibiting herbicides for more than two decades. As a result, smallflower populations resistant to ALS inhibitors are found throughout California's rice growing region. In addition, grower complaints indicate that multiple-resistant smallflower may be a budding concern.

The present research seeks to evaluate the level of resistance of ALS-resistant California smallflower populations, and to determine if multiple-resistance exists within select smallflower populations. Sample populations from previously-determined ALS cross-resistance patterns were self-pollinated and the progeny were subjected to dose-response studies with the ALS-inhibitors Londax (bensulfuron), Halomax (halosulfuron), Regiment (bispyribac), and Granite (penoxsulam), at rates ranging from 0.1875x to 12x label rate for resistant populations, and from 0.05x to 1.5x for a known susceptible population. In addition, these populations were screened at 0.5x, 1x, and 3x field rates for multiple resistance to Stam (propanil), Shark (carfentrazone), and Abolish (thionbencarb).

Dose response study confirms that one population is strongly resistant to all of the ALS inhibitors used in the study, regardless of application rate. This resistance is possibly due to a mutation causing insensitivity to the target enzyme. Another population is strongly resistant to each ALS inhibitor *except* Halomax, to which it is susceptible at 0.375x field rate. All other populations' tolerance/ resistance appears to be dose-dependent, and likely due to nontarget-site mechanism(s).

Multiple-resistance study indicates that none of the tested populations were tolerant/ resistant to Shark or Abolish, however many appear to have a dose-dependent tolerance to Stam. When treated with Stam, all populations but one had <50% mortality at the 0.5x rate, three populations had <50% mortality at the 1x rate, and all populations had >80% mortality when treated with Stam at 3x field rate.

Future research will seek to uncover the precise mechanisms of ALS resistance in these populations.

EFFECTS OF PLANTING DEPTH ON RICE CULTIVAR RESPONSE

❖ A. Ceseski, K. Al-Khatib, UCD

Decades of reliance on few herbicides for weed control have resulted in widespread proliferation of herbicide-resistant biotypes in the region. Managing resistance while maintaining economically viable yields is becoming increasingly difficult for some growers. Research is underway to refine a program of dry-seeding rice in which the seed is drilled below the surface-weed seedbank and is flush-irrigated for 4-5 weeks before establishing flood. This *preplanted stale-seedbed* technique delays crop emergence and should allow most grasses to be controlled by glyphosate or other economical broad-spectrum herbicides.

Greenhouse trials were conducted at the Rice Research Station and at University of California, Davis. Cultivars M-105, M-205, M-206, and M-209 were planted into draining plastic tubs to measure coleoptile vigor, emergence, and growth characteristics over a series of planting depths

The greenhouse studies indicate that at all depths, M-205 and M-209 had higher seedling vigor, higher emergence rates, and higher total emergence than M-105 and M-206. M-105 performed poorly at all depths below 1/2". When buried at 2”, M-105, M-205, M-206, and M-209 had 78%, 81%, 81% and 93% emergence, respectively. M-209 also reached 50% emergence 1-2 days earlier than M-206 and M-105 for most burial depths, and had an emergence window that was 1 1/2 days long at the 2” depth.

A field trial was conducted in 2018 to validate the growth and yield potential of M-206 and M-209 when drilled to 1-inch and 2-inch depths, and to evaluate the efficacy and crop-safety of a postplant/preemergent burndown glyphosate application.

Field results indicate that when applied just as rice is spiking, glyphosate can control over 60% of watergrasses, without sustained crop injury or yield penalty. In contrast to greenhouse findings, both cultivars began to emerge at 7 DAP, regardless of planting depth. Heading time for both cultivars was not affected by depth, with M-206 and M-209 reaching 50% heading at 75DAP and 83DAP, respectively. Yields for both cultivars were not affected by depth, with M-206 yielding 9,100 lb/ac and M-209 yielding 10,900 lb/ac. 2019 field trial with identical protocols is underway.

FLOODING DEPTH AND BURIAL EFFECT ON EMERGENCE OF FIVE CALIFORNIA WEEDY RICE BIOTYPES

❖ L. Galvin, D. Inci, W. Brim-DeForest, M. Mesgaran, K. Al-Khatib, UCD and UCCE

Weedy rice (*Oryza sativa*), a common pest in other rice growing regions of the world, has recently become a concern in California rice production systems. There are five genetically distinct weedy rice types that are unique to California and difficult to detect due to the physical similarities with cultivated rice. There are currently no herbicides available for controlling weedy rice in California. Despite this, understanding early season growth habits of weedy rice is imperative for creating effective control strategies in the future. To fill these knowledge gaps, an emergence experiment was conducted under controlled conditions to analyze the effects from flooding and tillage. Treatment combinations of four flooding depths at 0, 5, 10, and 15 cm (0, 2, 4, and 6 inches) as well as four burial depths, 1.25, 2.5, 5, and 10 cm (0.5, 1, 2, 4 inches), were applied in combination to the five weedy rice types, simply referred to as Types 1, 2 ,3 ,4, 5, as well as M-206 for comparison. Results showed that burial depth played the most significant role in reducing emergence; none of the rice types, including M206, were able to successfully emerge from depths at or below 5 cm (2 inches). Flooding depths greater than 10 cm (4 inches) significantly decreased emergence, but not to the extent of deep burial depths. M-206 had similar emergence patterns compared with types 1 and 2, types 3 and 5 had more emergence compared to the control, and type 4 had significantly less emergence compared with all other rice accessions. Despite these similarities, dry weight analysis indicated that all weedy rice types, with the exception of type 4, had significantly more biomass compared with M-206. Even though growers are unable to control the burial depth of weedy rice, this information could be incorporated into future control strategies. Additionally, the UCANR recommendations to keep continuous floods of 4-8 inches should help reduce weedy rice pressures, but will not eliminate this pest.

SURVEY OF BEARDED SPRANGLETOP RESPONSE TO CLOMAZONE IN CALIFORNIA RICE

❖ K. Driver, K. Al-Khatib, A. Godar, UCD

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

LEPTOCHLOA ACUMINATA FLOODING TOLERANCE IN CALIFORNIA WATER SEEDED RICE

❖ K. Driver, K. Al-Khatib, UCD

Bearded sprangletop (*Leptochloa acuminata)* is a problematic weed in California rice production. Flooding was thought to suppress bearded sprangletop germination, emergence, and growth; however after many years of continuous rice production, anecdotal evidence suggests that bearded sprangletop populations can tolerate flood pressures. A study was conducted over two years at the Rice Research Station in Biggs, CA to test the flooding tolerance of two bearded sprangletop populations against three irrigation depths. The study implemented a split block factorial design with sprangletop population being factor 1 and irrigation method being factor 2. The irrigation methods were 1) 5 cm flood; 2) 10 cm continuous flood and; 3) 20 cm continuous flood. The two bearded sprangletop populations tested consisted of one clomazone resistant and one susceptible population. There was no emergence of bearded sprangletop in the 20 cm flood depth of either population. Both populations emerged in the 5 cm flood depth. With a 10 cm flood, only the resistant population survived flooding pressure and produced significantly more tillers and seed than any other treatment-population combination tested. This suggests that there may be a fitness advantage related to clomazone resistance and that populations of bearded sprangletop have adapted to flood pressure.

EFFECT OF FERTILIZER APPLICATION RATES ON NUISANCE ALGAL GROWTH IN CALIFORNIA RICE

❖ S. Ohadi, J. Madsen, K. Al-Khatib, UCD

The early season rapid growth of nuisance algae in water-seeded California rice can interfere with the establishment of newly emerged rice seedlings. This rapid growth of algae is stimulated by the presence of nutrients in the water; adaptation of fertilizer management practices may reduce the negative effects of the algae on the early establishment of rice. A field and two controlled experiments were conducted to understand the responses of the algae growth to the amount of nitrogen (urea) and phosphorus (triple super phosphate) during the summer 2018. The field experiment was set up using PVC pipes (80 cm diameter), inserted into the soil and algae coverage were visually scored every second day for a month during the field experiment. In the controlled experiments, 19 L buckets were utilized as experimental unit and algae fresh and dry biomass and water chlorophyll a content were measured during the two weeks of experiment. Nitrogen was applied at 0, 50 and 150 kgh-1 at field experiment and at 0, 60, 120, 180, 240 and 300 kg ha-1 in controlled experiment in combination with phosphorus rates of 0, 35 and 75 kg ha-1 under field conditions and 0, 20, 40, 60, 80 and 100 kg ha-1 in the controlled experiment, respectively. The growth of algae was maximal when the two fertilizers were applied together (75: 150 N: P kg ha-1) under the field. On the contrary, the increased growth of algae were only stimulated by each fertilizer separately and not their interaction under the controlled condition. The initial results suggest that manipulation of the amount of fertilizer may change the growth of algae; however, such a change could be environmentally controlled. Further studies are needed for a better understating of the algae growth dynamics and its impact on rice seedling establishment.

EVALUATING DIFFERENT ALGAECIDES FOR CONTROLLING EARLY BLOOM OF THE ALGAE IN FLOODED RICE

❖ S. Ohadi, A. Godar, K. Al-Khatib, UCD

California rice production is challenged by nuisance algae in the beginning of the growing season. Rapid, early formation of algal mats at the time of flooding can prevent the establishment of newly emerged rice seedlings. The conventional method for controlling algae, i.e. the aerial application of copper sulfate, fails to consistently provide satisfactory results perhaps because the method of application (aerial) is suboptimal, selection of algae species in the flooded rice that have innate tolerance to the chemistry, or any combination thereof. Two bucket experiments (ten chemicals) and one field study (five chemicals). were conducted during the summer 2018 and ten chemicals with possible algaecide activity were tested. The chemicals were: test including Cutrine-Plus (a.i. copper ethanolamine complex), Cutrine-Ultra (a.i. copper ethanolamine complex), liquid peroxide (a.i. hydrogen peroxide), Goal 2XL (a.i. oxyfluorfen), Ronstar (Oxydiazone), Algimycin (a.i. chelated copper), Algimicyn+ AMP surfactant, liquid peroxide+AMP , zinc sulfate and elemental copper (blue stone). In the bucket study, algae were collected from the field and inoculated to the buckets one week before algaecide application. Chlorophyll *a* content of water, fresh and dry biomass of algae were measured every second day for 14 days. The results showed that chelated copper (Algimicyn) had the highest algae control (85.5%), followed by Protox herbicides (Goal2XL and Ronstar) (70%). Blue stone copper, Cutrine-Plus and Cutrine-Ultra controlled algae similarly (50-70%). Hydrogen peroxide only controlled algae by 50% and its efficacy dropped dramatically five days after treatment. Zinc sulfate was only effective at 1 DAT and algae recovered rapidly after that. The field experiment was conducted in the 3x3 ft plots. Fertilizer were minimally incorporated to the soil to stimulate uniform growth of algae. all the chemicals, except Goal 2XL, were applied at the time of the algae bloom (two days after flooding the field). Goal 2XL was applied three days before flooding to the soil surface as pre-emergence. Visual observations were taken every second day on the algae coverage at the water surface and scored from 0 (no algae coverage) to 100% (full coverage of the water surface). The maximum algae control (96%) was observed with the pre-emergence application of Goal 2XL while zinc sulfate gave the lowest algae control (21%) at 24 hours after algaecide application. Cutrine-Plus (70%), Cutrine-Ultra (60%) and liquid peroxide (60%) provided similar level of algae control while outperforming copper sulfate application (47%). The fastest algae recovery was observed in Cutrine-Ultra and Cutrine-Plus treated plots while the algae coverage in other treatments remained low even eight days after algaecide treatment. Rice was able to establish in all the algaecide treatments except Goal 2XL which severely damaged the rice crop. All the tested algaecides have the potential to reduce the early bloom of algae, however, further investigation is needed to determine the optimal time of application and their effects on rice.

MANAGEMENT OF TADPOLE SHRIMP WITH INSECTICIDES

❖ L. Espino, C. Sheppard, UCCE

Six insecticides were tested for control of tadpole shrimp (TPS) in leveed plots. Plots were seeded 3 days after plots were flooded (5 days after flood water was started). Not all plots developed TPS, so two 5x6.25x4.5 inch cages per plot were infested with 10 TPS 1 day before treatments. All treatments were applied 6 days after plots were flooded, and average TPS shell length of introduced shrimp was 4.1 mm. Complete control of TPS one day after treatments were applied was obtained with Warrior at 2.56 oz/a, Dimilin at 4 oz/a, Dimilin at 8 oz/a, Belay at 2 oz/a, and Sevin at 1.5 qt /a. In prior years, Dimilin at 4 oz/a had not kill all shrimp after 1 day, most likely because treatments then were applied to larger TPS.

All products labeled for TPS in this trial were effectively controlled shrimp quickly. In instances were TPS may be developing a tolerance to pyrethroids, Dimilin, Sevin, and Belay are effective alternatives for growers. Sodium Ferric EDTA, a product used against snails and slugs, was tested this year. While the shrimp were affected by the product, it did not completely control TPS in the cages and did not lower the natural population of TPS in plots.

INSECTICIDE TRIALS FOR ARMYWORM CONTROL

❖ L. Espino, C. Sheppard, I. Grettenberger, UCCE and UCD

Several insecticides were tested for armyworm control in a commercial rice field in 10x20 ft plots, replicated four times. Armyworm populations were evaluated before treatments were made, and 3, 5, and 7 days after treatment. To evaluate the armyworm infestation, four, 1-ft^2 quadrants per plot were thoroughly inspected and the number of larvae found recorded.

Larvae were identified as true armyworm. On average, the plots had an infestation of 3 larvae/ft^2 and were between the 4th and 5th instar before treatments were made. Overall, the population in the field was declining, most likely due to parasitism and pathogens affecting the larvae. The larval density in untreated plots reached 72% one week after treatments were made.

Larval mortality for each date and treatment was obtained by comparing the number of larvae surviving each treatment to the number of live larvae in untreated plots on each date. Plots treated with Intrepid at 10 oz/a and Prevathon at 14 oz/a reached 100% larval mortality 7 days after treatment. Coragen applied to the foliage at 3.5 oz/a, Dimilin at 8 oz/a, and Dipel at 1 lb/a produced between 80-90% larval mortality 7 days after treatment. Warrior at 2.56 oz/a and SpearLep at 2 pints/a + Dipel at 1 lb/a produced between 50-60% larval mortality.

METHYLMERCURY DYNAMICS IN SACRAMENTO VALLEY RICE FIELDS RECEIVING RECYCLED IRRIGATION WATER

❖ L. Salvato, M. Marvin-DiPasquale, J. Fleck, S. McCord, B. Linquist, UCD

In California, there is a high concentration of environmental mercury due to legacy mercury and gold mining. In anaerobic soils typical of flooded, wetland environments, inorganic mercury can be methylated by sulfate and iron reducing bacteria to form Methylmercury (MeHg), a pollutant known to cause neurological problems and reduced reproductive success in organisms in mercury contaminated ecosystems. Rice in CA is typically grown in flooded, agricultural wetlands that are known to stimulate the production of sulfate and iron reducing bacteria, however little is known about MeHg dynamics in rice fields. Surface water MeHg and total Hg (THg) imports, exports, and storage were studied in six commercial rice fields in the Sacramento Valley. Mercury loads from rice fields in the Sacramento Valley are much lower than in Delta rice systems, and Hg in soils and irrigation water in Sacramento Valley rice fields are lower than in the Yolo Bypass and Consumnes River preserve, where much of the previous work was conducted. The fallow winter season is a peak period of MeHg export from rice fields (consistent with studies in Cosumnes River Preserve and Yolo Bypass). Fields receiving recycled water were annual sources of MeHg, while fields receiving fresh water were annual sinks. The release of sediment bound MeHg into overlying water could be a primary driver for higher MeHg concentrations in the field and outlet water, relative to the lower inlet concentrations.

MEASURING AND MODELING NITROGEN LOSSES FROM AQUA AMMONIA FERTILIZER DURING DRY DOWN PERIODS IN CONVENTIONAL CALIFORNIA RICE PRODUCTION SYSTEMS

❖ B. Linquist, P. Geoghan, UCD

Dry-seeding, an uncommon management practice in California rice production systems, presents challenges with regard to nitrogen (N) fertilizer management. Some growers utilizing this system are applying N fertilizer in the form of sub-surface aqua ammonia before planting, as is common in water-seeded systems. In dry-seeded systems, fields are typically flush irrigated during the first three to four weeks before a permanent flood is established. These flushing events result in soils alternating between flooded (anaerobic) and unflooded (aerobic) conditions, and the conversion of soils to aerobic conditions promotes nitrification (conversion of ammonium to nitrate). Since newly germinated rice crops have little to no demand for N, much of this nitrified N is likely lost as N2 gas via denitrification when fields are flushed again or moved to a permanent flood. Earlier studies in California have shown up to a 50% loss in applied preseason sub-surface N, as a result of these dry down events. Unfortunately, it is currently difficult to know how much N is lost in a particular field, which is dependent on soil moisture, temperature, and various soil properties during the dry down events. This uncertainty for growers potentially leads to high variability in the amount of top dress fertilizer that growers apply to compensate for these losses later in the season.

To understand how these dry down periods affect nitrification, N2O emissions, and denitrification rates, we manipulated flooding at two sites using PVC rings to create two treatments to test: continuously flooded and drained during two dry down events at each site, lasting no longer than 10 days. Soil samples were collected and analyzed for ammonia and nitrate concentrations. Controlled experiments in the laboratory, mimicking conditions in rice fields during the dry down periods will be utilized to create a model to further enhance growers' ability to more accurately compensate for N losses. To measure the amount of N2O emissions caused by these dry down events, greenhouse gas (GHG) sampling is being conducted at one of the field sites in 2019 and will be replicated in the laboratory experiment. Through this study we hope to provide farmers with tools in the form of a model to predict N loss and optimize their N fertilizer management for maximum yield outputs while minimizing impacts these fertilizers have on the environment. Data from this study will also provide information on potential aqua-ammonia losses early in the season in conventional systems where soils are drained (intentionally or otherwise) to allow growers to make more informed decisions on how to correct for these N losses.

THE EFFECTS OF MIDSEASON DRAINAGE ON GREENHOUSE GAS EMISSIONS AND YIELD IN CALIFORNIA RICE SYSTEMS

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Rice (*Oryza sativa L.*) cultivation is a tremendously important part of global food security, yet it is also responsible for a significant portion of agricultural greenhouse gas (GHG) emissions. Midseason drainage of flooded rice fields is known to significantly decrease GHG emissions but its effect on grain yield is quite variable. In this two-year study, we aimed to measure the effect of severity and timing of midseason drains on GHG emissions without compromising grain yield. In 2017 treatments included High (HS), Medium (MS), and Low Severity (LS) drains, all of which started relatively early in the growing season, i.e. before panicle initiation (PI). 2018 treatments included one LS and two HS drains, one of which started before PI and another which began after PI. Methane (CH4) and nitrous oxide (N2O) emissions, soil nitrogen, grain yield, and yield components were measured. In order to monitor drain severity, several soil moisture parameters were monitored including volumetric water content, perched water table, gravimetric water content, and soil water potential. Across both years, midseason drainage reduced seasonal CH4 emissions by 8-67%, and N2O emissions were quite minor (average = 0.018 kg N2O-N/ha), as they accounted for only 0.2% of the seasonal global warming potential (GWP) across all drainage treatments. Within each year grain yield of drainage treatments also did not significantly differ from that of continuously flooded (CF) control treatments. These results indicate that midseason drainage of flooded California rice fields is a viable GHG mitigation practice with low overall risk for decreased yield.

THE EFFECTS OF FERTILIZER SOURCES AND PLACEMENTS ON AMMONIA VOLATILIZATION LOSSES FROM WATER-SEEDED RICE SYSTEMS IN SACRAMENTO VALLEY

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One of the main pathways of nitrogen losses from rice production systems is via ammonia volatilization, which results in lower nitrogen use efficiency and causes other environmental problems including eutrophication and air quality concern. There are many factors affecting ammonia volatilization from rice system including N-fertilizer source, placement, soil properties, air and soil temperature, and wind speed. Little is known about ammonia volatilization in typical commercial rice production systems in California. Therefore, ten field experiments were conducted in the 2017-2018 growing seasons to investigate ammonia volatilization from injected Aqua ammonia, banded Urea, and broadcasted Urea during a basal preplant application (150 IbN/acre) for a duration of about two weeks after field flooding. Furthermore, ammonia volatilization from topdressing applications of Urea and Ammonium sulfate (30 lb-N/acre rate) at around panicle initiation stage was measured for a duration of 7 days post application. Results show that nitrogen losses via ammonia volatilization from nitrogen basal broadcasted Urea were significantly higher than other treatments, but only accounted for less than 2% of total N-applied. Losses from injected Aqua ammonia and banded Urea were minimal and not significantly different from the control treatment (No N-applied). All observed losses occurred in the first 7-day after flooding. Ammonia volatilization losses from top-dressing applications were 1.49 % and 2.60% of N-applied from Urea and Ammonium sulfate respectively. Our results suggest that using injected Aqua ammonia at preplant and either Urea or Ammonium sulfate as topdressing is the best fertilizer management practice as there is little concern of nitrogen losses via ammonia volatilization.

USING DRONE TECHNOLOGY TO GUIDE MIDSEASON NITROGEN FERTILIZER APPLICATIONS

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Determining when to apply top-dress N fertilizer remains a challenge for California rice growers. Some tools are available to guide fertilizer decisions, such as the leaf color chart and SPAD chlorophyll meter, but these technologies have limited adoption as they are time consuming and cumbersome. The recent development of drone-based techniques; however, has provided an alternative method to quickly assess N status of an entire field. Drones with specialized cameras are flown over the crop to measure how much light is reflecting off the canopy, which can then be used to calculate a vegetative index such as the normalized difference red-edge (NDRE). The objective of this study is to evaluate the potential of NDRE to guide midseason N fertilizer applications. Specifically, our goal is to develop a 'response-index' capable of predicting the grain yield response to adding top-dress N fertilizer across a range of NDRE values. Eleven N rate experiments were established during the 2017 to 2019 growing season according to a split-plot randomized complete block design with main plot treatments being the varying rates of preplant N fertilizer ranging from 0-210 lbs N ac^{-1} (aqua ammonia injected into the soil), and subplot treatments being topdress N fertilizer at rates of 0 or 30 lbs N ac^{-1} (ammonium sulfate broadcast by hand at panicle initiation). Our results indicate that NDRE measurements taken at panicle initiation stage correlate strongly with rice N status. Furthermore, a NDRE based response-index value of 1.1 or greater indicates that the crop is likely to exhibit a positive yield response to top-dress fertilizer. These findings suggest that drone-based technologies have the potential to guide midseason nitrogen fertilizer applications.

IDENTIFICATION OF NOVEL MUTATIONS IN GENES INVOLVED IN SILICON AND ARSENIC UPTAKE AND ACCUMULATION IN RICE

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

FIELD TOURS OF RESEARCH

RES Rice Breeding Program

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Introduction

The RES Breeding Program develops improved rice varieties of 3 major rice grain types: 1) Medium Grains, 2) Short Grains, and 3) Long Grains. In the medium grains, the aim is to develop superior Calrose rice varieties with high and stable grain yield, with superior quality, improved seedling vigor, wide adaptability, cold tolerance and disease resistance, as well as premium medium grains or M-401 types. Breeding for short grains includes regular and premium short grains, waxy-type or sweet rice, low amylose-types, and Arborio-type or bold grains. In the long grains, high yielding and superior quality conventional long grains and specialty types that include long grain aromatics, Jasmine-type, and Basmati-type rice are being developed.

By grain type, the breeding program was distributed approximately 60% medium grains, 18% long grains and 22% short grains. About half of the breeding materials are conventional types (conventional medium, short and long grains) and half are specialty types (aromatics, Basmati, Jasmine, low amylose, waxy, bold grains and premium quality types).

Rice breeding for all grain types at RES is overseen by a Director of Plant Breeding who also supervises two full-time rice breeders. Five breeding assistants perform data collection activities, crossing work, and supervise seasonal workers hired to plant and harvest assorted breeding nurseries. The breeding program is supported by a DNA Marker Laboratory which generate molecular marker data for marker-assisted selection and DNA fingerprinting of rice materials. The DNA marker lab is led by a research scientist and assisted by a lab technician and is also under the supervision of the Director of Plant Breeding.

The major breeding objectives of the RES Rice Breeding Program are as follows:

1. High and stable yield potential
2. Superior grain quality and milling yields
3. Improved cold tolerance and seedling vigor
4. Improved straw strength and early maturity
5. Blast and stem rot resistance
6. Herbicide tolerance

The RES breeding nurseries are comprised of transplanted F_1 nursery, dry-seeded F_2 populations and seed maintenance plots, water-seeded F_3 to F_4 progeny rows, water-seeded replicated preliminary yield (PYT) and advanced yield (AYT) tests (10'x10' and 10'x20'), Statewide Yield Test (SW) at RES (10'x20'), milling plots and cooking strips, preliminary and foundation seed head rows, off-station nursery in San Joaquin (cold location nursery) and Hawaii (Winter Nursery), and cold tolerance screening in refrigerated greenhouse.

Due to late rainfall in mid-May of 2019, planting of nurseries spanned three weeks. Planting started in May 3 and finished by May 24. Wet-seeding planting of the main nurseries at RES comprising of preliminary and advanced yield plots, F_3 and more advanced progeny rows started on May 13 and continued until May 24. The F2 nursery was drill-seeded from May 3 to May 5 while the seed maintenance nurseries and milling plots were drill-seeded from the May 13 to May 14. The second-date planting was not planted this year, composed mainly of preliminary and advanced yield plots.

Performance of RES rice varieties in 2018 yield tests

Medium Grain Varieties

Varieties that are in commercial production in California such as M-105, M-205, M-206, M-209, M-210 and M-104 are being used as checks in experiments for Preliminary Yield (PY), Advanced Yield (AY), and preliminary and advanced Statewide (SW) Tests by University of California Cooperative Extension (UCCE). M-209, a released variety in 2015, continued to be the top yielding check variety with an average grain yield of 10,040 lbs./acre compared to M-206 and M-205 yields of 9,290 and 9,240 lbs./acre, respectively. For the last six years, the grain yield performance of M-209 at RES was better than both M-206 and M-205. It is adapted in warmer areas or where M-205 is successfully grown. However, it may not perform well in cooler areas like San Joaquin County. M-209 is lodging resistant and 3cm shorter than M-206. Among the check varieties, M-104 had the lowest yield (7,960 lbs./acre). M-210, a blast-resistant medium grain released in 2018 registered an average yield of 9,090 lbs./acre

Short Grain Varieties

Check varieties used in various yield tests include: S-102, Calhikari-201 (CH-201), Calhikari-202 (CH-202), Calmochi-101 (CM-101), Calmochi-203 (CM-203), Calamylow-201 (CA-201), and an Arborio-type germplasm line 89Y235. In all experiments and evaluations, the grain yield of CM-203 was the highest at 9,430 lbs./acre followed by CH-202 at 8,390 lbs./acre, while the yield of CA-201 was the lowest at 6,440 lbs./acre. The grain yield of S-102 and CH-201 were 8,190 lbs./acre and 8,200 lbs./acre, respectively.

Long Grain Varieties

Long grain check varieties include: L-207, L-206, Calaroma-201 (CJ-201), and A-202 for grain yield and agronomic performance in various yield tests. Grain yield of L-207, the new regular long grain variety released in 2016, was 10,200 lbs./acre compared to 9,690 lbs./acre for L206. The aromatic long grains A-202 released in 2014 and a Jasmine-type long grain, CJ-201 released in 2018 registered yields of 10,610 and 9,310 lbs./acre respectively. L-207 headed at 77 days after sowing, which is 3 days later than L-206 and two days earlier than CJ-201, with plant height taller by 18 cm without any lodging penalty.

New short grain variety released in 2019

S-202 (Conventional Short Grain)

S-202 (formerly designated 10Y2043) is a very high-yielding, early-maturing, semi-dwarf, temperate Japonica, conventional short grain type developed using the pedigree breeding method. It is a complex cross made in the spring of 2004 with the cross designation R29273 at the Rice Experiment Station in Biggs, CA. The pedigree of S-202 is“84Y254//M102/85Y13/3/DENGYU1/88Y013/4/84Y25/85Y013 //Calpearl/CM-101/3/S-102”. S-202 is an excellent alternative to S-102 in terms of grain yield and quality, and is acceptable to the short grains market as indicated in the internal and external quality evaluations.

Based on average result of Statewide Tests from 2015 to 2018, S-202 consistently outperformed S-102 across the state, with an average yield of 10,185 lbs./acre, and an average yield advantage of 16% over S-102 for three years. Seedling vigor of S-202 is similar to S-102, but the plant height is shorter by 4 cm on average. Lodging resistance is similar in both varieties, except in Butte, Glenn and Sutter trials. In all locations, S-202 requires an average of 83 days to flower, which is 2 days later than S-102 on average.

The grains of S-202 are smaller and lighter compared to S-102. The 1000-grain weight of S-202 milled rice is 21.1 grams compared to 25.3 grams for S-102. It is shorter (length=5.11 vs. 5.4 mm) and narrower (width=3.04 vs. 3.20 mm) but with a similar length/width ratio of 1.68.

The total milled and head rice percentage of S-202 and S-102 were taken at varying harvest moistures in 2018 milling plots. In 2018, milling yield at 16-19% moisture content of S-202 was 52/70 while S-102 was 52/68.

S-202 has a lower amylose content than S-102 with values of 14.4% and 16%, respectively. The protein contents of both brown and white rice of S-202 are higher by 1.3% than S-102.

S-202 showed higher cold tolerance than S-102, as reflected in its lower percent blanking (1.46 %) when compared to S-102 (1.96%). Greenhouse experiments suggest that both S-102 and S-202 have comparable levels of blanking.

Disease reactions of S-202 and S-102 to stem rot (SR), aggregate sheath spots (ASS), and blast (BL) were documented for several years. On average, both S-102 and S-202 are susceptible to stem rot, and moderately tolerant to ASS and blast diseases.

Promising advanced lines

12Y2175 (Medium Grain)

A medium grain advanced line, 12Y2175, is a line derived from a cross between M-206 and 06Y026 in 2007. Some notable parents in its pedigree are M-203 and M-205, which are early-flowering, high-yielding medium grain varieties, and M-401, a premium medium grain rice. The 12Y2175 has been in the statewide yield tests since 2013 and has consistently showed yield advantage over M-206, M-205, and M-209. Grain quality is and taste attributes are superior to Calrose-type medium grains and close to quality attributes of M-401 if not for the grain size.

In the Statewide tests, 12Y2175 reached 50% heading at 80 days which is 7 days later than M-105, but nearly the same as M-209. It is 3 cm taller than M-105 but 1-2 cm shorter than M-206 and M-209. It has better lodging resistance than M-105 in the early SW Tests. 12Y2175 has an average yield of 10,740 lbs./acre at RES and a pooled mean of 9680 lbs./acre in the SW Tests. In the late-intermediate group, 12Y2175 yielded 11,420 lbs./acre at RES and 10,960 lbs./acre at SW Tests. Overall, 12Y2175 had an excellent performance in 2018 with yield advantage of 10-21% over M-105, 9-19% over M-206 and 9% over M-209. The seedling vigor of 12Y2175 is similar to all check varieties. On average, 12Y2175 heads in 81 days, stands 5 cm taller than M-105 and M-209, lodging resistant (3.3%), but slightly more sensitive to cold stress compared to check varieties, and is susceptible to stem rot.

14Y1006 (Conventional Long Grain)

A conventional long grain designated as 14Y1006 is an early maturing sister line of L-207with superior agronomic and yield attributes. The line was evaluated in three SW maturity groups. In the very early SW Tests at RES, 14Y1006 has an average yield of 10,620 lbs./acre compared to 9,770 lbs./acre and 9,900 lbs./acre for L-206 and L-207, respectively. It heads in 73 days after planting, which is 2 days earlier than L-206, with plant height of 97 cm. In the early SW at RES, 14Y1006 yielded 10,990 lbs./acre, and consistently showed higher yield than L-206 with a mean yield of 9750 lbs./acre. Compared to L-207, it has a slightly higher yield with a mean yield of 10,120 lbs./acre. In the intermediate-late SW group tests, 14Y1006 showed better yield than L-206 and L-207. 14Y1006 is considered lodging resistant with 4% lodging percentage and also cold resistant with 4.7% blanking.

Milling yield of 14Y1006 is similar to L-207, and grains are less chalky. Internal evaluation of cooked 14Y1006 indicates favorable and similar texture to L-207. Based on RES experiments in 2018, the milled rice kernels of 14Y1006 has a 1000-kernel weight of 20.67 grams compared to 20.79 and 22.13 grams for L-206 and L-207, respectively. Milled grains of 14Y1006 were shorter (7.20 mm) than L-206 (7.26 mm) and L-207 (7.49 mm) narrower than L-206 (2.16 mm) and similar to L-207 (2.09 mm wide). The milling yield of 14Y1006 when harvested at 17-19% moisture is 67/70 (head/total) compared to 63/70 and 64/71 for L-206 and L-207, respectively.

Basic Ongoing research

Marker Assisted Selection (MAS)

MAS for both blast resistance and grain quality is a routine work at the RES DNA Lab. The laboratory is capable of screening multiple blast resistance genes in a single PCR reaction through multiplexing. The lab is using microsatellite or simple sequence repeats (SSR) markers to screen for the presence or absence of specific blast resistance genes. Four single nucleotide polymorphisms (SNP) markers and one SSR marker are being used to predict the grain quality parameters in both the LG and MG programs for grain quality. A microsatellite is also being used to detect the presence of fragrance gene in our breeding materials. Two microsatellite markers were identified for MAS of oxyfluorfen tolerance in addition to allele-specific SNP markers. In 2018, about 1400 breeding materials and 400 headrows of 17Y3000 were analyzed in the DNA lab for herbicide tolerance using SNPs markers. Selected materials were advanced to the next generation.

Herbicide Tolerant Rice

The RES Breeding Program is making intensive efforts in breeding and genetics to develop herbicide tolerant rice California rice growers. ROXY ™ is a non-GM trait in rice that gives a high level of resistance to the PPO herbicide oxyfluorfen discovered at RES in 2013. An accelerated breeding approach has developed a second generation advanced line, 17Y3000 that is entering the second year in multiple location yield, quality, and efficacy testing with other materials close behind. The improved ROXY lines are being used for the efficacy and registration data being conducted with Albaugh in pursuit of registration of the herbicide ALB2023 for use on rice with the ROXY trait.

Genetic mapping has revealed that herbicide tolerance to oxyfluorfen is located in chromosome 5 between two SSR markers spanning about 950-kb fragment. Using fine mapping population of 1,116 individuals reduced the 950-kb to a 35 kb region containing 6 candidate genes. Sequencing of the mutant lines and further genetic analysis have allowed the identification of the gene responsible for the oxyfluorfen tolerance provide by the ROXY trait. Efforts to confirm the gene's activity are being continued by evaluating mutations in other rice germplasm and in other plant systems to see if they also confer tolerance to oxyfluorfen. These detailed investigations of the genetics of the ROXY trait by the DNA Marker Lab will be useful in understanding the tolerance mechanism, supporting the intellectual property protection, and the commercialization of the "ROXY Rice Production System" for rice growers.

Stem Rot Resistance

To validate the resistance response of RES breeding materials to stem rot, greenhouse and field experiments were conducted. The inoculum was propagated and prepared from 16K1d1 Butte isolate collected by Jeff Oster in 2011.

For the stem rot greenhouse experiment, 185 recombinant inbred lines (RILs) and 52 F_2 lines, developed from a cross between M-206 and 87Y550 were evaluated in randomized block design. The whole experiment was replicated three times with five plants per line. M-206 is susceptible to stem rot infection while 87Y550 is a resistant line. The plants were grown in pots following the standard soil fertilization. During the tillering stage around 40 days after planting, additional nitrogen was applied to enhance stem rot infection. On the 55-58th day, each plant was inoculated with approximately 2 ml of stem rot dust sclerotia. Disease development such as black lesions on the stems were observed 4-6 weeks after inoculation. Some blanking and lodging were also observed in susceptible lines.

Screening for stem rot resistance was also conducted in the field using the same batch of stem rot inoculum in the greenhouse experiment. A total of 3,600 rows including RILs, F_2, entries in advanced and statewide yield trials, and Uniform Rice Nursery (URN) materials from the South were evaluated for stem rot resistance.

Greenhouse evaluations indicated that out of 185 RILs, and 52 F_2 lines, only 26 RILs and four F_2 showed resistance to stem rot. However, only 3 of the 185 RILs were resistant to stem rot in the field. There was a low positive correlation (correlations of only 0.37) between results of greenhouse and field screening, indicating the complexity of disease. The data suggest that although greenhouse experiment may be conducted for stem rot screening, field conditions are better for disease development and evaluation for resistance. All variety checks in field evaluation are susceptible to stem rot except for CM101, which showed moderate stem rot resistance (scored 3). Among the AY and SW entries, 7 lines in the advanced yield trail showed resistance and scored between 2 to 2.3.

Blast Disease Resistance

The presence of rice blast disease in California is not well documented in the past years. Nevertheless, effort on incorporation of blast resistance to California rice varieties was initiated. In 2005 and 2006, M-207 and M-208 were released as blast resistant varieties, containing *Piz* resistance gene. However, in 2009, M-208 succumbed to a new race of blast. This prompted the CCRRF to continue the effort in breeding rice for blast resistance. By backcrossing, several blast resistance genes (*Pib, Pik*^{h}*, Pik*^{m}*, Piz*^{5}*, Pi9, Pi40,* and *Pi-ta*^{2}) were introduced to M-206. In 2018, one of the near-isogenic lines of M-206 with a blast resistance gene, *Pi-b*, was released as a blast-resistant medium grain (M-210) to replace M-208. To prevent the spread of disease during screening, the use of DNA markers for selecting blast resistant lines has been successful and routinely used in the breeding program. These markers are also being used to pyramid blast resistance genes (*Pi40, Pik*^{h}, and *Pi-ta*^{2}) mostly in the medium grains.

Aggregate Sheath Spot Resistance

Development of resistance to aggregate sheath spot was initiated in 2005 by backcrossing the resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-206. Breeding lines developed in those crosses were advanced in the greenhouse and field. This year, greenhouse and field screening for aggregate sheath spot was not conducted due to the absence of a full time plant pathologist. Lines derived from the three donor parents are kept in the cold storage for future endeavor.

On the horizon

Building on the successes of the DNA Marker Laboratory, breeders and scientists at RES recognize the need to expand the capacity and capability of the lab to include basic genetics and genomics research and will be the foundation for the RES Genetics Laboratory under construction. Advances in genomics and its application in genetic selection has been a growing trend in successful breeding programs. More recently, the CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology has also been employed successfully in targeting important genes in rice. Employing these cutting-edge technologies requires investment in infrastructure and equipment, and utilizing the capabilities of recently hired breeders to enhance the research activities of RES in this decade and beyond. At the moment, the station has engaged in gene-editing work ONLY for experimental validation of oxyfluorfen tolerance gene in support of the ROXY™ trait patent. This non-GM technology offers great promise as a tool in future rice improvement.

Genomic selection

The majority of national and international rice breeding programs still use conventional breeding schemes. The pedigree method, which involves visual selection for several generations, takes so much effort and time. With the advancement of rice molecular genetics and genomics, MAS has been implemented in plant breeding programs. However, the overall efficiency of MAS to enhance breeding methods is still limited due to the small number of useable markers and the polygenic nature of most traits, which needs to be improved. A new approach called genomic selection (GS) showed enormous potential to enhance breeding efficiency by increasing the gain per selection per unit time. In this approach, instead of few tagged markers, genome-wide DNA markers are utilized to predict the most valuable lines in a breeding program to use as parents for next generation offspring, as well as in selection of progenies for quick advancement. By using genome-wide DNA markers, the GS model avoids ascertainment bias and information loss compared to MAS. Integrating GS in the RES rice breeding program will not only enhance the breeding efficiency, but also enhance genetic knowledge of rice for continued varietal improvement.

In 2018 a training population was developed to analyze the variability of all the advanced lines in the last five years. The training population size is 360, which consists of 210 medium grain type, 64 long grain, 73 short grain and 13 compound grain types. All released varieties of the RES are included in the training population, thus capturing all genetic diversity of the RES breeding program.

Weed Control in CA Rice: Evaluation of New Weed Control Products and Methodologies

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The UC Rice Weed Research Program at the Rice Experiment Station, Biggs, CA seeks to assist California rice growers in achieving their weed control and herbicide resistant management goals. This year's program focuses on the performance evaluation of new herbicides (including those under development) in mixtures and/or sequential combinations with existing herbicides primarily for continuously-flooded rice growing system but also include applications for drill-seeded rice. Highlights of this year's program include new techniques for reducing weed pressures as well as a demonstration of new modes of action incorporated into existing weed control programs.

Continuously flooded systems have historically been the most common rice production method in California due to the suppression of most competitive rice weeds including barnyardgrass, watergrass, and sprangletop. In this system, a water depth of 4 inches is maintained throughout the season after seeding rice into a flooded field. When late post-emergence foliar applications are needed, water depth is lowered to expose about two-thirds of weed foliage to the herbicide spray, but fields are never completely drained. Contrary to these traditional strategies, two techniques, a leather's method and a drill-seeded plot, will be demonstrated this year to determine whether these alternatives to continuous flooding have similar weed control.

This year the predominant weed species were late watergrass, ducksalad, ricefield bulrush, smallflower umbrella sedge, followed by barnyardgrass, monochoria, waterhyssop, redstem and sprangletop. All weeds evaluated in our program are susceptible to herbicides registered for California rice. Weed control efficacy of herbicide programs presented here primarily reflect the visual ratings (average of three or four replicates) 40 and/or 60 days after seeding (DAS). Rice injury (stand reduction, stunting, chlorosis, etc.) after herbicide application have also been noted wherever relevant.

Butte-Based Programs

This is the second year that Butte® has been available to California rice growers. Butte® is a granular mixture of benzobicyclon and halosulfuron active ingredients developed by Gowan Company. The benzobiclyclon component of Butte® adds a new mode of action (HPPD-inhibitor) to the herbicide portfolio for water-seeded rice in California and is meant to provide control for broadleaf weeds, grasses and sedges. Previous studies suggest that Butte® provides good broad spectrum weed control, however, there is great need to consider using Butte in combination with other herbicide such as Clincher, Cerano, Granite, propanil, and Regiment to specifically improve grass weed control. This year weed control efficacy of Butte was tested in programs followed by Regiment, Granite GR, Granite SC, and SuperWham mixed with Grandstand CA. The combination of Butte® followed by other herbicides has provided good weed control results this field season.

Pyraclonil Herbicide Programs

Pyraclonil, a PPO-inhibitor, is a granular formulation currently under development for weed control in CA rice by Nichino America, Inc. PPO-inhibitors are a new mode of action available for CA rice growers, and pyraclonil should provide good control for broadleaf weeds, grasses and sedges. Previous studies demonstrated that pyraclonil would be best used as part of a comprehensive weed control program, but demonstrations include this herbicide as a stand-alone product. This year pyraclonil was applied as a part of programs which included Butte, Cerano, Bolero, Regiment, Granite GR, and Loyant. Results showed outstanding weed control including smallflower umbrella sedge and broadleaf weeds. Additionally, rice did not show signs of injury from pyraclonil.

Loyant Incorporated Programs

Loyant (florpyrauxifen-benzyl) is being developed by Corteva Agriscience and is a post-emergence herbicide in liquid formulation meant to control broadleaf weeds, grasses and sedges. Loyant is an auxin type herbicide, representing a mode of action that currently does not have any known resistant weeds in CA rice. This year Loyant was used in programs with Clincher, Granite, RebelEX, Cerano, Bolero, and Butte. When applied alone, this herbicide provides good weed control outcomes, but seems to be the most effective as an addition to existing programs. For example, applications with Loyant plus Granite provided near complete weed control.

Combined Fungicide and Herbicide Applications

Many growers use propanil (SuperWham, Stam) as a post emergent herbicide to reduce weed pressures in their fields. Propanil is a photosystem II inhibitor that will control grasses and sedges after the crop has been established. Around the time of propanil application, many growers are also applying fungicides such as Stratego (propiconazole, trifloxystrobin), Quadris (azoxystrobin), and Tilt (propiconazole), all of which are liquid, broad-spectrum disease control chemistries. However, there is uncertainty as to whether or not propanil application combined with these fungicides can cause crop injury. Previous studies demonstrated that carbamate insecticide application tanked mixed with propanil can cause crop injury, so there has been speculation regarding fungicide-propanil effect on rice. The objective of this study is to determine if crop injury is occurring with combined application of fungicides and propanil formulations. Results showed that all tank mixed fungicides with propanil was safe on rice.

Timing of Weed Control after Leather's Method

Leather's method is used in water-seeded systems by draining the field within the first few days after seeding and reflooding→ once the crop has established shallow roots, roughly 1 week after seeding. This allows for good crop establishment and rooting, but also allows weeds the opportunity to become highly competitive with adequate moisture for germination and low water depths for emergence and rapid development. Many growers use Cerano (clomazone), a micro encapsulated granule, to control sprangletop, barnyardgrass by way of carotenoid biosynthesis which causes bleaching symptoms. Cerano has a day of seeding application timing with a 14-day water holding period once applied to a field. However, if growers are using a Leather's method, it is not possible to use Cerano because of the labeled water holding requirements. In this study Cerano was applied at the day of seeding and well as after a Leather's method, ~7DAS, to determine if there was adequate weed control as well as any crop damage. In general, Cerano applied after leathering accentuated injury on rice.

Rating Drill-Seeded Program for Weed Control Efficacy

This season saw continued field validation of weed control options and crop response when rice is drill-seeded to a 1" or greater depth. The strategy behind deep drilling is to place the rice seed below the zone of weed germination and emergence. This technique should delay stand emergence and allows for a burndown application of an economical broad-spectrum herbicide, such as glyphosate, to control the majority of grasses and sedges. The use of glyphosate can also aid in management of weeds that are resistant to common rice herbicides. This program relies on flush irrigation for the first few weeks, which inhibits broadleaf weeds and may also provide some water savings. In addition, foliar herbicide efficacy should be increased under early season flushing, as more of the weed leaf surface is exposed.

The current study uses M-206 and M-209 planted at 1" and 2" depths. Herbicide programs include a post plant, pre-emergence glyphosate burndown, followed by Regiment and either Prowl or Command (the liquid formulation of clomazone) for late season weed inhibition, and an application of Clincher for sprangletop. Results show excellent weed control for all treatments in 2018 and 2019. Yields for both cultivars were similar to local averages in 2018 with no depth dependent difference in yields; stand measurements for 2019 suggest similar results for the current field season.

Managing Nitrogen Fertilizer

Bruce Linquist, J. Ray Stogsdill, Peter Geoghan, and Telha Rehman, UCCE & UC

Assessing mid-season plant N needs

We generally recommend applying all the N fertility requirements for an average yielding year at the start of the season. This N is applied as either aqua-ammonia or as part of a starter fertilizer blend (the starter blend can be applied up to 4 weeks after planting if algae/scum is a problem). At panicle initiation (PI - about 45-55 days after planting), the crop should be accessed to determine if a top-dress of nitrogen fertilizer is necessary. A good assessment is important because not applying N when needed can lead to a reduction in yield; however applying N fertilizer when it is not needed can lead to lodging, delayed maturity, increased incidence of disease and reduced yields.

There are several tools available to do this. The Leaf Color Chart was developed to help with this assessment and is still a valid tool to use. Its limitations are that it is time consuming and limited to a relatively small area.

The Green Seeker handheld crop sensor is a new tool that we have been testing for this purpose. It measures the NDVI (Normalized Difference Vegetation Index) of the canopy. Based on preliminary data, we have developed a response index to help growers decide when a top-dress N application is necessary. We have found that an index of 1.1 or greater indicates the need for top-dress N application. The response index is the NDVI reading of an enriched N strip (representing a crop with unlimited N) divided by the NDVI reading from the field test area. The N enriched strip is an area where extra N was added to the field (could be done by overlapping an area with an aqua rig). For example if the N enriched strip gave an NDVI value of 78 and the field test area gave an NDVI value of 68, the response index would be 1.14 (78/68=1.15) and this would indicate the need for a top-dress N application. We would like to emphasize that this is based on preliminary data and further testing may change the response index. However, for now it does provide a useful guide. Some limitations to the Green Seeker are that it is still relatively limited in area that can be tested; although it is much faster to take readings and therefore get a better assessment of the field. You can also not use the Green Seeker when leaves have dew or rainfall on them. The Green Seeker also does not work well where there is poor stand establishment or a high amount of weeds.

Finally, drones can be used to access N status. Drones can be outfitted with cameras that provide NDVI values from the crop. The obvious advantage of using a drone is that one is able to access a much larger portion of the field quickly. Several disadvantages of a drone are that since the NDVI cameras do not have their own light source (they are too far from the canopy), to get accurate readings you need to fly near solar noon and fly during periods when there is no cloud cover. The NDVI values can theoretically be used in the same way as those from the GreenSeeker. This is an area we are still exploring in our research.

Using N fertilizers other than aqua-ammonia as the primary N source

Aqua-ammonia is the primary N fertilizer source for water seeded rice systems in California. It is a good source and is taken up very efficiently when water is managed well (i.e. fields are kept in a saturated or flooded state for the first month and half after planting). In 2019, high rainfall in May resulted in many growers flooding and planting their rice before they applied their traditional aqua fertilizer. This puts them in a position of having to apply all of the crop N needs after seeding, and likely, applying this fertilizer into flood water. This is not an ideal situation as N applied this way is highly susceptible to N losses. In this situation, the recommendation is to "spoon-feed" the N to the rice in order to provide small amounts of fertilizer when the plants need it.

In 2019, we examined the effect of applying three N sources (aqua, urea and ammonium sulfate). All N was applied at a rate of 150 lb N/ac. The aqua was applied preplant as normal (however, the soil was moist). The urea and ammonium sulfate were applied in 4 splits at 2 (20 lb N/ac), 4 (50 lb N/ac), 6 (50 lb N/ac) and 8 (30 lb N/ac) weeks after planting. We plan to examine the effect of these treatments on yield and N uptake at the end of this season.

Aqua-ammonia losses when soils dry

As mentioned above, we recommend applying aqua N preplant and then keeping the field flooded at least until the fertilizer N has been taken up (about 45 days after planting). This ensures efficient N uptake. However, for various reasons the field soil can become moist but not flooded which can result in N losses. These include:

1. Aqua N is applied and then it rains before field can get flooded and planted. In this case the soil becomes moist and the aqua-N begins to convert to nitrate (nitrification). This nitrate can be lost as gas (denitrification) when the field is flooded. It is also susceptible to leaching, although leaching is not a big concern in the heavy clay soils that most rice is grown in.
2. The field is drained after flooding for various reasons. For example, levees blow out after flooding resulting in the field being drained and becoming aerobic.
3. Some farmers that dry-seed rice, apply aqua-N preplant. The field is flush irrigated for the first 3 to four weeks before a

permanent flood. Between these flushing events the soil becomes aerobic and the N nitrifies (turns to nitrate). This nitrate is susceptible to denitrification losses when field is flooded.

In all of these scenarios, it is important to know how much N is lost so that it can be adequately replaced. We are conducting field and laboratory research to quantify how much N is lost in these various scenarios so that farmers can have confidence in managing their N fertilizer.

Top-dressing N following herbicide applications

Some herbicides negatively affect rice growth in addition to controlling weeds. An example is Regiment which can prune roots and stunt the rice. To help mitigate the negative effect of the herbicide, some growers apply a top-dress of N after the herbicide application. We are conducting a small study to see if such herbicide applications reduce yield and if top-dressing N helps mitigate N losses.

SYSTEMS MAP LEGEND

1. **Evaluation of aqua-ammonia, urea and ammonium sulfate as the only fertilizer N source for the season**: a total amount of 150 lbs. N/ac was applied. Aqua applied before planting. Urea and ammonium sulfate applied in four splits of 20, 50, 50 and 30 lbs. N/ac at 2, 4, 6, and 7 weeks after planting.

2. **Product Development**: testing of rates for a growth regulator.

3. **Product Development**: testing of rats for a foliar fertilizer.

4. **Control of stem rot with fungicides**: several fungicides are being tested at mid tillering, booting, and heading to determine their effect on the incidence and severity of stem rot.

5. **No-till vs. till**: no-till was leveled in 2018, weeds sprayed with roundup in May before planting.150 lbs. N/ac applied to both treatments.

6. **Control of stem rot with fungicides:** several fungicides are being tested at mid tillering, booting, and heading to determine their effect on the incidence and severity of stem rot.

7. **Tadpole shrimp seeding time study**: different seeding times after flooding are being tried to determine the time when rice seedlings are most susceptible to tadpole shrimp injury.

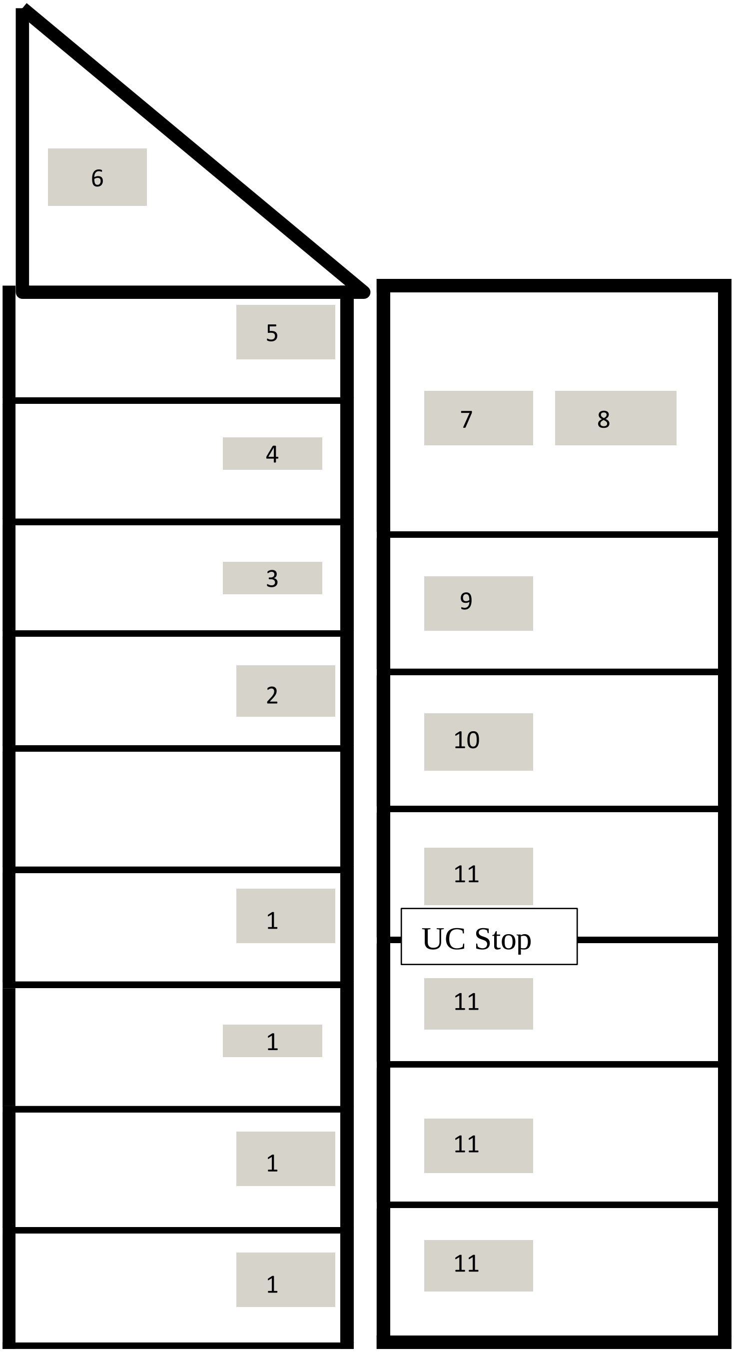
8. **Control of tadpole shrimp with insecticides**: registered and experimental insecticides are being tested for their effect on tadpole shrimp survival.

9. **Artificial defoliation study**: three levels of armyworm defoliation are being simulated to evaluate their effect on plant height, rice maturity, yield, and moisture content.

10. **Dry-seeded rice**: can you use aqua-ammonia as an N source? If aqua ammonia is used, some will be lost during the crop establishment flushes due to denitrification. How much is lost?

11. **Determining mid-season N needs using remote sensing**: evaluating the use of Green Seeker and various indexes from a drone to determine mid-season N needs.

SYSTEMS RESEARCH NURSERY (N →)



Research Area	UC Research Leader	Title/description	Field Location
Agronomy	Linquist	Fallow/Stale Seedbed	Systems
Agronomy	Linquist	Drill Seeded Nitrogen Management	Systems
Agronomy	Linquist	Aqua/Urea/Ammonium Sulfate	Systems
Agronomy	Linquist	Nitrogen Rates/Topdress	Systems
Agronomy	Brim-DeForest	Plant Growth Hormone	Systems
Agronomy	Brim-DeForest	Foliar Fertilizer	Systems
Weeds	Al-Khatib	Planting depth	Hamilton Rd.
Weeds	Al-Khatib	Cerano timing	Hamilton Rd.
Weeds	Al-Khatib	Herbicide Resistant Rice	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Experimental Herbicides	Hamilton Rd.
Weeds	Al-Khatib	Greenhouse resistance service	GH 4 D
Entomology	Espino	TPS control with insecticides	Systems
Entomology	Espino	TPS population dynamics	Systems
Entomology	Espino	TPS cultural control	Systems
Entomology	Grettenberger	Effect of defoliation on rice yield	Field 8
Entomology	Grettenberger	Evaluation of varieties against RWW	Field 8/J7
Entomology	Grettenberger	Non-target effects of pesticides	J7
Entomology	Grettenberger	RWW control with insecticides	Field 8
Diseases	Espino	Stem rot management with fungicides	Systems

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TRUCKS

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Delta Industries
Helena Chemical Company

PRODUCT/SUPPLIES

Biggs Farming Group (Straw Bales)
Butte County Mosquito & Vector Control District
Albaugh LLC (ALB 2023)
UPI (Super Wham®)
Wilbur-Ellis (Cerano®)
Far West Rice (sushi rice)

EQUIPMENT DISPLAY

Valley Truck and Tractor
Holt Ag Solutions
N&S Tractor
Peterson Cat