

RICE FIELD DAY

Wednesday, August 27, 2008



2007 Rice Breeding Program Review

*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 2007, the CCRRF initiated a scientific review of the Rice Research Trust-funded RES Rice Breeding Program. The picture on the cover includes the panel of outside experts and CCRRF staff who participated in the review.

Shown from left to right are Dr. Gurdev Khush (IRRI Director of Rice Breeding-ret.), Dr. J. Neil Rutger (USDA-ARS Geneticist/Director-ret.), Dr. Jacob Lage (Plant Breeder, Medium Grains) Dr. Virgilio C. Andaya (Plant Breeder, Short Grains), Carl W. Johnson, Ph.D., (Plant Breeder, Medium Grain-ret.), Mr. Jack Williams (UCCE Farm Advisor & County Director-ret.), Dr. Robert K. Webster (UC Professor of Plant Pathology-Emeritus), Dr. Kent McKenzie (RES Director), Mr. James Erdman (Rice Grower and CCRRF Board member-ret.), Jeffry J. Oster, M.S. (Plant Pathologist), and Dr. Farman Jodari (Plant Breeder, Long Grains).

CCRRF provided an extensive summary report on the Rice Breeding Program to the panel and met individually with project leaders and the RES Director. The panel provided a summary report and identified opportunities in a meeting with the Board. They also made themselves available over the past year to the RES Director and met again in June 2008 with scientific staff to discuss the potential of hybrid rice for California. This ongoing effort, along with input from growers and industry serves to address the needs of the California Rice Industry now and in the future.

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Ray Stogsdill, Staff Research Associate II
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2008 Rice Field Day Program

7:30 - 8:30 a.m. Registration and Poster Viewing

Posters and Demonstrations

1. Effects of Landscape and Crop Management on Herbicide Resistance Evolution in *Echinochloa* Spp. in California Rice Systems. (C. Marchesi, C. Greer, M. Jasieniuk, M. Canevari, R. Mutters, R. Plant, J. Eckert, A. J. Fischer; UCD)
2. Clomazone Resistance in Late Watergrass (*Echinochloa Phyllopogon*): Role of Herbicide Metabolism. (H. Yasuor, J. Eckert, A. J. Fischer; UCD)
3. Penoxsulam Faces Metabolic Resistance in California's Late Watergrass [*Echinochloa Phyllopogon* (Stapf) Koss.] (H. Yasuor, M. Osuna, A. Ortiz, J. Eckert, A.J. Fischer; UCD & Universidad Central De Venezuela)
4. Alternative Rice Establishment Systems for Controlling Weeds (B. Linquist, J. Eckert, L. Espino, A. J. Fisher, L. Godfrey, C. Greer, J. Hill, K. Koffler, M. Lundy, R. Mutters, M. Ruark, and C. Van Kessel)
5. Traits for Field Identification of *Monochoria vaginalis* and Species of *Heteranthera* at Different Growth Stages. (J. Eckert, UCD; J. Williams, CSUC, J. Lundberg, Lundberg Family Farms, A.J. Fischer, UCD)
6. Current Red Rice Situation in California (C.A. Greer, A.J. Fischer, L.A. Espino, R.G. Mutters, J.W. Eckert and J.E. Hill)
7. Influence of Rice Seeding and Establishment Method on the Populations of Rice Water Weevil and Larval Mosquitoes (W. Pinkston, K. Basuta, L. Godfrey)
8. Rice Water Weevil Sampling for Commercial Monitoring - Possibilities and Challenges. (L. Espino, UCD.)
9. Bakanae Disease of Rice Brochure (J.J. Oster, RES)
10. Progress in Breeding for Stem Rot Resistance (J.J. Oster, RES)
11. Blast, Stem Rot, and Sheath Spot Rapid Backcross Programs (J.J. Oster, RES)
12. Disease Symptom Posters (J.J. Oster, RES)
13. The *Oryza* Map Alignment Project (Omap) Introgression Lines for Allelic Diversity and New Germplasm Development (P. L. Sanchez, D. Kudrna, G. Eizenga, R. A. Wing)

14. Genetic Analysis of Seedling Cold Tolerance and Vigor in Rice (T. H. Tai, V. C. Andaya, S. Kim, P. M. Colowit, E. Easlon, and C. Takachi)
15. Isolation and Characterization of Low Phytic Acid Rice Mutants (S. Kim, C. Andaya, and T. H. Tai)
16. Induced Fissuring Protocols used in Characterization of 3 'RiceCAP' Milling Populations, (A.I. Roughton and F. Jodari)
17. Development and Screening of Rice Mutant Populations (T. H. Tai and P. Colowit)
18. A Tall Mutant of M-206 – Description and Preliminary Results (J. Lage, C.W. Johnson, K. S. McKenzie, V. C. Andaya, A. J. Fischer and J. W. Eckert)
19. Measuring the Moisture Distribution within a Rice Kernel Using Magnetic Resonance Imaging (Mri) (B. Prakash, S. Asavasanti, J. H. Walton, M. J. McCarthy and J. F. Thompson)
20. Head Rice Yield Stability of California Medium Grain Rice Varieties (J. F. Thompson, R. G. Mutters, and R. E. Plant) Infrared Drying of Rough Rice (B. Prakash and Zhongli Pan)
21. The Evaluation of Texture of California Rice Varieties of 2007 (T. Fung, T. Laokuldilok, W. Yokoyama, and C. Shoemaker)
22. Timing and Placement Effects of P Fertilizer on Weed Growth in California Rice Systems. (M. Lundy, A. Fischer, C. Van Kessel, M. Ruark, J. Hill, D. Spencer, R. Mutters, C. Greer, B. Linquist.)
23. Straw Management and Water Quality in Rice Production Systems (M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six, R.G. Mutters, C.A. Greer, and J.E. Hill)
24. Nitrogen, Phosphorus, and Potassium Losses From Flooded Rice Fields in Northern California (M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six, R.G. Mutters, C.A. Greer, and J.E. Hill)
25. The PHD Gene: Description and Genetic Characterization of a Spontaneous Mutant of Rice (V.C Andaya, C.W Johnson, J Lage, T.H. Tai, and K.S. McKenzie)
26. Water Quality: Rice Pesticides Program and Irrigated Lands Regulatory Program (California Rice Commission)
 - An update on water quality monitoring for rice pesticides
 - Forecast of additional regulation including ground water monitoring
 - Water monitoring results for rice pesticides

28. Air Quality Regulations: New Challenges on the Horizon
(California Rice Commission)
 - Pesticide VOC regulations and what this means to rice (qualifies for DPR CE)
 - How Greenhouse Gas standards affect rice (a scientific poster board on the carbon sequestration project is being prepared for the poster session)
 - Details of the diesel engine rule
29. Heat Stress in Agriculture (California Rice Commission)
 - An overview of U.S. EPA and DPR regulations to identifying and preventing heat stress in agriculture
 - Pesticide Regulation Update
 - Molinate cancellation update
 - Rice pesticide water-holding requirements
30. 2008 Farm Bill (California Rice Commission)
 - Current status of the Farm Bill with an emphasis on conservation
31. Variation in Digestibility of Two Rice Straw Varieties Using In-Vitro Gas Production (M. Santos, G. Nader and P. Robinson)
32. Improvement of Consistency and Accuracy of Rice Sample Milling (Z. Pan, J.F. Thompson and B. Prakash)
33. Infrared Drying of Rough Rice (B. Prakash and Z. Pan)

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

Welcome by Gary Simleness, Chairman, CCRRF

CCRRF Business Meeting

- Financial Report, Stacy Argo, Treasurer, CCRRF
- Directors Nomination Committee Report, Tom McClellan
- Rice Research Trust Report, Steve Willey, Chair
- California Rice Research Board Report, Mike Daddow, Chairman, CRRB
- D. Marlin Brandon Rice Research Fellowship Presentation, Kent S. McKenzie, RES
- California Rice Industry Award Presentation, Michael Rue, 2006 Recipient



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

Two tours occur simultaneously and repeat.

White & Green Groups to Trucks

Rice Variety Development, (F. Jodari, V. Andaya, J. Lage, and J.J. Oster, RES)

Improved Methods to Combat Rice Crop Invertebrate Pests and to Assist with Mosquito Management in Rice Fields (L.D. Godfrey, K. Basuta, and W. Pinkston, UCCE, UCD).

10:30 - 10:45 a.m. Refreshments - New Warehouse

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

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

Two tours occur simultaneously and repeat.

Red & Blue Groups to Buses

Rice Weed Control: Herbicide Performance, Combinations, New Chemicals, and Weed Management, (A.J. Fischer, J.W. Eckert, J.E. Hill, Y. Hasour, M. Milan, A. Ortiz, L. Boddy, C. Marchesi, S. Johnson, UCD)

10:30 - 10:45 a.m. Refreshments – Greenhouse

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

Noon Luncheon Concludes Program

3.0 hours of Continuing Education Credit for this 2008 Rice Field Day has been approved from Cal/EPA Department of Pesticide Regulation



Disclaimer

Trade names of some products have been used to simplify information. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

Introduction

By G. Simlness

As Chairman of the Board of the California Cooperative Rice Research Foundation, it is my privilege to welcome you to the 2008 Rice Field Day. Our Board of Directors, staff and UC Cooperators look forward to the opportunity to showcase our research projects and answer your questions. The highlight of the day's activities are our field tours, but please take some time to visit the posters, demonstrations and information booths around the meeting area. I think you will find the information interesting and useful.

Since 1912, this station has been serving the needs of the California rice industry. Our industry has proven to be very adaptive, and this station's Board and staff are keeping a constant watch as to the challenges and changing environment which we find ourselves in. Last year we completed an outside scientific review of our research activities to better position this station direction for the future. This year we had a follow-up review by the same respected industry professionals to monitor our progress and to further refine our course. The Rice Experiment Station and UC research projects would not exist without grower's financial support through the California Rice Research Board assessment. We appreciate your continued support and invite your comments and suggestions for improving research programs.

Weed research is being led by UC scientist Dr. Albert Fischer, who will be making presentations on your tour at our Hamilton Road Research Area. UC Cooperative Extension Entomologist Dr. Larry Godfrey is continuing his work on rice insect pests and will update you on the main station tour.

Varietal development remains the primary mission here at the Rice Experiment Station. Our overall goal still remains to develop varieties with improved disease resistance, quality and yield potential.

Dr. Farman Jodari will update you on his progress with the long grain varieties.

Dr. Virgilio Andaya will update you on the stations short grain breeding progress. He also heads up our DNA marker research lab.

Dr. Jacob Lage now heads up our medium grain breeding program with the recent retirement of Dr. Carl Johnson. Jacob will update you on his progress with our medium grain varieties.

Rice Experiment Station pathologist, Jeff Oster, continues his work on rice diseases focusing on stem rot, sheath spot and blast. Some of the results of his work will be highlighted on the main station tour, and is also presented in the poster area.

DNA marker capability is progressing at the Rice Experiment Station. This technology is a breeding tool that should help assist our breeders in making varietal selections in the breeding program. Markers will help in selecting the semi dwarfing gene, amylose content and resistance to rice diseases. The startup was facilitated by USDA geneticist Dr. Thomas Tai and his staff at UC Davis, grant support from the RiceCAP Project and funding by the Rice Research Trust.

The Rice Experiment Station remains committed to providing pure, high quality, weed-free foundation seed for the California rice grower. The purity and high quality of our seed has been clearly demonstrated to growers and to the industry over the past several decades. Recent discoveries of small pockets of red rice contamination have been discovered and isolated here in California. This news is of serious concern to all rice growers. One of the best preventative measures to protect against red rice contamination and spread is through the use of pure, high-quality rice seed which this station produces.

We have a cooperative program between the Rice Experiment Station and the Foundation Seed and Certification Services at UC Davis. The certified seed program is an essential part of maintaining the genetic integrity of our current varieties. This program has been very successful with an estimated 90 percent use of certified seed by the California rice industry. In 2008, "foundation seed" is being produced for 15 varieties.

I would like to acknowledge the many agricultural businesses and growers who continue to support Rice Field Day with their financial donations, agro-chemicals and the use of trucks for our tours. This support is greatly appreciated and is a large part of making this event a success. These supporters are listed in your program and on the posters next to the office.

Thank you for attending the Rice Field Day and supporting your rice research programs. We encourage you to contact any of the Directors, Rice Experiment Station or UC staff with any questions or suggestions.

D. Marlin Brandon Rice Research Fellowship

Dr. D. Marlin Brandon began his career in 1966 as a University of California Rice Farm Advisor in Colusa, Glenn and Yolo Counties. He served as Rice Farm Advisor for eight years. He was appointed Rice Extension Agronomist in the Department of Agronomy at the University of California at Davis and earned a Ph.D. in Soil Science.

He was instrumental in conducting research and developing educational programs showing that zinc deficiency caused alkali disease in rice, and in treating this nutritional problem. He also showed the advantage of band application of phosphorus in rice rotation crops, resulting in yield increases of 2500 to 4000 lb/acre. This management practice was widely adopted in only three years. Dr. Brandon and his colleagues improved fertilizer efficiency in rice by the use of plant tissue analysis and the establishment of critical levels of major plant nutrients for California rice varieties. They also developed “best management practices” to optimize grain production of the new California semi-dwarf rice varieties in the late 1970s. The combination of improved management practices, varieties, and progressive growers dramatically increased rice yields and positioned California as a world leader in rice yields and rice production technology.

In 1979 he moved to Louisiana as Agronomist at the Louisiana State University Rice Research Station at Crowley, Louisiana. With his vast experience, research, and team approach, Dr. Brandon expedited the rapid adoption of improved semi-dwarf varieties and management practices throughout the Southern U.S. This again provided the foundation for dramatic gains in rice productivity in that region. He was also active as a professor with students and on the international scene.

In 1985 he returned to California as Director and Agronomist at the Rice Experiment Station at Biggs, California. During this period, he continued his efforts to facilitate the development of improved rice varieties for California, including new specialty market types. He was an avid supporter of cooperative research with the University of

California, the USDA, and the private sector. His leadership and participation were very valuable in helping California address many complex rice production issues and challenges.

Dr. Brandon was elected as Fellow of the American Society of Agronomy, received the California Rice Industry Award, and twice earned the Distinguished Rice Research and Education Award. He was a mentor and teacher of rice production science to colleagues, students, and growers everywhere. He had an unselfish desire to share his knowledge and expertise with others, and did that at every opportunity.

As a tribute to Dr. Brandon, a memorial fellowship was established to provide financial assistance to students pursuing careers in rice production science and technology. 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 being used to fund the fellowship that will be awarded at Rice Field Day. Recipients will be known as D. Marlin Brandon Rice Scholars.

Dr. Brandon was a well liked and respected professional, and made tremendous contributions during his lifetime. This fellowship honors and perpetuates his legacy.

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

POSTERS AND DEMONSTRATIONS

EFFECTS OF LANDSCAPE AND CROP MANAGEMENT ON HERBICIDE RESISTANCE EVOLUTION IN *ECHINOCHLOA* SPP. IN CALIFORNIA RICE SYSTEMS

❖ C. Marchesi, C. Greer, M. Jaseiniuk, M. Canevari, R. Mutters, R. Plant, J. Eckert, A. Fischer, UC Davis

Late watergrass (*Echinochloa phyllopogon*, LWG), early watergrass (*E. oryzoides*, EWG) and barnyardgrass (*E. crus-galli*, BYG) are the most competitive and difficult weeds to control in rice. Herbicide resistance in some of these species was confirmed in California in 1998. Resistance is the result of an evolutionary process in which preexisting mutants are allowed to proliferate under selection pressure. Selection pressure is determined by herbicide factors, weed characteristics and management factors. It is crucial to understand not only how resistance evolves but also how it spreads. Factors that shape the incidence, evolution and spread of herbicide resistance weeds can be associated with crop management and landscape properties. Resistance of various ECH to herbicides with different modes of action has been reported in California. Further research has shown the prevalence of metabolic cross-resistance in California watergrasses, which has evolved and spread differently for each species. Different studies have associated either the effects of diverse crop management practices or the extent of gene flow with the temporal distribution of R biotypes. However, interactions between these driving factors also need to be considered. My objective is to develop an integrative study that establishes how interactions between crop management practices, landscape variables and mechanisms of resistance dispersal contribute towards defining the patterns of ECH resistance currently observed throughout the rice area in California. A downscaling approach from a regional scale using GIS will be used to investigate the complexity of the mentioned interactions. The research involves a field survey and controlled environment studies. Geo-referenced seed samples representing populations of EWG, LWG or BYG, were taken from rice fields (U-shaped transect and problematic patches). Seed from each population along with known R and S controls are being screened for resistance against a thiocarbamate, ACCase inhibitor and ALS inhibitor. Detailed field histories (herbicide use, water management and other rice cultural practices) are being collected via questionnaires. Molecular data from known R and S biotypes is available. Data will be subject to multivariate analysis to assess relationships between these variables and levels of herbicide resistance. Preliminary data

are quite interesting suggesting various levels of resistance, different for each ECH species. Establishing the relevance of management and landscape variables, and a population's genetic structure will be crucial to explain such differences between species, and finally, appropriate management strategies could be suggested.

CLOMAZONE RESISTANCE IN LATE WATERGRASS (*ECHINOCHLOA PHYLLOPOGON*): ROLE OF HERBICIDE METABOLISM

❖ H. Yasour, J. Eckert, A. Fischer, UC Davis

Echinochloa phyllopogon (late watergrass, LWG) is a major weed of California rice. Since populations of this weed with known metabolically-based resistance to multiple herbicides have been poorly controlled by clomazone, we conducted cross-resistance studies, assessed the involvement of enhanced P450 detoxification or of possible photo-oxidative stress tolerance. Low-level cross-resistance to clomazone (R/S near 2.0) was found in several LWG biotypes with known resistance to multiple herbicides. A resistant biotype (R) showed similar R/S level for clomazone as for its active metabolite, 5-ketoclomazone, thus resistance should relate to a differential ability to cope with 5-ketoclomazone. Adding a P450 inhibitor (disulfoton or ABT) to clomazone treatments protected both R and S plants from injury. Disulfoton protected 5-ketoclomazone-treated S plants from injury but did not protect R plants, suggesting that P450-mediated metabolism of this compound may produce yet other herbicidally-active intermediates in S plants, and that these toxic 5-ketoclomazone metabolites are either not formed or are rapidly detoxified by R plants. ABT did not significantly synergize 5-ketoclomazone toxicity to R plants, suggesting resistance to clomazone involves non-P450-dependent mechanisms. HPLC analysis of ¹⁴C-clomazone-treated plants showed that both biotypes metabolized clomazone similarly. Clomazone, 5-ketoclomazone, and an unknown polar metabolite that eluted 10 minutes before clomazone, were the main labeled compounds eluted. In addition, 30% of the radioactivity probably corresponded to sugar conjugates. Disulfoton reduced the proportion of conjugates and increased parent compound and unknown metabolites contents; 5-ketoclomazone content was unchanged. These results suggested that disulfoton blocked P450-mediated clomazone metabolism and bioactivation in these R and S plants. Clomazone-resistant plants were also less susceptible to paraquat. LC-MS metabolic profiling showed significantly different profiles, before clomazone (50 μM) treatment and by 48 and 96 HAT. In summary, clomazone is converted to a more active compound in both R and S LWG. Both biotypes degrade

clomazone similarly. However, metabolic profiling shows distinct differences between biotypes, and these may also differ in responses to photooxidative stress. We are in the process of identifying these metabolites in order to detect pathway differences between biotypes that could be related to clomazone and herbicide resistance in R LWG.

PENOXsulAM FACES METABOLIC RESISTANCE IN CALIFORNIA'S LATE WATERGRASS [*ECHINOCHLOA PHYLLOPOGON* (STAPF) KOSS.]

❖ H. Yasuor¹, M. Osuna¹, A. Ortiz², J. Eckert¹, A. Fischer¹; ¹ UC Davis; ² Universidad Central de Venezuela

Echinochloa phyllopogon is a major weed of California rice that has evolved multiple-herbicide resistance. Cross-resistance to penoxsulam was evaluated in a resistant (R) population collected in a rice field. Ratios (R/S) of the R to S GR50 values of about 5 were observed in whole-plant and seedling dose-response assays. Adding malathion (P450 inhibitor) enhanced herbicide phytotoxicity to R plants, while pre-treatment with thiobencarb (P450 substrate) antagonized penoxsulam. HPLC assays with ¹⁴Cpenoxsulam showed higher clomazone metabolism in R plants; malathion inhibited penoxsulam metabolism and accumulation of parent compound in R plants was similar to S plants treated with penoxsulam alone. ALS activity assays were similar for R and S plants. These results suggest *E. phyllopogon* resistance to penoxsulam is due to P450-mediated enhanced metabolism and not due to reduced ALS sensitivity.

ALTERNATIVE RICE ESTABLISHMENT SYSTEMS FOR CONTROLLING HERBICIDE RESISTANT WEEDS

❖ B. Linquist, L. Espino, A. Fischer, L. Godfrey, C. Greer, J. E. Hill, K. Koffler, M. Lundy, R.G. Muters, M. Ruark, C. van Kessel

Herbicide-resistant weeds are one of the main problems affecting the long-term sustainability of California's rice-based systems; in fact more weed species are resistant to herbicides in California rice systems than in any other crop or geographic area in the United States (Heap 2007). Rice, the major crop grown in the Sacramento Valley, is produced on about 500,000 acres annually. Eliminating spring tillage combined with a stale seedbed offers new opportunities to control herbicide-resistant weeds. A stale seedbed refers to the practice of flushing or flooding a field with water to induce weed seed germination and then killing the weeds (usually with glyphosate) before planting. Research has been ongoing at the Rice Experiment Station (RES) since 2004 to evaluate the use of stale seed beds in

water- and drill-seeded rice systems. Five treatments have been evaluated:

1. Conventional water-seeded
2. Conventional drill-seeded
3. Water-seeded with stale seedbed
4. Water-seeded, minimum-till, stale seedbed
5. Drill-seeded, minimum-till, stale seedbed

In each of these systems, the effect of the stale seedbed was evaluated as a means of controlling weeds, appropriate fertilizer management strategies were determined and differences in rice pests was monitored.

Four years of research has shown that the yield potential of each of these 5 systems is similar. While the data is inconclusive as to the best management practices for N fertilizer in these systems, the data clearly indicate that the water-seeded stale seedbed system (treatment 3) requires more N fertilizer to achieve its yield potential.

Stale seedbed systems have demonstrated their potential for good yields while drastically altering the kinds of weed species that emerge with rice. Aquatic sedge and broadleaf weeds dominated the water-seeded systems, while the aerobic seedbeds of the drill-seeded systems favored grasses. The lowest weed infestation occurred where rice was water-seeded after a stale seedbed without spring tillage. Alternative rice establishment systems may be used to effectively manipulate the kinds of weed species that establish with rice and to enable the use of a broader range of herbicides to control resistant weed types.

Populations and/or damage from rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel, armyworms (*Spodoptera* spp.), and mosquito immatures were monitored. Leaf feeding by RWW adults (indicative of population magnitude) was about three times higher in the other treatments compared with the conventional water-seeded treatments. The highest numbers of RWW larvae were found in the two drill-seeded treatments. These results are contradictory to previously conducted studies that showed reduced larval numbers in drill-seeded plots. Those studies were in micro-plots (several square feet) and results often change as the plot size increases to more realistic sizes. The mosquito dip results showed that there was a reduced number of mosquito larvae collected from the conventional drill-seeded and the stale no-till drill-seeded plots

while the three water-seeded plots showed higher numbers of mosquito larva. The mosquito data warrant further investigation to determine if the pattern of larval reduction holds over an extended number of years. Finally, armyworm damage was monitored in each plot at one-week intervals through August 2007; no damage or armyworms were found.

In summary, this research has shown the potential for stale seedbed systems to control herbicide resistant weeds while maintaining yield potential. In addition, the use of these systems may save time and fuel costs due to the reduced number of tractor passes. Reducing the number of tractor passes would theoretically reduce dust pollution. Finally, there is the potential for improvements to water quality because fewer herbicides are used.

TRAITS FOR FIELD IDENTIFICATION OF *MONOCHORIA VAGINALIS* AND SPECIES OF *HETERANTHERA* AT DIFFERENT GROWTH STAGES.

❖ J.W. Eckert, UC Davis, J. Williams, CSU Chico, J. Lundberg, Lundberg Family Farms, A. Fischer, UC Davis

Two species of duck salad (*Heteranthera*; Pontederiaceae) are currently described as being present in California rice fields. *Heteranthera limosa* (Sw.) Willd. is found in California as the white-flowered form of this species although other color variants exist in other regions. Identifying characteristics include individual flowers with six tepals equally separated to the top of the corolla tube, generally rigid petioles and rarely develops elongate stems. *Heteranthera rotundifolia* (Kunth) Griseb. is found in California as the blue-flowered form although other colors exist in other regions. Identifying characteristics include individual flowers with six unequally separated tepals with the middle tepal of the upper three not separated all the way to the top of the corolla tube, has flexible petioles and commonly develops elongate stems that may produce roots at each node. The 1976 Rice Field Day booklet notes duck salad first recorded in Glenn County in 1948. It also notes a marked spread of the weed during the early 1970s. From anecdotal evidence, this duck salad was the white-flowered *H. limosa*. The first herbarium specimen of *H. limosa* was collected in Glenn County in 1966. The first blue-flowered specimen was collected in 1983 and initially identified as *H. limosa* by a botanist at UC Davis. A blue-flowered specimen was collected in 1991 and identified by Vern Oswald at California State University, Chico and confirmed by Charles N. Horn at Newberry College, South Carolina as *H. rotundifolia*. The 1983

specimen has just recently been re-examined by UC Davis herbarium curator Ellen Dean and reclassified as *H. rotundifolia*. One specimen of blue-flowered ducksalad located at California State University Chico that was originally identified as *H. limosa* has been re-examined by curator Lawrence Janeway and reclassified as *H. rotundifolia*. Several other specimens of blue-flowered ducksalad at other California institutions initially identified as *H. limosa* are also being re-examined for potential reclassification as *H. rotundifolia*. Adding to the confusion between species of *Heteranthera* is the long-term misidentification of *H. rotundifolia* as monochoria (*Monochoria vaginalis* (Burm. F.) Kunth) by most rice professionals and growers. It is unclear when this began, but is likely due to its blue flower color. *M. vaginalis* is documented as being present in California rice fields, but the extent of infestation is unclear. *M. vaginalis* is in the same family (Pontederiaceae), but has some very distinctive differences from *Heteranthera*. Characteristics that easily separate *M. vaginalis* from *Heteranthera* are: thin lanceolate early leaves, large waxy heart shaped adult leaves and clusters of light blue flowers that are not prominent and often open under water. The blue-flowered ducksalad (*H. rotundifolia*) has largely displaced the white-flowered ducksalad (*H. limosa*) in most fields where it has been introduced. The displacement appears to happen within a few years after initial infestation. One possible explanation for the rapid spread is mid-season seed dispersal while flood water is moving through the field. Organic rice growers have expressed concern over the spread of the blue-flowered ducksalad due to the more aggressive creeping stem behavior. This creates a dense mat of plants that is more difficult to kill with the field dry down method of control. This creeping behavior also tends to pull the rice down at early stages of growth. Differential herbicide efficacy on the two *Heteranthera* species has not been examined. Additionally, a plant specimen from the west side of the Sacramento Valley was delivered to the Rice Experiment Station (RES) this season. It has multiple flowers on a stalk and the leaf shape is different from the other ducksalad species. It is in the process of being studied, but has not yet been positively identified.

CURRENT RED RICE SITUATION IN CALIFORNIA

❖ C.A. Greer, A.J. Fischer, L.A. Espino, R.G. Mutters, J.E. Hill and J.W. Eckert

Threat of Red Rice

Red rice poses a serious risk to the California rice industry and has the potential to impact rice yield and quality if this weed is allowed to spread and establish populations throughout rice fields in the state.

This weed is prevalent in all of the southern U.S. rice producing states and continues to be a major constraint to production there. The name “red rice” refers to the distinguishing red bran that covers the kernels of red rice grain.

Red rice is problematic because of the weedy characteristics it exhibits. This weed has vigorous growth and tillering habits that makes it a better competitor for space and resources than cultivated rice varieties. Competition for these resources leads to reduced rice yields. In addition, red rice has an asynchronous reproductive cycle in which heading may occur over a prolonged period of time producing seeds that shatter easily at maturity. Seeds that fall to the soil surface may germinate when conditions are favorable or remain dormant for several years before germinating. Dormancy of red rice seeds leads to some challenges in developing an effective management strategy for this weed. In addition, chemical control of red rice during a rice cropping season is difficult since this weed is the same species as cultivated rice.

Red rice is also a serious cause of concern at the mill. The presence of red rice can lower the grade of milled rice. For example, there is a maximum limit of 0.5% red rice and damaged kernels (singly or combined) for Grade U.S. No. 1. Removing the red rice grains at the mill may be done using optical sorters and additional milling but may increase the cost to the miller and result in a reduced price for the producer.

Current California Situation

Red rice has been identified in six fields in Colusa and Glenn Counties since 2003. Growers with identified red rice infestations have been proactive and aggressive in removing red rice plants from fields prior to heading and should be commended for their actions. The rice industry as a whole must show this same dedication if we are to gain the upper hand on this pest.

How can you help protect the California Rice Industry?

Red rice has the potential to have a serious economic impact on the California rice industry through reduced yields and quality as well as the costs associated with management of this weed. The California rice industry must be proactive if we are to effectively manage this pest and prevent the more widespread dissemination and establishment of red rice. One of the most important contributions you can make to the industry at this time is to scout your fields very closely for the presence of red rice. Prior to heading, red rice may be

mistaken as watergrass escapes because it is about a foot taller and lighter green in color than our calrose varieties. Upon closer examination, it is apparent that the red rice plants are in fact rice and have prominent ligules and auricles that are absent from watergrass plants. Leaves of red rice plants are also much longer and rougher to the touch than our calrose varieties. Panicles of red rice plants are long and bare seed that are pubescent, with straw colored hulls, long awns and red bran at maturity. It is impossible to accurately identify red rice from your pick-up so please take a closer look at any weeds that seem suspicious.

Please contact us if you suspect you have red rice

UC in conjunction with growers, County Agricultural Commissioners, the California Rice Experiment Station and the California Rice Commission has been working to develop effective management strategies for infested fields. Thus far, these plans have shown promise in reducing red rice populations in infested fields but it must be realized that there is no quick fix for this pest. Seed dormancy of this weed makes this a multi-year endeavor in cleaning up a field. If you suspect you have/had red rice in one of your fields please contact Chris Greer (Sutter, Yuba, Sacramento, and Placer), Luis Espino (Colusa, Glenn, and Yolo) or Cass Mutters (Butte), UC Cooperative Extension Farm Advisors, for help with identification and developing a monitoring and management plan.

INFLUENCE OF RICE SEEDING AND ESTABLISHMENT METHODS ON THE POPULATIONS OF RICE WATER WEEVIL AND LARVAL MOSQUITOES

❖ W. Pinkston, K. Basuta, L. Godfrey, UC Davis

The “systems study” has been ongoing at the RES for the last few years – we have been involved in this project from invertebrate pest management standpoint for the last 4 years. The primary goal is to investigate alternative seeding and establishment methods in order to open up new opportunities for weed management. The stale seedbed and dry (drill) seeding are two of these techniques. These changes in rice production need to be used without disrupting other aspects of rice agronomy and pest management. The multi-disciplinary team that is working on this project, with some ~12 UC Davis- and county-based CE researchers, is ideal for investigating all aspects of rice production. In terms of invertebrates, these techniques may affect insect pest populations (and, also perhaps mosquitoes). Insects can respond to minor factors (often times invisible to the “human eye”) when opting to infest areas of a field or

entire fields. Leaf color, light reflectance parameters, leaf shape, temperature, etc. can all drive insects to invade areas or conversely to pass to other areas. Water presence, depth, the surface water vs. plant material ratio, etc. can all play a role. In 2007, plots were maintained with the following variations of rice stand establishment methods: 1.) Conventional water-seeded, 2.) Conventional drill-seeded, 3.) Delayed spring-tilled water seeded, 4.) Stale seedbed (no spring tillage) water-seeded, and 5.) Stale seedbed (no spring tillage) drill-seeded.

In 2007, we monitored pest populations including rice water weevil (RWW) (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study. Data were collected on 20 June (adult scarring) and 30 June and 13 July, 2007 (RWW immatures) using standard methods. For example, adult leaf scarring was determined by examining 100 seedlings per plot and recording the number with feeding scars on either of the two newest leaves and larval samples were collected using five 11.4 cm diameter core samples taken from two sides of the treatment plots with samples processed with a washing-flotation technique to recover the larvae. RWW infestation in this plot was low, with the highest average larval population in core samples being 0.8 per sample and most were in the 0.1 to 0.3 range (the threshold for yield loss is 1.0 RWW per sample). Adult scarring was 5.5% in the water-seeded, conventional treatment and was roughly 3x higher in all the other treatments. I would classify this as a low to moderate population. Compared to the conventional water-seeded treatments, all the other treatments had significantly more scarring from RWW adults. Larval populations were much higher in the drill-seeded treatments (conventional and stale seedbed no-till) than the water-seeded conventional treatments. Previous work has shown that drill-seeding reduces RWW populations because the adults are not attracted to rice during "dry periods". This work was done, however in very small plots and in this situation, the adults were able to move easily to a more favorable environment for oviposition, i.e. flooded. With larger plots as in the systems study, this range of movement may not be possible and the RWW adults may adapt to the drill-seeded situation.

The seeding method and production system may influence mosquito populations. Obviously, by mid-season, all the plots were flooded. However, the amount of residue (such as burnt-down weeds), frequency of draining, timing of flooding, water depth, etc. may all influence mosquito production; the organic matter can provide nutrients that aid in immature mosquito development. Mosquito

populations were monitored in each plot on 12 Sept. 2007 by taking 150 dips with the standard mosquito dipper. Across all plots, populations averaged 4.2 mosquito larvae per 50 dips. Compared to the standard water-seeded treatment, there were ~30-60% fewer larvae in the drill-seeded treatments and ~30% more larvae in the two water-seeded stale seedbed treatments.

Finally, armyworm damage was monitored in each plot on 2 Aug., 9 Aug., 16 Aug., 23 Aug., and 29 Aug, 2007. The percentage damage was estimated and the number of armyworms seen during a 15-minute search period was recorded; no damage or armyworms were found.

RICE WATER WEEVIL SAMPLING FOR COMMERCIAL MONITORING- POSSIBILITIES AND CHALLENGES

❖ L. Espino, UCCE

The rice water weevil is the most important insect pest of rice in the Sacramento valley. Populations vary considerably with year and location. Because of the irregularity of infestations, preventive insecticide applications are not always appropriate. Curative insecticide applications should be based on field population levels. However, current rice water weevil monitoring methods are difficult, time consuming and some are not reliable.

Larval populations can be monitored taking soil core samples. This is not appropriate for commercial monitoring but is effective for research purposes. Adult feeding scars were used in the past to determine the need for insecticide applications. Since the phase out of carbofuran this monitoring method is not recommended. Direct observation of adults is arduous due to their small size (aprox. 1/8") and crepuscular and aquatic habits. Light traps offer a relative measure of the abundance of adults but not a reliable indication of larval populations in the field. Aquatic barrier traps, sometimes used for commercial monitoring, have not been widely adopted.

Given the aquatic habits of adult rice water weevils in rice fields, the use of an aquatic net may constitute an easy-to-use and cost-reliable monitoring method. Early during the 2008 season, aquatic net and soil core samples were taken in two commercial rice fields. The average number of larvae/core per check was regressed against the average number of adults captured with the aquatic net in the corresponding check. Results show that it may be possible to predict larval populations based on the number of adults caught with the

aquatic net or the proportion of aquatic net samples that caught adults (proportion infested). Research using different net types, under different field conditions and during several seasons is necessary before recommending an adult monitoring method.

BAKANAE DISEASE OF RICE

❖ J.J. Oster, RES

(Note: this information with color photos is available as a brochure in the poster display area)

Research on seed treatment chemicals was concluded in 2005. Data has been accumulated on several additional seed treatment chemicals in case bleach is not available in the future. Some work continues on varieties and advanced breeding material susceptibility.

PROGRESS IN BREEDING FOR STEM ROT RESISTANCE

❖ J.J. Oster, RES

For the past six years, stem rot resistant lines have been tested along with current varieties in an inoculated large plot disease nursery. Yields and agronomic traits of several long grain and short grain lines are close to those of current varieties. Results for entries in the 2007 trial are presented below.

Variety	Year	Yield (lb/A)	Lb/A increase	% increase	Stem rot score
L205	2002	9763	--	--	6.0
	2003	9108	--	--	5.3
	2004	8584	6.7
	2005	8165	--	--	5.8
	2006	7444	--	--	6.5
	2007	8298	--	--	6.0
01Y501	2003	9532	424	4.6	3.8
	2004	9323	739	8.6	5.5
	2005	8684	519	6.4	4.7
	2006	7927	483	6.5	5.7
	2007	8146	-152	-1.8	5.1
03Y496	2004	9222	638	7.4	4.8
	2005	9906	1741	21.3	4.0
	2006	9010	1566	21.0	5.2
	2007	8938	640	7.7	4.5
06Y701	2007	10230	1932	23.3	3.7
S102	2002	8989	--	--	5.6
	2003	8139	--	--	4.7
	2004	8152	5.8
	2005	8028	--	--	5.8
	2006	8438	--	--	7.2
	2007	8703	--	--	6.2
M206	2005	7181	--	--	5.7
	2006	8321	--	--	5.9
	2007	9263	--	--	5.4
87Y550	2002	9307	-456	-4.7	3.2
	2003	9138	30	0.3	3.3
	2004	7650	-934	-10.9	3.8
	2005	7811	-354	-4.3	3.8
	2006	8037	593	8.0	4.9
	2007	6499	-1799	-11.7	4.1

87Y550 is an old long grain in the pedigree of most advanced long grain SR resistant lines.

IMMEDIATE BACKCROSS PROGRAM TO TRANSFER BLAST, STEM ROT, AND SHEATH SPOT RESISTANCE

❖ J.J Oster, RES

A new variety with blast resistance was released in 2005 as M-208. It is the second blast resistant variety released in California, and has the major gene Pi-z obtained from the southern variety Lafitte. Major genes for disease resistance largely prevent development of disease lesions on resistant rice. However, major gene resistance can break down within a few years of varietal release. Since only one race of the blast pathogen is present in California, different major genes conferring resistance to this race cannot be distinguished from one another using only this race. But, it is desirable to have more than one major gene available to combat the blast disease. With this in mind, recently developed rice accessions were imported from the International Rice Research Institute (IRRI), which each have one major gene for disease resistance (monogenic lines). Seven lines with genes conferring broad-spectrum race protection were chosen for a rapid backcross program. These lines are likely to be very poorly adapted to California. The aim of the program is to transfer each of these genes separately into an adapted M-206 background by a series of immediate backcrosses while simultaneously screening for blast resistance. Five backcrosses have now been completed. Marker confirmation of the resistance genes has been confirmed by Dr. Virgilio Andaya. Theoretically, they should contain over 98% M-206 genes. These lines are being grown in the field for breeder evaluation. Resistance genes may then be “stacked” (or pyramided) using molecular markers to prevent the blast pathogen from overcoming resistance so easily.

A similar immediate backcross program has been started to transfer stem rot resistance derived from *Oryza rufipogon* 100912 and *O. nivara* 105316 into a medium grain (M-206) background. Both long- and short-grain high yielding resistant lines were used as donors in this transfer. Hopefully, such a procedure will break the linkages which have so far prevented incorporation of this resistance into medium grain backgrounds. Since the inheritance of the *O. nivara* resistance is not known, crosses have been made and genetic studies will be conducted in 2007. So far, the third backcrosses have been made to M-206 from all resistant materials. In addition, starting with the first backcross, advanced generations will also be screened to be sure that the resistance is not lost and/or recessive genes for

resistance are detected. Finally, Dr. Andaya has started research to develop molecular markers, which could detect the resistance derived from *O. rufipogon*.

Finally, sheath blight resistance was found by southern researchers in Jasmine 85, Te Qing, and MCR10277 (Sheath blight is similar to the sheath spot disease we have in California.). There are reports of dominant, single-gene resistance in Jasmine and Te Qing, with the resistance gene being different in each variety. MCR10277 reportedly has two recessive resistance genes. These varieties are also resistant to sheath spot. Unfortunately, Jasmine 85 and Te Qing are of the *indica* race, which does not breed well with the *japonica* race grown in California. A backcross program similar to that being followed for SR (now on BC₃) will be used to transfer this resistance into California-adapted backgrounds. One reason for using these parents is to take advantage of a nation-wide effort to develop markers to detect resistance genes derived from these parents. Recently, a marker was reported to be associated with 24-29% of the resistance found in Jasmine. Further results may enable marker-aided selection.

Molecular markers may make it feasible in the future to combine resistance to several diseases into the same variety. Without markers, multiple disease resistance using conventional screening would be very difficult and slow.

DISEASE SYMPTOM POSTERS

❖ J.J. Oster, RES

Posters describing symptoms of bakanae, stem rot, and sheath spot will be on display throughout the field day program.

❖ Jeffrey Oster is the Rice Pathologist at RES.

THE ORYZA MAP ALIGNMENT PROJECT (OMAP) INTROGRESSION LINES FOR ALLELIC DIVERSITY AND NEW GERMLASM DEVELOPMENT

❖ P.L. Sanchez, D. Kudrna, G. Eizenga, R.A. Wing

The *Oryza* Map Alignment Project (OMAP) has developed a genus-wide model system for the study of rice that will ultimately provide a complete understanding of the genus. The purpose of this project is to capitalize on the strengths of the Arizona Genomics Institute (AGI), OMAP participants and the rice breeding community to continuously

provide, for years to come, useful and previously unexplored germplasm materials to increase rice genetic diversity and initiate new cultivar development. At this point in the project, immediately the AA genome species can be crossed to cultivated rice for creating new diverse genotypes. We will use three approaches: (1) advanced backcross (ABC) populations for allele identification, (2) chromosome substitution lines (CSSL) for analytical introgression of wild germplasm segments using marker-assisted selection (MAS) and (3) construction of the first molecular genetic maps of more distant *Oryza* species for long term mining of useful genes and alleles from rice relatives. The ABC and CSSL populations, MAS and QTL mapping will be used for identifying environmentally useful traits (i.e., cold and aluminum tolerance, stress, drought, etc.), disease and insect resistance, milling quality and yield traits. For particular interest, we selected elite rice cultivars M202, LaGrue and Nipponbare as introgression recipient lines. M202 and LaGrue are grown largely in California and Southern regions in the US; both are in line for alignment re-sequencing to the IRGSP pseudo-molecules that will strengthen their utility and usefulness. Nipponbare was the first cultivated rice genome completely sequenced and has vast molecular resources for downstream research that may involve structural and functional genomics as well as proteomics. The AA genome wild rice accessions are of interest for identification of potential useful alleles and genes as well as for advanced scientific study. Of interest: *O. meridionalis* (IRGC104092), *O. glumaepatula* (IRGC100969) because of their geographical origin (Australia and Suriname) which is different from *O. rufipogon* accession used in CSSL development. In addition, *O. meridionalis* has been reported to have drought tolerance and rare secondary branching. *O. glumaepatula* may provide a new cytoplasmic male sterility source for hybrid rice. *O. meridionalis* (W2112, W1625) from Australia may provide interesting alleles for drought tolerance due to possible evolution of the species in semi-dry environment. *O. barthii* (IRGC101937) has good potential as a donor for abiotic stress tolerance, especially if we consider the possibility of observing transgressive effects. *O. glumaepatula* (GEN1233) was chosen for its good level of aluminum tolerance, which represents a promising trait for cultivating rice on acid soils. In addition, useful agronomic, biotic and abiotic traits from the wild rice species outside AA genome will also be utilized.

MEASURING THE MOISTURE DISTRIBUTION WITHIN A RICE KERNEL USING MAGNETIC RESONANCE IMAGING (MRI)

❖ B. Prakash, S. Asavasanti, J.H. Walton, M.J. McCarthy, J.F. Thompson

Determination of kernel moisture distribution is essential to understanding the rice drying process. Although many theoretical studies have been done to describe moisture distribution, they are seldom compared with the measurements. We have developed a method using Magnetic Resonance Imaging, (MRI) to measure the moisture distribution inside a rice kernel during drying. We dried a single rice kernel (M202) with hot air at 43 °C for eight hours in a 9.4T MRI instrument. Using this technique, we achieved resolution on the order of 100 microns within the kernel. Obtained drying profiles agree with the typical grain drying characteristics where moisture removal rate decreases as drying progresses.

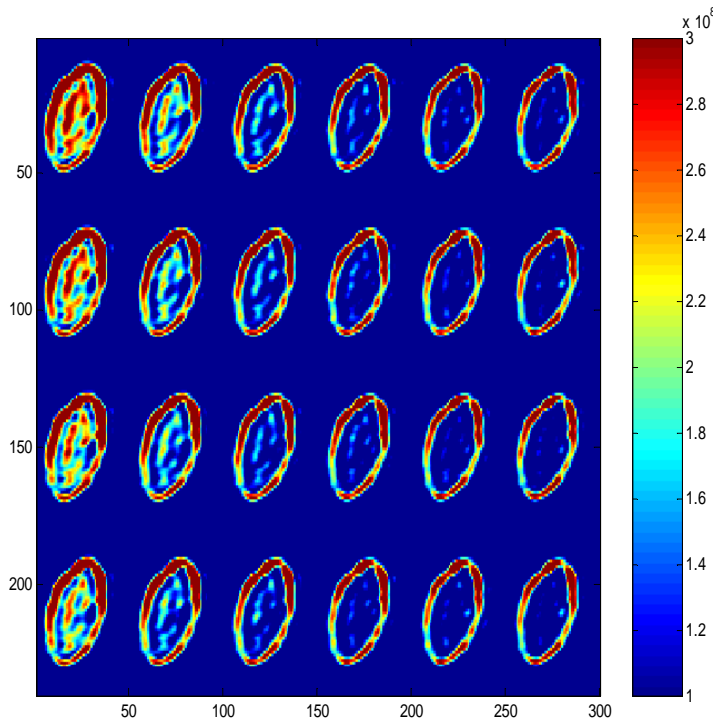


Figure: MRI of a rough rice kernel during hot air drying at 40°C (Higher signal intensity indicates more moisture content)

HEAD RICE YIELD STABILITY OF CALIFORNIA MEDIUM GRAIN RICE VARIETIES

❖ J.F. Thompson, R. G. Muttters, R.E. Plant, UC Davis

Tests at the Rice Experiment Station near Biggs, CA and trials near Colusa and Natomas, CA demonstrated for a second year that California medium grain rice variety M-206 maintains high head rice quality over a wide range of harvest moisture contents, compared to the older M-202 variety, Figure 1. The 2007 season results also indicated it has high head rice quality and high yield when drained about one week earlier than normal. A replicated laboratory test where paddy rice was continuously soaked in distilled water verified that M-206 is less susceptible to fissuring than M-205, which in turn is less susceptible than M-202. Variety M-205 has better stability in head rice quality than the older variety M-202 but less than M-206. If testing over additional seasons and in more growing areas verifies these results, the stability of headrice quality for M-206 will allow the industry to harvest at lower moisture content and reduce column-drying costs.

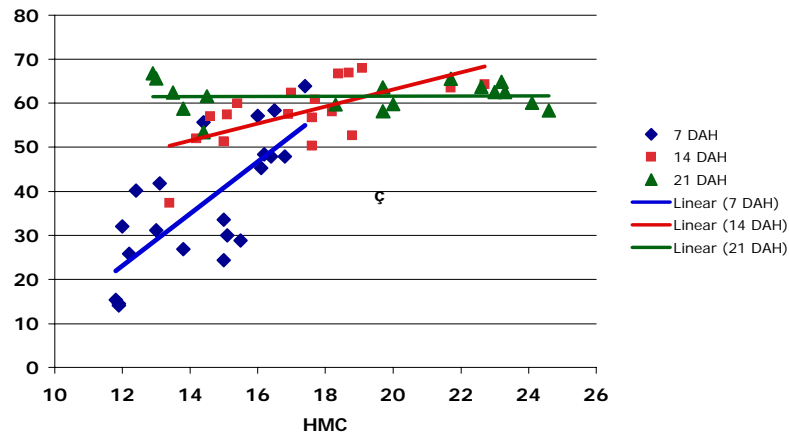


Figure 1. M-206 maintains high head rice yield at a wide range of moisture contents when drained 21 days after 50% heading, typical drain timing. Harvesting one week earlier, 14 DAH, also caused good head rice yield over a wide range of moisture contents. Experiment was conducted at the Rice Experiment Station in Biggs, CA.

TIMING AND PLACEMENT EFFECTS OF P FERTILIZER ON WEED GROWTH IN CALIFORNIA RICE SYSTEMS

❖ M. Lundy, A. Fischer, C. van Kessel, M. Ruark, J. Hill, D. Spencer, R. Mutters, C. Greer, B. Linqvist.

There are more herbicide resistant weeds in California rice systems than in any other crop or geographic region in the United States¹, and weed control via herbicides represents as much as 20 percent of the overall cost of producing rice in California. Improved phosphorus management may lead to greater weed control in this system without an escalation of herbicide regimes. The objective of this study was to determine whether the timing and placement of phosphorus (P) fertilizer applications affects the growth of weed species that are competitive with rice. Studies were conducted on-farm and in controlled pot studies over the course of two seasons.

In 2007 and 2008 we compared the effect of surface applied P to zero P treatments on percent weed cover at mid-tillering in twenty farmers' fields. In 2007, treatments with surface applied P had significantly greater total weed cover (107%), duck salad cover (127%), and waterhyssop cover (498%) than treatments with zero P ($p < 0.05$). In 2008 surface P treatments again had significantly greater total weed cover (47%), duck salad cover (39%), and waterhyssop cover (57%) than treatments with zero P ($p < 0.1$). In 2008 we also compared the surface applied P treatment to an early P treatment (P applied before spring tillage), and the surface P treatment had significantly greater total weed cover than the early P treatment ($p < 0.1$) (Table 1). In 2007 there were no significant differences in soil P at mid-tillering or in rice yield between treatments. Soil analysis for 2008 is ongoing. To date there have been no significant treatment differences in soil P at mid-tillering.

In a 2007 pot study, we compared weed abundance and biomass in pots with three P treatments: zero P, surface applied P, and P buried 2.5 cm. Weed counts from two harvests (the first 21-26 days after planting and the second 28-33 days after planting) were significantly affected by P treatment. Pots with surface applied P had higher percentages of total weeds (132%), smallflower (189%), duck salad (127%), waterhyssop (104%), and redstem (303%) as compared to the zero P treatment ($p < 0.05$). Weed counts in the buried P treatment were between the zero P and surface P treatments. The weed biomass per pot was not significantly different between treatments.

¹ Heap, 2007.

A 2008 pot study replicating the zero P and surface P treatments and replacing the buried P treatment with a winter-flooded P treatment is ongoing.

Based on two years of on-farm and controlled pot studies, we can conclude that the timing and placement of P fertilizer in the soil has a significant effect on weed populations. Small-seeded aquatic weeds such as ducksalad, smallflower and waterhyssop are most dramatically affected by changes in P fertilizer application. Whether their responses are due to effects on germination, vigor, competition or some combination of these is not clear and should be examined further. Pinpointing the effect of P fertilizer on weed populations has the potential to indicate management practices that reduce weed populations in California rice without an escalation of herbicide use.

Table 1. Percent weed cover at mid-tillering as affected by P fertilizer treatment (averaged over all fields, by year and treatment). Significant differences denoted by * ($p < 0.1$).

P Treatment	Ducksalad	Smallflower	Waterhyssop	Total Cover
2007 Zero P	1.12*	3.48	1.21*	9.35*
2007 Surface P	2.55*	4.69	7.25*	19.38*
2008 Zero P	9.42*	2.46	0.56*	12.96*
2008 Surface P1	13.08*	3.97	1.28*	19.06*
2008 Early P	8.49	1.64	0.47	11.32*
2008 Surface P2	9.13	2.89	1.47	14.22*

STRAW MANAGEMENT AND WATER QUALITY IN RICE PRODUCTION SYSTEMS

❖ M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six, R.G. Mutters, C.A. Greer, and J.E. Hill

In California's Sacramento Valley, approximately 200,000 hectares of land is used for rice production. The regulated reduction of rice straw burning has increased the amount of land flooded during the winter, which may increase dissolved organic carbon (DOC) and sediment losses to surface waters. High concentrations of DOC in surface waters have been linked to the formation of trihalomethanes during drinking water disinfection. The overall objective of this study was to determine the effects of straw management on seasonal and yearly DOC and sediment loading from rice production fields into the Sacramento Valley surface waters. Between April 2006 and April 2007, paired fields (straw-incorporated vs. burned) at four locations throughout the Sacramento Valley were studied. Outflows were

measured with pressure sensors and rectangle weirs. Each grower managed their water differently causing a wide range of water losses (10,000 to 450,000 m³ yr⁻¹). At the onset of drainage early in the growing season, incorporated fields had greater (>14 mg L⁻¹) DOC concentrations than burned fields in two of four field sites. However, the flow-weighted (FW) DOC concentrations over the entire growing season were similar among all fields. During winter flooding, incorporated fields had much greater DOC concentrations (24 to 75 mg L⁻¹) than burned fields (7 to 18 mg L⁻¹) at the onset of drainage and maintained higher concentrations through the winter. Yearly losses of sediment ranged from 2 to 1100 kg ha⁻¹. Yearly losses of DOC and sediment were strongly correlated with yearly water loss. The results suggest that yearly losses in DOC and sediment may be more affected by water management compared to straw management. However, straw-incorporated fields had larger seasonal spikes in DOC concentration compared to burned fields, which may contribute to seasonal spikes of DOC concentrations in the Sacramento River.

NITROGEN, PHOSPHORUS, AND POTASSIUM LOSSES FROM FLOODED RICE FIELDS IN NORTHERN CALIFORNIA

❖ M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six, R.G. Mutters, C.A. Greer, and J.E. Hill

Rice production accounts for approximately 200,000 ha of land in California's Sacramento Valley. Dissolved nutrient losses from these flooded fields can have agronomic, economic, and environmental impacts. Increasing nitrogen (N) and phosphorus (P) concentrations in surface waters can cause increase eutrophication and alter natural in-stream processes. Over the past 10 years, management of rice straw has changed from burning to incorporation. While this has likely led to improvements in air quality, little is known regarding its effects on water quality. The overall objective of this study was to determine the effects of straw management on seasonal and yearly N, P, and potassium (K) loading from rice production fields into the Sacramento Valley. Specific objectives were to determine (1) water flux, (2) N loads and flow-weighted (FW) concentrations [as total dissolved nitrogen (TDN), nitrate, ammonium, and organic N], (3) P loads and FW-concentrations [as total dissolved reactive phosphorus (DRP) and total P], and (4) K loads and FW-concentrations [as dissolved potassium (DK)] from burned and straw-incorporated rice fields. Between April 2006 and April 2007, paired fields (burned vs. incorporated) at four locations throughout the Sacramento Valley were studied. The outlets of each field were outfitted with rectangle weirs and pressure sensors to record water flow. Yearly losses of

TDN, DRP, and DK ranged from 0.2 to 8.9, 0.1 to 5.7, and 0.5 to 7.8 kg ha⁻¹, respectively. Yearly FW-concentrations of TDN suggest that incorporated fields would lose greater amounts of TDN compared to burned fields. However, TDN concentrations were noticeably higher during the winter months for incorporated fields, while burned fields had noticeably lower concentrations. There were no apparent differences in DRP and DK between incorporated and burned fields. The total water losses were significantly and positively correlated with TDN, DRP, and DK losses.

THE PHD GENE: DESCRIPTION AND GENETIC CHARACTERIZATION OF A SPONTANEOUS MUTANT OF RICE

❖ V.C. Andaya, C.W. Johnson, J. Lage, T.H. Tai and K.S. McKenzie

Recently, the Rice Experiment Station in Biggs, CA, isolated a spontaneous tall mutant of the California medium grain variety M-206 and initially named as DW-206. DW-206 has a mutation in a gene designated as *Plant Height Discovery* or *PHD* and believed to be different from the *EUI* genes previously characterized in rice. Inheritance pattern in the F1 and F2 generations has determined that *phd* allele is a single recessive mutation.

Initial phenotypic characterization has shown that the *phd* allele confers improved seedling emergence under flooded condition and better stand establishment under water-seeded rice culture. Compared to M-206, the mutant has longer leaves and internodes, and bigger kernels. Experiments comparing plant stands under varying water depths revealed that DW-206 showed faster seedling emergence under deep water compared to the wild-type M-206. The *phd* allele caused the elongation of the lower internodes, allowing the seedlings to emerge faster under submerged conditions. The allele has a potential to contribute to weed competitiveness of rice under direct seeding.

The rice microsatellite linkage map is well-developed and very robust in rice. With the sequencing of the rice genome completed, the development of markers that can be used to detect genes of interest is now routine. Two F2 mapping populations were generated from the crosses DW-206xM-104 and DW-206xM-208 to map the location of the *PHD* gene using microsatellite markers. The rice varieties M-104 and M-208 are both medium grain rice released for California. Based on the DNA fingerprinting of California rice varieties using genetic markers at the USDA-ARS in Davis, CA, microsatellite markers are initially selected based on their polymorphism within the medium-

grain varieties. These markers were then screened for polymorphism using DW-206, M-208, and M-104.

Initial findings showed that the *phd* allele did not map to the location of *eui-1* in chromosome 5 or the *sd-1* in chromosome 1. However, the lack of useful markers in chromosome 10 did not exclude the possibility that the *phd* allele may be similar with *eui-2*. The medium grains types have a relatively narrow genetic base making it difficult to find polymorphic markers to adequately map the *PHD* gene. There is a need to develop additional mapping populations using more diverse parents.

IMPROVEMENT OF CONSISTENCY AND ACCURACY OF RICE SAMPLE MILLING

❖ Z. Pan, J.F. Thompson and B. Prakash, UC Davis

We investigated the effects of rice sample preparation procedures, such as drying temperature, tempering procedure and storage time after drying, on rice milling quality appraisal and developed a quicker rice sample preparation procedure using Infrared (IR) drying.

Rice samples with two initial moisture contents, (MC) of 21.9% and 25.6% were dried to 14% MC with air at three different temperatures, 23, 36, and 43°C. The rice samples dried using air at 36°C and 43°C were dried for 20 min each time and followed by ambient tempering for 4 hours. In addition, the rice dried with 43°C was also tempered in a 43°C incubator. The rice samples were milled with the new standard rice milling procedure after they were stored for 1, 2, 3, 4 and 14 days. Rice dried with 43 °C air followed by heated tempering had higher milling quality compared to the other drying and tempering procedures. The maximum head rice yields (HRY) were achieved when the rice was milled two days after drying. The whiteness of rice samples dried with ambient air was slightly higher than the other drying and tempering procedures, but the observed differences were not significant.

To develop a quicker rice sample preparation procedure using IR drying, rice samples with two initial moisture contents were dried as a single layer using IR heating up to three drying passes. Samples were heated for one minute to achieve about 60 °C. After IR heating the samples were tempered at corresponding temperatures in an incubator for 2 hr before slow cooling. After reaching the required number of drying passes, the rice samples were dried to 14% MC with ambient air. The milling quality was not affected for low MC rice with

two drying passes or high MC rice with three passes. The two and three drying passes removed 5.4 and 9.5 percentage points of MC for the low and high MC rice respectively. After the IR drying, the moisture contents of dried rice were 17.5% and 16.1%, which is close to 14%, that is required for rice milling. The results indicate that rice milling samples can be prepared by using IR drying with much reduced drying time.

**FIELD TOURS
OF
RESEARCH**

Rice Variety Development

The RES breeding program consists of four research projects. Three rice breeding projects focus on developing adapted varieties for specific grain and market types and are each under the direction of a RES plant breeder. The rice pathology project, under the direction of the RES plant pathologist, supports the breeding projects through screening and evaluating varieties for disease resistance, rice disease research, and quarantine introduction of rice germplasm for variety improvement. All projects are involved in cooperative studies with other scientists from the UC, USDA, and industry including off station field tests, nurseries, quality research, and biotechnology. Brief highlights of the RES breeding program are discussed here and will be presented during the field tour of the breeding nursery.

Long Grains (Farman Jodari, Plant Breeder, RES)

The objective of the long-grain project is to develop superior conventional long-grain and specialty long-grain varieties for California. Main emphasis in the conventional (southern) long-grain breeding category includes superior cooking quality, yield potential, milling yield, milling yield stability, cold tolerance, seedling vigor, and disease (stem rot, blast, and aggregate sheath spot) resistance.

L-206, A very early to early maturing conventional long-grain variety, was released in 2006. L-206 has shown improved cooked grain texture, higher grain yield, and slightly lower head rice yield as compared to L-204. Average heading date is 5 days earlier than L-205 and M-202. Plant height is 6 cm shorter than L-205 and 11 cm shorter than M-202. L-206 has slightly stronger amylographic profile, as shown by higher cool paste viscosity and RVA setback values. Consequently cooked grain texture of it is less sticky than L-204. Similar to Southern long grain, L-206 has intermediate amylose and gelatinization temperature types.

Grain yields of L-206 compare favorably with L-205 and M-202, average yields in 2007 Statewide trials for L-206, L-205, and M-202 was 9310, 8720, and 8510 lb/acre, respectively. It is adapted to most of the rice growing regions of California except the coldest locations of Yolo and San Joaquin counties and the warmest locations of Glenn County. Average head rice yield of L-206 is 62%. Fissuring studies indicate that L-206 is significantly more resistant to grain fissuring than L-204, indicating a better milling yield stability at lower grain moisture contents.

A number of promising experimental long grains, including 06-Y-513 and 04-Y-706, have shown excellent agronomic, cold blanking resistance, and quality traits. Both of these lines have higher milling yield and similar grain yield and cooking quality as L-206. Yield performance of conventional long grain lines being tested in multi-location statewide trials have significantly increased in recent years. Average yields of the 6 best long grain entries ranged from 105 to 119 percent of standard medium grain variety M-202 during 2004 to 2006 (RES annual reports). During the cool to moderate temperatures in 2007 season, both L-206 and experimental line 06-Y-513 have maintained same yield levels as in previous warmer years.

The genetic base of long-grain breeding material at RES has significantly increased in recent years through the use of germplasm from Southern US and world collection sources. This diversity is being used to incorporate the desirable agronomic and quality traits in the elite California lines. The 2007 growing season with a lower than average 'Degree Day' accumulation provided an excellent opportunity to identify and advance long grain breeding lines with better adaptability to cooler climates.

Specialty long grain breeding efforts were expanded in 2007, as market demand for these types continued to increase. Currently, efforts are underway to develop soft cooking aromatic jasmine, elongating aromatic basmati, and conventional long-grain aromatic types adapted to California.

Calmati-202, An early maturing basmati type variety was released in February 2006. Quality improvements in this variety include more slender kernels, higher cooked kernel elongation ratio, and more flaky grain texture. Similar to Calmati-201, this variety is adapted to warm growing areas. Grain yield of CT-202 has averaged 6740 lb/acre, which is 73% of L-205 and 74% of M-202 yield potentials. Head rice yield recovery of this variety is considerably lower than standard varieties due to its slender grain shape, averaging 58%. This line has a semidwarf pubescent plant type with good seedling vigor. Maturity is similar to CT-201 at 93 days to 50% heading. Milled kernels of this variety are longer and narrower than CT-201 but not as slender as imported basmati.

Grain fissuring studies have shown that both CT-201 and CT-202 are susceptible to fissuring at low harvest moistures. Timely harvest and proper handling is recommended to preserve milling as well as cooking qualities of this variety. Due to slender grain shape and pubescent hull and leaf, drying rate of the grain at harvest is

significantly faster than standard varieties. Recommended harvest moisture is 18%.

Several basmati lines including 07-Y-152 are being tested in 2008 statewide trials that have shown cooking qualities that are nearly indistinguishable from imported basmati types. Grain and milling yields of these lines, however, seem to be similar to or lower than CT-202. Their adaptability thus far is limited to warmer rice growing region. Breeding efforts is now directed toward improving yield and milling of these lines while maintaining their desirable basmati type qualities.

Efforts were significantly increased in jasmine type breeding in 2007. Conventional pedigree and mutation breeding methods are being used. Jasmine type germplasm lines from southern breeding programs and foreign introductions including the original Thai Jasmine variety, 'Khao-Dawk-Mali 105', are being utilized. A number of early mutants as well as lines derived from crossing have been obtained and are currently being evaluated in preliminary yield tests. Entry 02-Y-710 is a Jasmine type mutant with excellent aroma (>2000 PPB 2-AP aroma compound), cooked grain texture and intermediate maturity. Further improvements in the milling quality of this line are underway. Four jasmine type and 2 conventional aromatic selections are being tested in 2008 statewide trials.

Stem rot resistance research and breeding efforts continue to combine improved stem rot resistance, low blanking, and early maturity. Several moderately resistant advanced lines including and 03-Y-496 and 07-Y-534 have significantly out-performed susceptible checks such as L-205. Five stem rot resistant lines are currently being tested in 2008 statewide trials.

RES is also participating in "RiceCAP" project which is a new USDA initiative with the objective of applying genomic discoveries to improve milling quality and disease resistance in rice. RES is taking part in extensive fissuring studies for this project as well as phenotyping MY3, a California long grain milling population. An update of the RiceCAP-California efforts is presented in a 2008 Rice Field Day poster as well as the RiceCAP web site at <http://www.uark.edu/ua/ricecap>. Funding for California RiceCAP group has been extended through December 2008 to complete a second year of phenotyping of the MY3 milling population.

Medium Grains (J. Lage, Plant Breeder, RES)

The Calrose Medium Grain Rice breeding project has undergone several changes since the retirement of Dr. Carl Johnson. These changes are mainly adjustments to the breeding methodology, the objectives of the project largely remains identical.

Yield will continue to be the most important trait in Calrose Medium Grain Rice. Given the current commodity prices there is a real incentive to grow high yielding medium-grain rice. Data from the Statewide Yield Test 2007 showed that over four locations M-206 yielded 15% more than the long time favorite M-202. 18 years of breeding separates the release of these two varieties and should serve as a clear example of the value of a viable rice breeding program in California. In breeding circles it is widely acknowledged that the higher yield gets pushed the harder it becomes to make additional progress. Only through continuous incorporation of “new blood” combined with improved breeding technologies can we hope to push the boundaries even further.

Second to yield is milling yield. From our foundation fields in 2007 M-202 and M-206 showed very similar milling yields around 67% whole rice at 20% harvest moisture, but as the rice dried down to 16-17% the milling yield of M-202 dropped to around 62% whereas M-206 more or less maintained its high level of milling. This tolerance to breakage at low harvest moisture is also observed in M-205, and together with Dr. Jim Thompson from the UC Davis Biological & Ag Engineering Department we are trying to understand the factors contributing to this improved milling. One thing is certain and that is that letting the rice dry in the field with minimal penalty in milling yield may become a very attractive alternative to drying the rice after harvest given the current energy costs, not only saving money but also benefitting the environment.

The further south in the Sacramento Valley rice is grown the more important resistance to cold blanking becomes. M-205 is likely our highest yielding variety in the northern part of the rice growing areas, but in test plots in the San Joaquin area blanking as high as 75% was observed in this variety in 2007. M-104, which is the preferred variety in the southern parts, still blanks up to 20% with M-206 being a little better. Tolerance to blanking will continue to be a very high priority in the Calrose Medium Grain Rice project with the aim of decreasing blanking to around 10% in the future.

Next on the list of important traits in Calrose Medium Grain Rice are resistance to lodging and tolerance to stem rot. These are two very difficult traits to work with and may well be interconnected, with lodging caused by weakening of the stem due to stem rot. A vigorous backcrossing project is underway in collaboration with RES pathologist Jeff Oster focusing on disease rating and keeping track of all the crosses and with Dr. Virgilio Andaya working on identifying molecular markers associated with tolerance to stem rot. Success of this project will be of immense importance to growers of Calrose Medium Grain Rice.

Blast luckily never became a large threat to the rice industry in California but can still be a problem locally in blast “hot-spots.” With the release of blast-resistant M-208 in 2006, rice growers in such hot-spot locations now have a very efficient way of securing themselves against loss due to blast. Given the facts that blast is not a statewide issue and that M-208 efficiently addresses the issue, breeding for future blast resistant Calrose Medium Grain Rice has been down prioritized thereby freeing resources to other focus areas.

Although Calrose Medium Grain Rice is not targeted to the premium-quality rice market, any future Calrose rice will naturally have to meet the standard of cooking and eating quality. With introduction of new genetic variability to boost yield or increase stem rot tolerance, we will have to closely monitor the impact on quality to ensure we maintain the well-known standards of Calrose Medium Grain Rice.

Promising Experimental Lines

A very early and an early experimental line are in the final stages of testing before being considered for release. 05-Y471 is a very early rice with M-104 as one of the parents. Over four locations it yielded 4% more than M-104 blanked 3 percentage points less, had 1 percentage point higher head rice, and “only” had 60-70% lodging compared to the almost flattened M-104 in the test plots.

05-Y724 is an early experimental line with M-206 as one of the parents. This line yielded on average 2% more than M-206 in the statewide test, had similar tolerance to blanking and lodging, and about 1 point better head rice.

Both experimental lines are planted in seven locations in the statewide test in 2008 and in small increases at RES. The yield and quality data from 2008 will show if one or both of these continue to

perform well, and the larger increase will ensure sufficient rice for large strip trials next year if needed.

The tall mutant of M-206 (plant height discovery *phd*) is still being evaluated in collaboration with the UC Davis team lead by Dr. Albert Fischer. It remains uncertain if the added 4-6 inches in plant height significantly improves this experimental line's ability to tolerate increased water depth as a way of controlling certain weed species. Further evaluation is needed and no eminent release of a tall Calrose Medium Grain Rice is planned.

Short Grains & Premium Quality (V.C. Andaya, Plant Breeder, RES)

The short grains and premium quality (SGPQ) rice breeding project is in charge of the development of improved rice varieties for the following quality types and specialty rice: 1) conventional short grains, 2) premium quality short grains, 3) premium quality medium grains, and 4) specialty rices that include waxy (mochi) short grains, low amylose short grains, and big-seeded (Arborio-type) rices. Though breeding goals vary for the different grain, quality, and specialty types, conventional breeding methods (as well as non-conventional methods) such as mutation breeding and DNA-marker technologies are being employed in order to meet the challenges of producing superior rice varieties that combine high yield potential, improved milling yields, premium grain quality, disease resistance and adaptation to low temperature environments.

The market for short grains, premium quality and specialty rice remains an important component of the California rice industry. The standard conventional short grain variety, S-102, remains to be the predominant regular short-grain in commercial production in California. This variety has high yield potential, very early maturing, is resistant to blanking and has large kernels. It has been a consistently high yielding check variety in the very early advanced group of the UCCE Statewide Yield Test. S-102, however, is very susceptible to stem rot and has a rough (pubescent) hull. The primary breeding goal for the conventional short grain, therefore, is to capture the excellent agronomic characteristics of S-102, and incorporate stem rot resistance and smooth (glabrous) hulls. Combining these traits proved to be a difficult task and the advanced lines with smooth hulls and disease resistance that were tested in the statewide yield trials failed to surpass the performance of S-102. Since last year,

parental materials used for crossing work are carefully evaluated and the strategies for selecting progenies are being developed and streamlined to move forward the conventional short grain varietal development.

In today's market, there is always a demand for premium quality rices. Thus, breeding for premium quality short and medium grain rice varieties remains the primary focus of this project. Premium quality rice is defined as the type of rice that cooks very glossy and slightly sticky, has a smooth texture, tastes tender and slightly sweet, has subtle aroma, and remains soft after cooling. These cooking and eating quality characteristics are exemplified by the California medium-grain cultivar M-401 and the Japanese premium short grain varieties Koshihikari. Premium quality is culturally defined and breeding for locally-adapted, high-yielding premium quality rices continues to be a difficult challenge.

The rice variety Calhikari-201 is the first premium quality short grain variety developed and released by the Rice Experiment Station for California. It was derived from a cross using Koshihikari and S-101 as parents. This variety has high yield potential, good seedling vigor, early maturity, lodging resistance, and its grain quality approaches that of Koshihikari. Premium quality Japanese varieties are being used extensively in crossing to capture their excellent grain quality to be incorporated into the adapted short grain varieties. The premium quality short-grain experimental line, 04-Y177, is being evaluated for yield potential and agronomic performance in more statewide yield test locations this year. 04-Y177 heads earlier than Calhikari-201 and has higher yield potential. The cooking quality evaluations by a number of testers so far yielded positive feedback. More stringent tests will be performed this year to confirm this line's consumer acceptability.

The breeding for premium quality medium grain (MPQ) rices aims to capture the excellent grain and cooking characteristics of M-401. Lines are selected agronomically based on early maturity, high seedling vigor, resistance to blanking and lodging, synchronous flowering, and high milling yields. Cooking tests are given heavy emphasis in the selection process. This year, a total of twelve MPQ entries are being tested in the Statewide Yield Test. These experimental lines will be compared with the performance of the check variety M-402 in terms of yield potential, agronomic characteristics, and grain quality.

The breeding for specialty rices are divided into three groups: a) waxy short grain, b) low amylose short grains, and c) big-seeded (Arborio-type) grains. Calmochi-101 is currently the one that is widely grown among the mochi rices developed at the station. It has a very high yield potential and better resistance to blanking but has rough hulls. Emphasis is given in breeding for smooth hulls while maintaining the large kernels. Three advanced experimental lines are being tested statewide this year. Amylose content is considered as a major determinant of eating, cooking, and processing quality of rice. The rice variety Calamylow-201 is the first low-amylose (7%) variety developed for California and is a mutant derived from Calhikari-201. Compared to Calhikari-201, it has reduced grain weight and panicle size and has a lower yield potential. Improvements on the agronomic characteristics of Calamylow-201 are being made. Breeding for big-seeded grains similar to the Italian variety Arborio is making progress. Agronomic and milling performance of advanced lines tested so far are far superior to Arborio. However, standard quality evaluation still has to be defined for consumer groups and marketing organizations.

The DNA marker laboratory at the rice experiment is up and running with the acquisition of a DNA sequencer. Testing and development of molecular markers is for application in marker-assisted selection primarily on rice blast resistance, accurate classification of lines to specific grain quality groups via the *Waxy* gene, identification of introgressed regions from the stem rot resistance donor *O. rufipogon*, and mapping of the *PHD* gene. As a long-term goal, the DNA marker lab will develop procedures to identify, and develop molecular markers to select for traits such as blast and stem rot resistance, cold tolerance, grain quality, and other important traits, and devise ways to efficiently implement a marker-assisted selection scheme for all projects at the station.

Disease Resistance (J. Oster, Plant Pathologist, RES)

Lines with resistance derived from *O. rufipogon* and good agronomic traits have been obtained in short and long grain but not medium grain backgrounds. A large-scale rapid backcross program has been started to transfer resistance in adapted short and long grain lines to medium grains (now at BC₄). Screening of temperate rice germplasm has failed to identify any other good sources of SR resistance. Resistance from two lines derived from *O. nivara* have also been

entered in this program. A study is being continued in 2008 to determine mode of inheritance. Experimental lines derived from SR resistant populations are currently under evaluation in the statewide and preliminary yield tests. Under disease pressure, some materials yield 10-20% more than present varieties.

Major gene blast resistance almost completely suppresses disease, but this type of resistance tends to break down in varieties after several years. A rapid backcross program has been started (now at BC₆) to incorporate more than one gene for resistance and other forms of resistance into future varieties to avoid this problem (see report in poster section of this booklet). Considerable time is necessary because non-adapted varieties must be used as sources of resistance. The station has purchased equipment for molecular-marker-aided selection and is setting up a functional lab. Dr. Virgilio Andaya has identified good markers for the seven genes being transferred. This would allow screening for resistance genes without presence of the fungus. It would also allow detection of more than one resistance gene in a single variety, which is not possible by screening with the one race now present in California.

A backcross program to transfer sheath spot resistance from Jasmine 85, MCR 10277, and Teqing is now at BC₄. The Rice CAP program has identified a marker associated with about 25% of the sheath blight resistance in Jasmine 85. This marker may be useful in transferring sheath spot resistance as well.

Bakanae disease was discovered in California 1999. Field and greenhouse studies have determined incidence and potential for economic damage. The disease has spread throughout most of the rice growing region, but incidence in 2003-8 in most fields was low (less than a percent affected seedlings), except where seed treatment was not used. Research indicates that planting seed from diseased fields can result in a 5-60 fold increase (average of 13) in affected seedlings. Since this disease is seed-borne, significant control can be obtained with the use of seed treatment chemicals. Use of bleach can greatly reduce seed lot infestation. See the bakanae brochure (copies available in poster area) and the poster section of this booklet for more details. All statewide yield trial entries are screened for bakanae resistance.

Greenhouse facilities at RES are in full use. Stem rot, sheath spot, blast, and bakanae research is being conducted in this facility. This

greenhouse allows greatly expanded disease screening efforts and other breeding research.

Improved Methods to Combat Rice Crop Invertebrate Pests and to Assist with Mosquito Management in Rice Fields (L. Godfrey, K. Basuta and W. Pinkston)

Research was conducted in 2007 on the biology and management of key invertebrate pests of California rice. Concentrated efforts continued on rice water weevil (RWW) and limited studies were continued on armyworm (AW), two important rice arthropod pests of rice in CA. In addition, research was done on two early-season pests of seedling rice, seed midge and tadpole shrimp. The goal was to refine IPM schemes for these pests and to maximize the management in light of the environmentally sensitive nature of the rice agroecosystem. The cost effectiveness of any management efforts in rice must also be carefully considered. Four overall themes provided direction for the 2007 research program. Follow-up studies are in progress in 2008, but most results are not yet available.

- 1.) CA-DPR is currently placing pyrethroid insecticides into reevaluation based on their propensity to accumulate and move off-site on organic sediment. Therefore, studies continued to develop alternative active ingredients and classes of chemistry for arthropod pest control.
- 2.) Best Management Practices have been developed and put forth for the industry to aid in mitigation of mosquito populations. This area has taken on added importance with the emphasis on West Nile Virus in California. A study was continued to evaluate the effects of registered and experimental rice insecticides on non-target invertebrates, which could play an important role in mosquito management in rice fields. As part of this, possible changes in rice seeding methods were studied and the role of these changes in mosquito populations monitored.
- 3.) Early-season invertebrate pests were more common in 2007 than in recent years. To respond to grower questions about control of these pests, studies were done on seed midge and tadpole shrimp control.
- 4.) Exotic pests moving into California are unfortunately becoming a more common occurrence. Thus far, the rice system has avoided being infested by several potentially serious invertebrate pests that occur in other parts of the U.S and in other countries. The rice panicle mite was found in the southern U.S. rice belt in 2007.

Samples from California were processed for this pest, and so far, there has been no occurrence of the panicle mite in California. Communication and education on this pest was hastened in 2007.

Rice Water Weevil: Studies were conducted in 2007 in ring plots to evaluate experimental materials versus registered standards for RWW control and to modify the use patterns of the existing products to facilitate management. Twenty treatments (using a total of eight different active ingredients) were established in ring plots to accomplish this research. Research continued on four experimental insecticide active ingredients; etofenprox (Trebon®), indoxacarb (Steward®), rynaxypyr, and clothianidan. In summary, etofenprox, indoxacarb, and clothianidan all appear to have significant potential for RWW management. All these products are a few years from any possible registration. Idoxcarb is active via a post-flood application whereas clothianidan has the most flexibility in terms of application timing. Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. These active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc. In these studies, Dimilin, Warrior (preflood and 3-leaf), Trebon (etofenprox) (3-leaf), V10170 (clothianidin) (preflood+3-leaf, preflood only, and 3-leaf only), Mustang Max, and Steward (indoxacarb) (0.11 rate) significantly reduced the RWW populations compared with the untreated plots. The best control was a 95% reduction in larval populations. The Trebon 3G preflood applications were not effective; it had shown some promise in testing in 2005 and 2006, but it appears that the 3-leaf stage application is going to be the preferred application method for this product. The Clorox seed soak (used for Bakanae control) greatly affected the activity of V10170 seed treatment; the soaked treatment was largely ineffective whereas without the Clorox soak the activity was good. This was not observed in studies in 2006. The E2Y45 (rynaxypyr) seed treatment was largely ineffective, although these seeds were similarly soaked in Clorox. This likely affected the activity. Additional studies concentrated on E2Y45 seed treatment in 2008; this product is registered as Dermacor for use in southern Rice under a Section 18 registration. Only Warrior was evaluated, among the pyrethroids, as a preflood application in 2007. In summary, the early preflood application of Warrior (1 week before flooding) provided only about 50% control, whereas the preflood application immediately before flooding was equally effective as the 3-leaf stage application. We have generally had excellent results with an application made up to 7

days before flooding, but there have been some inconsistencies in control with this application at the longer intervals before flooding. Environmental conditions between application and flooding undoubtedly influence the residual control results. It appears that those undefined conditions reduced efficacy in 2007. Warrior was registered for use with this application method in 2007. Aza-Direct, a neem-based product containing azadirachtin, was evaluated and provided RWW control in the 50% range.

The effects of insecticide treatments in rice on populations of non-target invertebrates and mosquitoes were studied. I believe it is important to continue an effort in this area as long as West Nile Virus is prevalent and an issue in northern California. Summarizing the last 3-years we have done this research, a pre-flood Warrior application reduced populations of aquatic insects compared with the untreated for the first week after application but not thereafter. Seven treatments applied at the 3-leaf stage were compared and V10170 and Mustang reduced aquatic insect populations at 2 and 3 weeks after application; averaged over the 5-week period following application, all the treated plots had levels of aquatic insects equal to or greater than in the untreated. Warrior was evaluated as a representative material that could be applied against armyworms in July and this treatment was very damaging to populations of aquatic insects at 1 and 2 weeks after treatment.

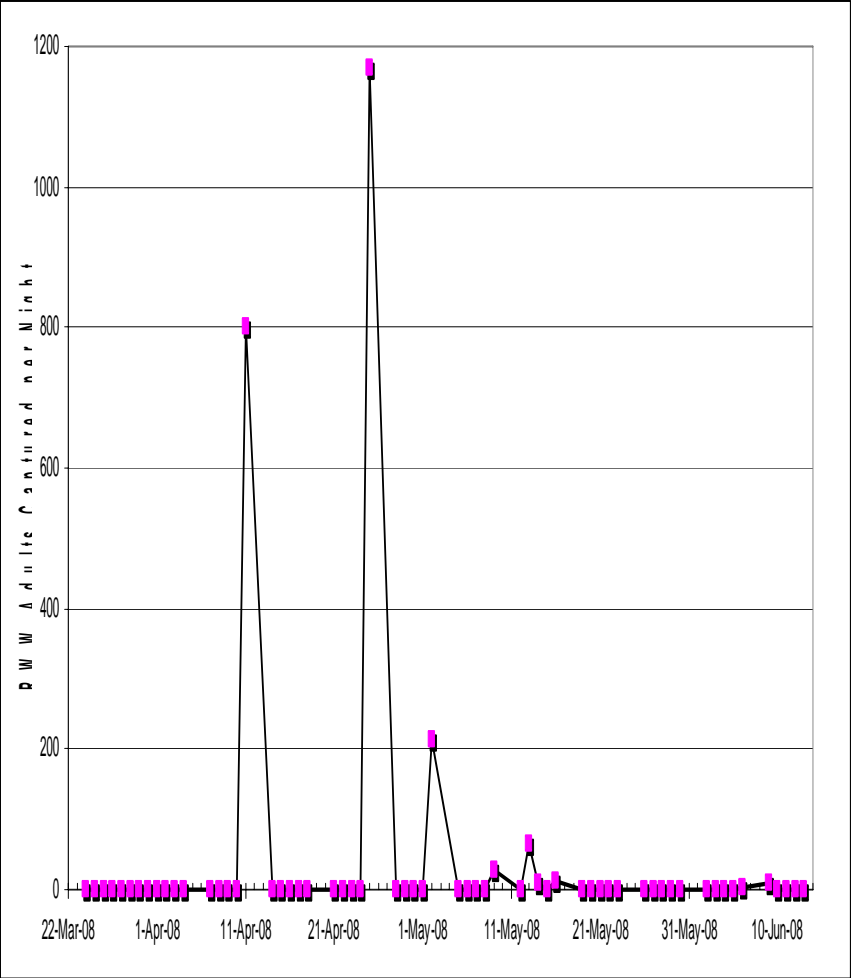
RWW biology was studied in terms of adult flight, relative susceptibility of commonly grown rice varieties to RWW infestation and to yield losses, and the influence of rice seedling establishment methods on RWW population severity. The RWW flight was fairly spread out in 2008; the first flight peak was on 11 April, followed by 25 April, and 2 May to 16 May. Even a few RWW adults were still flying on 12 June. The total of 2300 RWW adults captured was comparable to 2007. Twelve rice varieties were compared for susceptibility to and yield loss from RWW in field plots with a moderate natural infestation in 2007. M-104, M-206, M-202, and S-102 had the highest levels of RWW leaf scarring and these same varieties, along with Calamy-low-201, had the highest larval populations. S-102 was most responsive with a severe negative yield loss to RWW infestation, Calhikari-202 and Calamy-low-201 were moderately responsive, and the PI line, M-206, and M-202 showed slight yield losses. The other six varieties showed no yield losses across the levels of RWW present in these plots. In ring plots infested with RWW, ~1/3 as many larvae survived on Calmati-202 compared

with the other three varieties but grain yield losses were highest in Calmati-202 on a loss per larva basis.

Armyworm Biology and Infestations in Rice: Armyworm larval populations and damage were monitored in two studies at the RES and were too low to draw meaningful conclusions.

Early-Season Invertebrate Pests: Tadpole shrimp populations occur in many rice fields and damage can range from minimal to severe. In recent years, there have been reports that copper sulfate is not reducing shrimp numbers as well as previously. Recent results from Board funding showed the interaction of rice straw residue and reduced algal control with copper sulfate; this may also explain the lack of shrimp control in some cases. Seven registered and experimental insecticide treatments were evaluated in ring plots infested with tadpole shrimp. Stand counts showed that numerically the lowest stand count was in the copper sulfate treatment and the highest value was in the Dimilin treatment. Seed midge populations were unexpectedly high in the spring of 2007. This pest is generally worse during cool springs when the rice struggles to germinate and to establish; conditions which generally were not present in 2007. The unpredictable nature of this pest makes it a difficult subject on which to conduct research, but we flooded a field and delayed seeding to try to facilitate populations. There were no significant differences in stand counts or yield among treatments in this study and no clear sign that the pest was present.

2008 Rice Water Weevil Flight



Rice Weed Control: Herbicide Performance, Combinations, New Chemicals, and Weed Management (A.J. Fischer, Associate Professor, Weed Science Program, Department of Plant Sciences, J.W. Eckert, Staff Research Associate IV, J.E. Hill, Rice Extension Specialist, H. Yasuor, postdoctoral researcher, M. Milan and A. Ortiz are visiting scientists, L. Boddy and C. Marchesi are PhD. Students, S. Johnson, SRA I.

Our field program includes the testing of herbicides, their mixtures and sequential combinations for the rice growing systems that currently prevail in California. Experiments consisted of water-seeded continuously flooded rice, pinpoint systems, drill-seeded systems and alternative establishment systems. At this year's field day we will show highlights of our weed control experiments conducted on the Rice Experiment Station's (RES) Hamilton Road field. In addition, our research effort also includes a large area (J-9 field) at the RES plus one cooperating grower's field heavily infested with multiple-herbicide resistant late watergrass ("mimic"). We continue to test new products and to assist the rice industry in the registration of new herbicides as options become available. We have a strong emphasis towards the diversification and sustainability of weed management in rice, thus we continued work on a long-term field experiment with new alternative rice-stand establishment systems in order to develop novel but feasible solutions for controlling herbicide-resistant weeds. Our efforts seek to assist California rice growers in their critical weed control issues of preventing and managing herbicide-resistant weeds, achieve economic and timely broad-spectrum control and comply with personal and environmental safety requirements.

Continuous flooded rice:

This system intends to maximize weed suppression by flooding, notably the elimination of barnyardgrass and sprangletop as problems. After seeding into a flooded field, water depth is maintained at 4 inches throughout the season. When late post-emergence applications are needed, water is lowered to expose about 70% of weed foliage to the herbicide spray, but fields are never drained. Watergrasses (early and late) were the predominant weeds, followed by ricefield bulrush, duckweed, monochoria and waterhyssop. Super Wham (6qt/a + 1.25% crop oil concentrate

(COC)) applied when most weeds had emerged (1-3 tiller stage of rice) provided excellent broad-spectrum weed control. However, since early weed control is essential to maximize yields, other excellent treatments were Cerano (12 lb/a) applied at the day of seeding (DOS) either followed by Granite GR (15 lb/a) at the 2-3 leaf stage of rice (lsr), Regiment (0.66 oz/a) or Super Wham (6 qt/a) at the 1-3 tiller stage of rice. Alternatively, another excellent program was the early (2-3 lsr) application of Granite GR (15 lb/a) followed by propanil (Stam 80 EDF at 7.4 lb/a + 2.5% COC); if water level drops and sprangletop becomes an issue, Granite can be followed by Clincher (15 oz/a) at 1-3 till.

Pinpoint flood rice:

Often, cold weather or windy conditions in spring require early field drainage to favor rice establishment, which precludes the use of into-the-water treatments. In this experiment, weeds were controlled by foliar herbicide treatments applied during a period of field drainage for good weed exposure to the herbicides. Prevailing weeds were early and late watergrass, ricefield bulrush, ducksalad and waterhyssop. Excellent overall treatments in this non-resistant site were Regiment (0.54 oz/a) alone or in tank mix with Abolish (1.5 qt/a) applied at the 3-4 lsr. Ricefield bulrush was difficult to control in this experiment and good treatments for this weed were mixtures containing Super Wham (4 qt/a), Regiment (0.54 oz/a), or Halomax 75 (Halosulfuron; 1.33 oz/a + 0.5% non-ionic surfactant) all applied at the 3-4 lsr.

Drill seeded rice:

This is the system that offers flexibility for herbicide use when proximity to sensitive crops impose restrictions to aerial applications. Drill-seeding favors weeds adapted to dryland seedbeds (sprangletop is typically problematic) and is less favorable for aquatic species (ricefield bulrush, ducksalad, redstem), and is thus useful for alternation with water-seeded systems when the pressure of aquatic weeds becomes problematic.

Prowl is a pre-emergence herbicide that can protect from weed emergence after seeding rice during the period prior to the installation of the permanent flood. It controls watergrass, barnyardgrass, and has some activity on smallflower umbrellasedge. Other good sprangletop herbicides are Abolish, and Clincher. Main weeds in the experiment were the *Echinochloa* complex and sprangletop. But overall, weed control in this experiment was obtained with the watergrass synergized mixture of Abolish +

Regiment (1.5 qt/a + 0.45 oz/a; 2-3 lsr) followed by Super Wham + Whip (6 qt/a + 6 oz/a + 1.25% COC applied post permanent flood). Other good overall treatments were Granite SC (2 oz/a + 2.5% COC; 2-3 lsr) followed by Clincher (15 oz/a + 2.5% COC); Clincher (13 oz/a + 2.5% COC) followed by Super Wham (6 qta + 1.25% COC; post permanent flood); Abolish (2 qt; pre-emergent after the first germination flush) followed by Regiment (0.22 oz/a + 0.125% non-ionic surfactant; 2-3 lsr); or Super Wham (6 qt/a + 1.25% COC) and Prowl (2 pt/a pre-emergent after the germination irrigation flush) followed by Super Wham (6 qt/a + 1.25% COC).

Herbicide resistant weed management:

Three experiments were conducted in a cooperating grower's field in Glenn County that is heavily infected with multiple-herbicide-resistant late watergrass. In a water-seeded and continuously flooded system, Cerano (12 lb/a applied at the day of seeding) followed either by Super Wham (6 qt/a + 1.25% COC) or Granite SC (2.4 oz/a + 1.25% COC) or Regiment (0.79 oz/a + 0.125% silicon based surfactant) applied when rice is at the 4-5 lsr. Other weeds (ricefield bulrush and ducksalad) were also well controlled, although Regiment was weaker on ricefield bulrush. Other excellent treatments in this system were Granite GR (15 lb/a; 2-3 lsr) followed by Super Wham (6 qt/a + 1.25% COC).

At this same site, a stale seedbed technique was implemented in conjunction with pin-point herbicide use (field drained for early post-emergence applications). The field was spring tilled and irrigation was applied in early May (shallow flood) during 10 days to encourage weed emergence. Then Roundup (2% + 2% UAN) was applied over the entire area of the experiment. By August 5, this Roundup application accounted for 100% control of watergrass and sprangletop. Later emergence of weeds that were not exposed to the Roundup spray (ricefield bulrush, smallflower umbrellasedge and ducksalad) was controlled when rice was at the 3-4 lsr with either Super Wham (4 qt/a + 1.25% COC), Granite SC (2 oz/a + 2.5% COC), or Regiment (0.79 oz/a + 0.125% silicon based surfactant). This same stale seedbed technique followed by a Granite SC + Clincher (2 oz/a + 15 oz/a + 2.5% COC) was also employed with success in the remaining area of the 10 acre field where the experiment was conducted.

Herbicide resistant weed management systems in rice using alternative stand establishment techniques:

Five alternative stand establishment techniques were employed for four consecutive years. These systems highlighted the advantages of

each in the shift of the weed seedbanks throughout the years. This season, the techniques were switched to take advantage of the impact the new system would have on weed recruitment and the established seedbank. Water-seeded systems tend to favor aquatic weeds while dry or drill seeded systems tend to favor aerobic/dryland weeds. Added to the two basic techniques is the use of a stale seedbed where weeds are encouraged to germinate prior to seeding the crop then eliminated with a total herbicide like glyphosate ("stale seedbed" technique). This dramatically reduces the weed pressure on the crop as long as the soil surface is not disturbed after the stale seedbed glyphosate application.

This year, plots from this experiments received alternative treatments to validate the potential of shifting aerobic and anaerobic stand establishment, and the value of implementing a stale seedbed with glyphosate to deplete fields from all kinds of herbicide resistant weeds. Thus, plots where rice had been conventionally water-seeded were heavily infested with aquatic weeds. Weeds almost disappeared from these plots when rice was drill-seeded (no-till) following a stale seedbed with Roundup. Plots with heavy barnyardgrass and sprangletop infestations after 4 years of drill-seeding rice were switched to water-seeding after a stale seedbed with Roundup without any spring tillage and again, weeds were almost absent from these plots as a result of the change in rice establishment method. All this was achieved without any additional herbicide applied besides the Roundup. Herbicides can still be applied if 100% weed control is desired and to prevent seed set by late emerging weeds. Alternating rice establishment systems from aerobic (dry-seeding) to anaerobic (water-seeding) regimes (and vice versa), combined with the use prior to seeding of a total non-selective herbicide for which resistance does not yet exist in weeds of rice (such as Roundup or other), allows for a major reduction of herbicide-resistant weed infestations in rice. These management practices allow a major reduction in overall herbicide use and the associated costs.

Herbicides used and their active ingredient

	<u>% ai</u>	<u>lb ai/gal</u>
Abolish	84	8.0
Bolero	15	NA
Cerano	5	NA
Clincher	29.6	2.4
Granite SC	24	2.0
Granite GR	0.24	NA
Grandstand	44.4	3.0
Strada WG	50	NA
IR5878 GR	0.5	NA
Londax	60	NA
Ordram Ultramax	15	NA
Prowl H ₂ O	42.6	3.8
Regiment	80	NA
Shark H ₂ O	40	NA
Stam 80 DF	81	NA
Super Wham	41.2	4lb
Wham 60DF	60	NA
Whip 360	6.59	0.57
Ricestar HT	6.70	0.58
MCPA	39.67	3.7
Stam 4SC	41.4	4.0
Halomax 75	75	NA
Harbinger	37.4	3.3



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