RICE FIELD DAY

Wednesday, August 29, 2007

Monochoria   Ducksalad White flowered   Ducksalad Blue flowered

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

It has recently been noted that there is a widespread misconception/misidentification of one of the predominant weeds in California rice. Ducksalad (*Heteranthera limosa*) has been a common weed in California rice for many decades. At least two forms of this plant are currently present in California rice fields, white flowered and blue flowered types. The blue flowered type has been called monochoria (*Monochoria vaginalis*), however this is incorrect. Monochoria is present in California rice, but the extent of infestation is not known at this point. Please take a look at the poster on identification of these weeds. Photo by James Eckert.

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James Lang, Laboratory Assistant
Jennifer Williams, Student Assistant

2007 Rice Field Day Program

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

Posters and Demonstrations

1. The Effect of P Placement on Weed and Algae Growth in Rice Systems (B. Linquist, C. van Kessel, A. Fischer, J. Hill, D. Spencer, G. Pedroso and M. Lundy, UCD, R. Mutters and C. Greer, UCCE)
2. Effects of Different Periods of P Application on Water and Soil P Availability and Algae Growth for Flooded Soils (Gabriel Pedroso, Bruce Linquist, Chris van Kessel, Dave Spencer)
3. Linking Changes In Early Season Water Management to Changes in Nitrogen Dynamics in California Rice Systems (K. Koffler, B. Linquist, J.E. Hill, L. Felipe Tiene Da Silva, F. Kiyohara and Chris van Kessel, UCD, R.G. Mutters and C.A. Greer, UCCE)
4. Early Season Water Management Impacts on the Availability of Soil Nitrogen in Rice Systems (K. Koffler, B. Linquist, F. Kiyohara and C. van Kessel, UCD)
5. Estimating Low Water Temperature Associated Yield Loss with Thermal Infrared Imaging (R.G. Mutters, UCCE, A. Roel, INI and R.E. Plant, UCD)
6. Plant Diversity: The Foundation of Tomorrow's Rice Varieties (P.G. Lemaux, UCB and C.A. Greer, UCCE)
7. Penoxsulam Faces Metabolic Resistance In California's Late Watergrass (M.D. Osuna, J. Eckert and A.J. Fischer, UCD, N. Saldain, INIA and R. De Prado, UCS)
8. Clomazone Resistance in Late Watergrass (*Echinochloa phyllopogon*) (A.J. Fischer, H. Yasour, P.L. Ten Brook and J. Eckert, UCD and D. Cheetham)
9. Traits for Field Identification of *Monochoria vaginelis* and *Heteranthera limosa* at Different Growth Stages (J. Eckert and A.J. Fischer,UCD, J. Williams, CSUC, J. Lundberg, LFF)
10. Dissolved Organic Carbon Losses From Rice Production Systems Under Various Straw and Water Managements (M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six and J. Hill, UCD, C.A. Greer and R.G. Mutters, UCCE)
11. Disease Symptom Posters (J.J. Oster, RES)

12. Progress in Breeding for Stem Rot Resistance (J.J. Oster, RES)
13. Bakanae Disease of Rice Brochure (J.J. Oster, RES)
14. Immediate Backcross Program to Transfer Blast, Stem Rot and Sheath Spot Resistance (J.J. Oster, RES)
15. Rice Water Quality Programs (California Rice Commission)
16. Conditional Agricultural Discharge Waiver for Rice (California Rice Commission)
17. Propanil Update (California Rice Commission)
18. Molinate Phase-out (California Rice Commission)
19. West Nile Virus (California Rice Commission)
20. Pesticide SIP and VOC (California Rice Commission)
21. Red Rice in California (C.A. Greer, A.J. Fischer, R.G. Mutters and J. E. Hill)
22. Herbicide Resistance Stewardship in Rice (A.J. Fischer and J.E. Hill, UCD, R. G. Mutters and C.A. Greer, UCCE)
23. Studies on Refining Management of Sporadic Invertebrate Pests of Rice (L.D. Godfrey and W. Pinkston, UCD)
24. 'RiceCAP' Efforts at RES: Year 3 Progress Report (A.I. Roughton and F. Jodari, RES)
25. Integration of DNA Markers in the Breeding Efforts at RES (V. Andaya, T. Tai, P. Colowit, F. Jodari, C. Johnson, J. Lage, J. Oster, A. Roughton and K. McKenzie)

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, David Lundberg
- Rice Research Trust Report, Rob Meyer, Chair
- California Rice Research Board Report, Tom McClellan, Chairman, CRRB
- D. Marlin Brandon Rice Research Fellowship Presentation, Kent S. McKenzie, RES
- California Rice Industry Award Presentation, Charlie Mathews, Jr., Chair

9:20 - 10:45 a.m.   MAIN STATION TOUR
Two tours occur simultaneously and repeat.

Blue & Green Groups to Trucks

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

New Insecticides under Development for Managing Rice Water Weevil in Rice (L. D. Godfrey, UCCE)

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

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

9:20 - 10:45 a.m. Hamilton Road Tour Red & White Groups to Buses

Rice Weed Control: Herbicide Performance, Combinations, New Chemicals, and Weed Management, A.J. Fischer, J.W. Eckert, J.E. Hill, L. Boddy, M.O. Ruiz and C. Marchesi, UCD

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

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

Noon Luncheon Concludes Program

Cal/EPA Department of Pesticide Regulation approved 3.5 hours of Continuing Education Credit for this 2007 Rice Field Day

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Introduction

By G. Simleness

As Chairman of the Board of the California Cooperative Rice Research Foundation, it is my privilege to welcome you to the 2007 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.

For 95 years, since 1912, this station has been serving the needs of the California rice industry. Our industry has proven to be very adaptive, changing and evolving as the result of external influencing factors. Your Station's Board and staff are mindful of the industry's current environment. We have just completed a scientific review of our research activities to better position the Station for the future. 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 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 joined the staff as a short grain breeder in April, and is providing expertise in our DNA marker research lab. Dr. Carl Johnson has been a keystone breeder in the progress, development and release of many superior medium grain varieties over his tenure here at the experiment station He has chosen to retire next year and your Board and staff have completed an exhaustive search for an experienced breeder to continue Dr. Johnson's fine work. I am pleased to announce that were successful in our endeavors. Dr. Jacob Lage joined our research staff in July to overlap with Dr. Johnson on the medium grain program.

Rice Experiment Station pathologist, Jeff Oster, continues his work on rice diseases focusing on stem rot, sheath spot, and blast. He has reduced emphasis on seed treatments to control the Bakanae seedling disease with the success of the bleach soak. 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 has arrived at the Rice Experiment Station. This technology is a breeding tool that should help improve the effectiveness and efficiency of selection in the breeding program. Markers will help in selecting the semi-dwarfing gene, amylose content and resistance to rice diseases. This has been facilitated by USDA Geneticist Dr. Thomas Tai and his staff at UC Davis, grant support from the RiceCaps Project and funding by the Rice Research Trust.

The Rice Experiment Station remains committed to providing pure, weed free, and high quality foundation seed for the California rice growers. The high quality of our seed purity was clearly demonstrated to the growers and in the market place over the past year. CCRRF Foundation seed was the first to be tested for Liberty Link contamination and tested a total of 4 different times by two independent labs and the USDA, all with no positive detection. Our staff and our UC cooperators are continuing to work on projects to address the needs of the California rice growers. Through his efforts, Dr. McKenzie was instrumental in demonstrating that the California rice industry's seed supply did not contain illegal GMO contamination. This important issue has negatively impacted the southern rice production regions.

This is 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 2007 "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

POSTERS AND DEMONSTRATIONS

The Effect of Phosphorus Fertilizer Placement on Weed and Algae Growth in Rice Systems

❖ M. Lundy, A. Fischer, C. van Kessel, M. Ruark, G. Pedroso, J. Hill, D. Spencer, B. Linquist, UCD and R. Mutters, and C. Greer, UCCE

Weed control is a major challenge in California rice systems. Ninety-eight percent of growers depend on herbicides for weed control, and control via herbicides represents as much as twenty percent of the overall cost of producing rice. Due in part to the widespread use of herbicides, there are more herbicide resistant weeds in California rice systems than in any other crop or geographic region in the United States. Thus, greater weed control without an escalation of herbicide regimes could potentially decrease production costs and improve the long-term sustainability of California rice.

The effect of fertilizer management practices on weed growth and abundance in California rice systems is not known. The objective of this study was to evaluate the effect of phosphorus (P) fertilizer and its placement in the soil on weed growth, cover, and abundance. Two studies were conducted.

In an on-farm study of ten fields, we compared the effect of surface applied P to zero P on weed cover at mid-tillering. Depending on the field, in pots with surface applied P there was greater cover of waterhyssop (300%), ducksalad (100%), smallflower (100%), bulrush (90%), watergrass (130%), and redstem (100%) as compared to pots with no P fertilizer (Table 1).

In a controlled pot study, we compared weed abundance and biomass in pots under two water management conditions, flooded and unflooded (to simulate drill seeding), and with three P treatments: zero P, surface applied P, and P buried 2.5 cm. Algae, harvested from the flooded pots 8 days after planting, yielded greater biomass in pots with surface P (100%) and buried P (30%) than in pots with no P (Table 2).

Weeds were harvested twice, first between 21-26 days after planting and again between 28-33 days after planting. Comparing weed counts in the two water management systems, in the initial harvest there were 57% more weeds in the unflooded system than the flooded system, and the dominant weed species varied.

In both flooded and unflooded pots, P placement affected weed abundance. Weed counts from the initial harvest in the flooded system resulted in significantly higher percentages of smallflower (257%), waterhyssop (82%), the grouping of ducksalad, monochoria, and arrowhead (150%), and the grouping of redstem and smartweed (363%) in the surface P treatments relative to treatments with zero P (Table 2). Weed counts in the buried P treatment were between the zero P and surface P treatment counts. With the exception of watergrass, the weed species that responded to P fertilizer in the flooded pots were similar to the weeds observed in the on-farm study (Table 1), where all the fields sampled were water seeded and flooded.

In the unflooded pots, weed counts from the initial harvest resulted in significantly higher percentages of waterhyssop (333%), bulrush (60%), the grouping of ducksalad, monochoria, and arrowhead (140%), and the grouping of redstem and smartweed (185%) in surface P treatments relative to treatments with zero P (Table 3). As in the flooded system, weed counts in the buried P treatment were between the zero P and surface P treatments. While there were 420% more grasses in the unflooded system than in the flooded system at the initial harvest, P placement had no observable effect on grasses in either the flooded or unflooded system.

In conclusion, the placement of P fertilizer in the soil has a large effect on weed populations based on both pot and field studies. This study has begun to identify which weed species demonstrate a response to P. However, whether these responses are due to 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. Percentage of weed cover at 35 days after rice planting at 10 on-farm fields where fertilizer P was either not applied (0P) or was surface applied (+P)

Location	P Treatment	Water-hyssop	Ducksalad	Smallflower	Bulrush	Watergrass	Redstem
Colusa BA1	+P/0P					23/14	
Colusa BA2	+P/0P					5/1	
Butte GO1	+P/0P	11/1					
Butte JO1	+P/0P		10/5				2/0
Colusa KA1	+P/0P	2/0	4/1				
Butte SC1	+P/0P	5/1					
Butte SC2	+P/0P	15/5	10/5	30/15			
Butte SC3	+P/0P	14/5			23/12		
Colusa TI1	+P/0P		18/10				
Glenn VI1	+P/0P					18/5	

Table 2. Weed species (and number) and algae in flooded treatment as affected by P fertilizer and placement

P Treatment	Total Weeds	Small-flower	Ducksalad/ Monochoria/ Arrowhead	Redstem/ Smart-weed	Water-hyssop	Grasses	Bul-rush	Algae (g)
No P	114B	14B	28B	11B	28B	3A	16A	0.14B
Surface P	286A	50A	70A	51A	51A	3A	25A	0.28A
Buried P (2.5cm)	181B	24B	48AB	21B	31AB	4A	22A	0.18B

*Because ducksalad, monochoria and arrowhead are difficult to distinguish at their early growth stages, we are reporting them as a group. We have done the same with redstem and smartweed.

Table 3. Weed species (and number) in unflooded treatment as affected by P fertilizer and placement

P Treatment	Total Weeds	Bulrush	Ducksalad/ Monochoria/ Arrowhead	Redstem/ Smartweed	Waterhyssop	Grasses	Smallflower
No P	237B	15B	20B	20B	6B	16A	121A
Surface P	405A	24A	48A	57A	26A	19A	160A
Buried P (2.5cm)	271AB	19AB	34AB	27B	11B	17A	122A

*Because ducksalad, monochoria and arrowhead are difficult to distinguish at their early growth stages, we are reporting them as a group. We have done the same with redstem and smartweed.

EFFECTS OF DIFFERENT PERIODS OF P APPLICATION ON WATER AND SOIL P AVAILABILITY AND ALGAE GROWTH FOR FLOODED SOILS

❖ Gabriel Pedroso, Bruce Linquist, Chris van Kessel, Dave Spencer.

The seeding period for rice growers has a lot of operations that need to be done in a short length of time. Every operation, such as P application, that can be dislocated to another period would bring benefits for the growers. Besides, P applied after harvest, could still be available for plant uptake, reduce algae problems and P contaminations in the drain water. It was used in 4 treatments to evaluate the effects of different periods of P application, all of them with and without straw: fall P mixed in the soil, spring P mixed in the soil surface, spring P without mixing and no P. The results suggest that the P applied in the fall (after harvest) is still available for plant uptake in the spring, reducing water P levels and algae growth. P applied on the surface caused the highest soil P concentrations but also the highest algae growth and water P levels, followed in sequence by spring mixed, fall P and no P.

ESTIMATING LOW WATER TEMPERATURE ASSOCIATED YIELD LOSS WITH THERMAL INFRARED IMAGING

❖ Randall G. Mutters, UCCE, A. Roel, INI and Richard E. Plant, UCD

Prolonged exposure to suboptimal water temperatures impedes the growth and productivity of rice. There are no systematic studies designed to ascertain the magnitude and geographic extent of the cold-water-associated yield loss. The objectives of the study were to develop methodology to extrapolate field-based observations to a regional scale using remotely-sensed infrared images. A rice field was instrumented with a network of recording temperature sensors. Water and canopy temperatures were recorded hourly. The spatial distribution and duration of the water temperatures (T_w) below a previously established threshold were recorded. Predawn thermal infrared images (TIR) were captured on three days. TIR best predicted actual T_w at panicle initiation (R^2=0.85). TIR predicted the duration of exposure to water temperature below 18 C (R^2=0.83). TIR was also a good predictor *of YL ($R^2 = 0.81$).*

Plant Diversity: The Foundation of Tomorrow's Rice Varieties

❖ Peggy G. Lemaux, UCB and Chris A. Greer, UCCE

Classical breeding efforts in rice, coupled with availability of widely diverse rice germplasm and induced and spontaneous mutations, have led to many improved varieties, like semidwarf Calrose 76 created by induced mutation from tall Calrose and mutations turned the late flowering Calrose into an early flowering variety. Classical breeding efforts that involved crossing the semidwarf and early flowering varieties produced new cultivars with improved agronomic performance, but no effects on grain quality. Classical breeding efforts are strengthened by the wide diversity of traits in wild, cultivated and landrace varieties of rice. Some changes can be seen, while others cannot. This genetic diversity is a kind of "insurance policy" for the future – needed to insure the ability to generate improved varieties for tomorrow's needs. An improved breeding technology, called marker assisted selection (MAS), has been developed to speed the movement of traits from one variety to another. MAS makes use of new information generated from the study of the genetic information in rice. This leads to the development of markers that act like chemical flags to indicate the presence of certain genetic information. For a breeder, knowing that, for example, marker KFP170, is in a plant makes it likely that the genetic information for sheath blight resistance is in the plant too, because the two are closely linked – like seeing a sign for Hwy 170 West and knowing you are close to your favorite diner, Betty's. Markers let breeders screen large numbers of plants quickly, dramatically speeding up breeding. In the USDA CSREES-sponsored RiceCAP project, researchers are identifying markers for sheath blight resistance and milling quality. The display, Plant Diversity: The Foundation of Tomorrow's Food, focuses on plant diversity in cereal crops, especially rice, and the role of MAS plays in providing useful tools for rice improvement.

Penoxsulam Faces Metabolic Resistance in California's Late Watergrass

❖ Maria D. Osuna, James Eckert and Albert J. Fischer, UCD, Nestor Saldain, INIA and Rafael De Prado, University of Cordoba, Spain

Penoxsulam is a new acetolactate synthase (ALS) inhibitor herbicide for control of annual grasses, sedges, and broadleaf weeds in rice. A late watergrass (LWG, *Echinochloa phyllopogon*) population presumed resistant (R) to penoxsulam was found in rice growing areas of California. Whole-plant bioassays were conducted to study LWG response to penoxsulam and to detect the possible involvement of cyt P450 monooxygenases in LWG resistance to penoxsulam using the cyt P450 inhibitor malathion (previous studies had already shown cyt P450-mediated resistance to thiobencarb, bispyribac-sodium and bensulfuron-methyl in this population). The ratio (R/S) of the GR50 values of the resistant to susceptible plants was 9.8 for penoxsulam. Pre-treatment with thiobencarb antagonized penoxsulam. Results suggest cyt P450 involvement in LWG resistance to penoxsulam. ALS activity was assayed on leaf extracts from R and susceptible (S) plants for a range of penoxsualm concentrations. These assays demonstrated that resistance in R-LWG is not due to reduced ALS sensitivity. Studies are under way to clarify the metabolic routes of penoxsulam degradation in R and E *E. phyllopogon*.

CLOMAZONE RESISTANCE IN LATE WATERGRASS (*ECHINOCHLOA PHYLLOPOGON*)

- Albert J. Fischer, James Eckert, Hagai Yasuor and Patti L. Ten Brook, UCD and Dave Cheetham, UCD (currently Helena Chemical)

Late watergrass (Echinochloa phyllopogon) is a major weed of rice in California, and several populations showed resistance to multiple herbicides of differing modes of action. Low level of resistance to clomazone was found in dose response studies with three late watergrass biotypes collected in rice fields of the Sacramento Valley. This level of resistance corresponds to escapes seen in the biotype of this weed. The dose-response studies were conducted under flooded conditions, with a four inch flood, and the weed at the one-leaf stage of growth. Fresh weight was harvested 20 days after treatment. Clomazone rates were: 0, 1/4X, 1/2X, X, 2X and 4X; X is the field rate = 673 g ha^{-1}; a commercial formulation of clomazone (CERANO) was used. Growth reduction (50%) values were significantly lower for the susceptible biotype compared to the resistant biotypes. Application of clomazone in combination with disulfoton or oxydemeton reduced clomazone toxicity to resistant late watergrass biotypes, suggesting that an oxidative step is required for activation and toxicity of this herbicide. Studies are under way to clarify the mechanism of resistance.

TRAITS FOR FIELD IDENTIFICATION OF MONOCHORIA VAGINALIS AND BIOTYPES OF HETERANTHERA LIMOS A AT DIFFERENT GROWTH STAGES

❖ James Eckert, University of California, Department of Plant Science, UCD; Albert Fischer, Department of Plant Science, UCD, Jennifer Williams, CSU, Chico, CA; Jessica Lundberg, Lundberg Family Farms, Richvale, CA;

It has recently been noted that there is a widespread misconception/misidentification of one of the predominant weeds in California rice. Ducksalad (*Heteranthera limosa*) has been a common weed in California rice for many decades. The 1976 Rice Field Day booklet notes ducksalad first recorded in Glenn County in 1948. It also notes a marked spread of the weed during the early 1970's. From anecdotal evidence this ducksalad was the white flowered biotype. A blue flowered biotype was collected in 1983 by then Butte County farm advisor Carl Wick. It was found on the Rice Experiment Station at this same time (Bill Brandon, personal communication). At present the blue-flowered biotype has been classified as *Heteranthera rotundifolia* (Kunth) Griseb., but is currently listed as a synonym of Heteranthera limosa by DiTomaso in Aquatic and Riparian Weeds of the West. The blue-flowered ducksalad appears to be more aggressive than the white-flowered biotype. This blue-flowered biotype of ducksalad has been called Monochoria by growers across the Sacramento Valley. A survey of ducksalad/monochoria populations is warranted to clear up this misidentification. The blue-flowered ducksalad has largely displaced the white-flowered biotype in most fields where it has been introduced. The displacement appears to happen within a few years after initial infestation. Ducksalad produces copious amounts of seed that is very small. It is likely spread by tillage equipment, harvest equipment, wildlife and water. Young ducksalad leaves form on long petioles and are elliptic to lanceolate in shape with rounded tips. Later leaves that also form on long petioles, are ovate to elliptic with rounded tips. The blue-flowered biotype appears to be more likely than the white-flowered biotype to develop creeping stems with roots developing at each node. Both biotypes of ducksalad are early season annuals that bloom June through July and begin to die back once seed is set in late July. Ducksalad flowers form on a single long stalk and are very prominent. The flowers open above the water. Additionally, there may be a third ducksalad being found on the west side of the Sacramento Valley. This ducksalad resembles *Heteranthera reniformis*. It has leaves that are round with a deep scallop at the point of attachment to the petiole. Multiple flowers (2-8) form on a spike and are light purple.

Early monochoria leaves are longer and narrower than ducksalad and come to a more defined point. The early leaves often float on the water surface. Later leaves are heart shaped and come to a more distinct point. Monochoria leaves are more waxy and often darker green than ducksalad. Monochoria flowers form as a cluster on a short stalk, are often under water and also often open under water. The flowers are blue, but are generally not noticeable due to position under the canopy of leaves. Flower formation begins mid to late July. Organic rice growers have expressed concern over the spread of the blue-flowered biotype of 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.

Dissolved Organic Carbon Losses From Rice Agroecosystems Under Various Straw and Water Management Practices

❖ Matthew D. Ruark, Bruce A. Linquist, Chris van Kessel, Johan Six, Jim E. Hill, UCD, Chris A. Greer and Randall G. Mutters, UCCE

Managed wetland ecosystems (including rice agro-ecosystems) dominate the landscape of California's Sacramento Valley. Historically, rice straw was burned, but since the mid-1990s, most rice straw is incorporated and fields are flooded over winter to promote decomposition. While this practice has improved air quality, some water quality concerns have arisen related to the potential increase in dissolved organic carbon (DOC). Greater quantities of DOC exported into surface waters can affect in-stream biogeochemical processes, and in turn, the quality of drinking water. The objectives of this study were to (1) measure seasonal concentrations and fluxes of DOC from rice agro-ecosystems and (2) assess how varying straw and water management practices affect DOC losses. At four locations, straw-burned and straw-incorporated fields were monitored between 2006 and 2007. Water samples were collected from field inlets and outlets during winter flooding and growing season flooding. Weirs and pressure sensors were used to estimate drain flow. During the first month of winter flooding, DOC concentrations among all straw-incorporated fields ranged between 35 and 77 mg L^{-1}. Burned fields were not typically flooded over winter, but DOC concentrations in runoff ranged between 6 and 14 mg L^{-1}. At the onset of drainage during the growing season, DOC concentrations from straw-incorporated fields were larger (2 sites) or similar (2 sites) compared to straw-burned fields. No practical differences in DOC concentration were observed later in the growing season. Results indicate that changes in rice straw management have increased annual DOC flux and seasonal DOC concentrations from these managed wetlands.

PROGRESS IN BREEDING FOR STEM ROT RESISTANCE

❖ J.J. Oster, RES

For the past five 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. Under severe disease pressure, long grain line 01-Y-502 out yielded L-205 by about 1000 lb/acre in 2001. Results for 2002-6 are presented on the next page. Due to applicator errors in herbicide and fertilizer, variability for the 2004 trial was very high.

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
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
01Y502	2002	12019	2256	23.1	4.6
	2003	10451	1343	14.7	3.9
	2004	9126	542	6.3	4.7
	2005	8140	-25	-0.3	4.4
	2006	7123	-321	-4.3	5.1
02Y565	2006	8786	1347	18.0	5.6
03Y496	2004	9222	638	7.4	4.8
	2005	9906	1741	21.3	4.0
	2006	9010	1566	21.0	5.2
04Y702	2005	8540	375	4.6	3.7
	2006	8454	1010	13.6	4.7
05Y751	2006	7890	446	6.0	5.0
05Y753	2006	7988	544	7.3	5.2
05Y754	2006	7989	545	7.3	5.1
06Y491	2006	7941	497	6.7	5.1
S102	2002	8989	--	--	5.6
	2003	8139	--	--	4.7
	2004	8152	..	..	5.8
	2005	8028	--	--	5.8
	2006	8438	--	--	7.2
03Y576	2004	9375	1223	15.0	4.9
	2005	8474	446	5.6	4.7
	2006	8420	-18	-0.2	5.1
04Y634	2006	8477	39	-0.5	4.8
04Y638	2005	8362	334	4.2	4.6
04Y641	2006	8537	99	1.2	4.9
	2006	8504	66	.7	4.7
05Y338	2006	8878	440	5.2	5.8
05Y654	2006	8217	-221	-2.6	4.4
05Y657	2006	8102	-336	-4.0	5.3
M206	2005	7181	--	--	5.7
	2006	8321	--	--	5.9
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

87-Y-550 is an old long grain in the pedigree of most advanced long grain SR resistant lines.

As more data is accumulated, it may be possible to determine yield loss associated with a given disease severity level and at what disease level resistant varieties show a yield advantage.

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.

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.

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, experience elsewhere in the world has shown that 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 contain one major gene for disease resistance (monogenic lines). 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 6 backcrosses. F1 plants will be screened against the California race of the blast pathogen during the seedling stage, and susceptible plants will be discarded. Resistant plants will be crossed back to M-206, and the F1 again screened. Five backcrosses have now been completed. Within 1/2 year, each of 7 broad-spectrum resistance genes will be transferred into an M-206 background (over 99% M-206 genes). Resistance genes will then be "stacked" (or pyramided) to prevent the blast pathogen from overcoming the major gene resistance so easily. This "stacking" of genes will be accomplished using molecular marker-aided selection (equipment has been obtained and techniques are now being evaluated) and should be accomplished in 2 years.

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 will be 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 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.

A report in the literature describes a very wide cross between *Zinzania latifolia* and *Oryza sativa*. Normally, such a cross is not possible—no fertile offspring would be produced. This procedure was attempted with *O. officinalis* 101399, a wild relative of rice with much higher stem rot resistance than *O. rufipogon*. Three plants (0.25%) showed resistance. These plants closely resemble *O. officinalis*, but appear to have resulted from a successful cross. Further backcrossing will continue. In the past, crosses were attempted with *O. officinalis* both at the Station and at IRRI (which has made such crosses in the past using embryo rescue). IRRI succeeded in making crosses, but failed to make backcrosses. Lines resulting from the initial cross have been brought through quarantine, but none have SR resistance.

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 each variety, with the resistance gene being different in each variety. These varieties are being screened against sheath spot, and simultaneously, a first backcross has been completed and progeny are being screened for resistance. 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 (now on BC_3) for SR will be used to transfer this resistance into California-adapted backgrounds.

RED RICE

- ❖ Aida Ortiz, Albert J. Fischer and James Eckert, UCD and Chris Greer, UCCE

A morphological typification of the red rice accessions found in California is presented.

'RICECAP' EFFORTS AT RES; YEAR 3 PROGRESS REPORT

- ❖ Iestyn Roughton and Farman Jodari, RES

RES is participating in a USDA funded multi-institutional research project, 'RiceCAP', with the objective of applying new rice genomics information into breeding programs. Focus is on two complex traits, Milling quality and sheath blight resistance. Candidate genes and genetic markers are expected to be identified through this project that will ultimately be used as highly focused and effective breeding tools to improve these quantitatively inherited traits. **Specific areas that RES is contributing to this project include: 1) characterization of 3 milling populations (MY1, MY2, MY3) for fissuring resistance and 2) development and phenotyping of a California milling population (MY3) for milling yield.**

During the first year of this 4-year project, a large capacity fissure induction system was developed at RES that allows characterization and screening of rice varieties/breeding lines of all grain types, long, medium, and short grains, for fissuring resistance.

Characterization of the MY2 milling population, using samples grown in Louisiana and Arkansas, was completed in spring 2007 and detailed data was provided to the RiceCAP Bioinformatics cooperator. Preliminary results indicate that considerable differences exist in the fissuring resistance of parental lines and the progeny of this population. For MY2 parents, Cypress and Lagrue, field fissuring averaged 2 and 6 percent respectively, while induced fissuring was 17 and 39 percent respectively. Field fissuring for the entire population was low since they were mostly harvested at estimated optimum moisture content. Induced fissuring, however, had a wide range, and averaged between 5 and 47 percent. The means were from a 2 replication RCB test grown in Arkansas. Initial observations indicate that with a low variability between replications there is good confidence in identifying resistant RILs. Genotyping and association analysis of MY2 population by other RiceCAP cooperators for milling yield and fissuring resistance is expected to be completed soon.

Even though the 3 milling populations in this study are long grain, the results are expected to be applicable to all grain types. Special emphasis is being placed in fissuring resistance studies that is essential for California rice production environment.

The California milling population, MY3, is currently being advanced as F7 generation at RES breeding nursery. This population (L204/01Y110) is a cross between a high milling parent L-204 and a low milling parent 01Y110. A total of 265 RILs of this population will be phenotyped and genotyped during years 3 and 4 of the RiceCAP.

RiceCAP efforts at RES has been instrumental in capacity building for fissuring and milling studies as well as establishment of a marker lab at RES over the past 2 years. In 2007, 1200 long grain samples were analyzed for waxy gene marker which determines amylose type. This process has been expedited with the recent supervision from Dr. Virgilio Andaya since April 2007.

INTEGRATION OF DNA MARKERS IN THE BREEDING EFFORTS AT RES

- V. Andaya, T. Tai, P. Colowit, USDA, F. Jodari, C. Johnson, J. Lage, J. Oster, A. Roughton, and K. McKenzie, RES

The DNA marker technology has come of age for rice improvement. The number and type of molecular markers generated and developed for rice throughout the years and the continuing efforts to map genes of economic impact make this technology important, if not essential, in modern rice breeding efforts. And with the cost of equipment and laboratory supplies going down significantly, routine application of DNA markers in critical aspects of a breeding program is not only feasible but also sustainable and a cost effective tool.

For the past couple of years, advanced lines generated out of the long grain breeding program has been routinely screened with a microsatellite marker (RM190) for the waxy gene. This marker enables the breeder to classify and predict accurately an important grain quality characteristic (amylose content) based on marker genotype alone. Recently at the Rice Experiment Station (RES), a marker for the blast resistance gene *Pi-z* from the donor variety 'Lafitte' was developed and its use in marker-assisted selection (MAS) was validated using advanced lines from the medium grain breeding project. The marker, designated as AP5930, was able to identify materials, even those with complex pedigrees, which contain the *Pi-z* gene. Efforts are now underway to develop similar markers for other broad-spectrum blast resistance genes that can be of potential use in routine MAS, gene pyramiding, and backcrossing efforts.

Collaborative activities to develop and validate markers for stem rot resistance, cold tolerance, semi-dwarfing genes, and other important traits are being continued and strengthened.

Here we describe collaborative current status of the various applications of DNA markers in the RES Rice Breeding Program.

STUDIES ON REFINING MANAGEMENT OF SPORADIC INVERTEBRATE PESTS OF RICE

❖ L.D. Godfrey and W. Pinkston, UCCE

Rice water weevil and armyworms continue to be annual threats to rice production in California. Research has been conducted on these pests for the last decade. Management plans have evolved over the years based on this research and these techniques are effectively used. Several other invertebrate pests, insects and related organisms, are sporadic pests of rice in California. The "hit and miss" nature of these pests makes research difficult due to the unpredictability. In addition, management with insecticides is also challenging because infestations are not consistent. However, under some conditions, these pests can occur at high levels and are very important and damaging in these cases. These pests include the

Rice Crayfish: *Procambarus clarki* and *Orconectes virilis*

Rice Seed Midges: *Cricotopus sylvestris*, *Paralauterborniella subcincta*, and *Paratanytarsus* spp.

Tadpole Shrimp: *Triops longicaudatus*

The biology and management recommendations for these pests will be briefly discussed. The most recent management information can be found at http://www.ipm.ucdavis.edu/PMG/selectnewpest.rice.html. Cultural controls are very important for these pests and represent cost-effective control measures. Studies conducted in 2007 will be briefly discussed.

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 variety, was released in February 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, averaging 8930, 8850 and 9000 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% which is 1% less than L-205. Kernels of L-206 are slightly shorter than L-204 and slightly larger than L-205.

A number of promising experimental long grains, including 04-Y-508 and 04-Y-706, have shown excellent agronomic 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).

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.

Newrex quality germplasm is also being used in the improvement of the conventional quality long grains. Newrex is a special, quality-type rice that is characterized by having 2 to 3% higher amylose content and a stronger viscogram profile than conventional long grains. Because of these characteristics, Newrex types cook dry and exhibit minimal solids loss during cooking process, and are therefore regarded as superior type for soup canning, parboiling, and noodle making. It is also anticipated that the dry cooking nature of a Newrex type variety may address the soft cooking tendency of California grown conventional long grain. The Newrex type variety, L-205, has shown superior processing and agronomic characteristics. Average grain yields of L-205 at cool and warm locations is expected to be slightly higher than M-202, Milling yields of L-205 under optimum harvest moisture is 63%. Cold tolerance ratings of this variety is significantly higher than L-204. Two advanced Newrex type experimental lines, 03-Y-151 and 06-Y-599 are being purified in 2007 head row blocks. Entry 06-Y-599, despite a higher amylose content, has shown very similar cooked grain texture to Southern long grain varieties.

Efforts are underway for the development of elongating aromatic basmati types and soft cooking aromatic jasmine types adapted to California. A number of basmati lines with improved cooking quality attributes and grain characteristics are currently being evaluated in 2007 yield tests.

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 semi-dwarf 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 are being tested in 2007 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, and may or may not be in the acceptable range.

Efforts are also underway to develop Jasmine types through pedigree and mutation breeding. Jasmine type germplasm lines from southern breeding programs and foreign introductions including the original Thai Jasmine variety, 'Khao-Dawk-Mali 105', are being used. 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.

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 01-Y-501 and 03-Y-496 have significantly out-performed susceptible checks such as L-205. Four stem rot resistant lines are currently being tested in 2007 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 2007 Rice Field Day poster as well as the RiceCAP web site at http://www.uark.edu/ua/ricecap.

Medium Grains (C.W. Johnson and J. Lage, Plant Breeders, RES)

M-206 update and review of variety performance from a variety of information sources are as follows:

- M-206 field yields are equal or superior to M-202.
- M-206 overall whole grain head rice is 1-2% better than M-202. Jim Thompson (UCD- Ag Engineering) and others are studying various factors contributing to higher whole grain head rice of M-206.
- M-206 is adapted to the entire rice growing area and serves well as a companion to other CRMG varieties to spread the harvest.
- Field observations indicate a similar reaction to blast, like M-202, in blast problem fields, is not as susceptible as M-104 and M-205.
- M-206 is more synchrous in heading than M-202 (shorter flower duration).
- Multi-year moisture measurements and grower comments confirm that most M-206 fields dry-down rate slows and remains relatively constant 3-5 days in the moisture range 24 to 20 percent. This is in contrast to most CRMG that continue to dry down.
- M-206 maturity is 3-4 days earlier based on statewide test information. Several growers noted that some M-206 fields were later in harvest maturity than M-202 planted at approximately the same date in 2005 (2003, 2005 and 2006 were late planting seasons with periods of extreme heat in July and August). M-206 maturity in 2006 was 2-3 days earlier than M-202. Year 2007 should provide clarification of what happens in a more normal planting season (planting dates and temperature ranges).

M-208 is an early, smooth, high yielding, semidwarf Calrose quality medium grain with CA blast race IG1 derived from the *Pi-z* gene was released in 2006. Agronomic information and grower comments are as follows:

- M-208 is essentially an M-202 agronomic type that heads 2 days later than M-202.
- Fertilization requirements are similar to M-202.

- M-208 is adapted to most of the M-202 growing areas (Colusa/Yolo county line north).
- M-208 has a larger seed size (5% larger than M-202), but can be commingled in storage with other CRMG's.
- Visual, cooking and taste evaluations by various milling, marketing and individuals noted a slight improvement of M-208 characters over M-206 and M-202.
- West side grower fields in 2006 with a history of blast occurrence(s) reported no blast, 4% higher yield and 1% more whole grain head rice for M-208 when evaluated with comparable M-202 fields.

04-Y-227, 05-Y-471 and 05-Y-724 are very early to early smooth CRMG's that have improvements for yield (3.5%) and/or stable whole grain head rice (1-2 points) compared to M-104. 2007 VESW tests should identify the best for future testing and increase. A special large plot yield trial with CRMG preliminary materials is being conducted in the delta. The purpose is to identify specific diverse CRMG entries that are also being tested at the RES and have applications to both production areas.

There are 2 CRMG breeder's increases. 07-Y-89 is an earlier (6 days) version of M-208. The other is the new CRMG germplasm that has potential for an 8 inch or deeper continuous flood thru stand establishment for weed control issues.

This new CRMG germplasm is being utilized and evaluated at the RES in fast track varietal development including hybridization to other CRMG's genetic studies, and various varietal breeding tests. Briefly, the information can be summarized as follows:

- The trait(s) are heritable.
- Various 2006 breeding tests indicate yield, milling, blanking, etc., are similar to variety from which it was derived.
- A special 2007 continuous deep water test (8 inch) indicated it comes through faster than the variety from which it was derived, and was close to M-202.
- This germplasm is in the early statewide yield trial.
- There are no major direct pleiotropic or indirect negative effects.

Appropriate steps were taken to document and describe germplasm utilization and concept in varietal development for a patent.

The medium grain breeding project continues to incorporate agronomic characteristics needed to improve varieties for present and future markets. High yield potential, resistance to lodging and blanking, seedling vigor, improved milling yields, and insect and disease resistance are a few of the agronomic and quality objectives. During the past decade there had been an effort to incorporate Southern U.S. and foreign varieties into the California medium grain program to increase genetic diversity. Major project emphasis is being made to improve blast and stem rot resistance.

Recent introgression of CRMG's with various stem rot resistance sources has provided several medium grains with satisfactory stem rot scores in 2006. 2007 survivors will provide excellent building blocks for varietal development with SR resistance.

A significant amount of blast resistant germplasm developed by multiple backcrosses continues to be evaluated including rows, small plots and a special large plot yield test from 2000 thru 2007. Since 2000 there has been a special CRMG large-plot yield trial to evaluate new entries with blast resistance. Since 2002, this trial has demonstrated improvements in reducing yield drag, higher blanking levels and poorer milling yields. The yield drag is eliminated but continuing improvements are being made in lodging resistance and milling yields. There are 12 new CRMG blast entries in various statewide tests. New blast materials continue to provide higher yields with improved agronomic quality and adaptation to California production areas.

DNA marker for CRMG blast resistance is now on line at the RES and producing excellent results. Progress continues as additional markers for specific objectives are refined. Other CRMG breeding and research activities continue.

Capsule Summary

1. M-206 and M-208 updates.
2. 04-Y-227, 05-Y-471 and 05-Y-724 are very early to early semidwarf CRMG entries in VESW Yield Trials with improved yield and stable head rice compared to M-104. 2007 tests will help identify a candidate for increase.
3. Two breeder increases include a 6 day earlier M-208 and new CRMG germplasm with continuous deep water (8 inches) during stand establishment.

4. The evaluation of the new CRMG germplasm continues for its potential as another weed control tool.

Final Note: This will be my last field day. Jacob Lage (CRMG breeder replacement) and I are reviewing various goals, objectives, CRMG germplasm and techniques in significant detail how the program operates. It is my goal to utilize the remaining 10 month overlap and facilitate a seamless transition for this project. It may serve as a model for other projects to emulate. It has been a rewarding and interesting trail.

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

The short grains and premium quality breeding project is charged with the development of improved rice varieties of three main sub-groups: 1) conventional short grains, 2) premium quality short and medium grains, and 3) specialty rice varieties that include waxy, low amylose, and big-seeded rice. Great efforts are being exerted to meet the challenge of producing a superior rice variety that combines premium grain quality, high yield potential, disease resistance, and adaptation to low temperature environments.

The standard conventional short grain variety remains S-102. This 10-year old variety is the predominant short-grain in commercial production in California because of its very high yield potential in combination with very early maturity, resistance to blanking, and large kernel size. It has been a consistently high yielding check variety in the very early advanced group of the UCCE Statewide Yield Test. S-102 is however very susceptible to stem rot and has a rough (pubescent) hull which is considered a drawback in seed processing. Thus, the primary breeding goal for the conventional short grain 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 daunting 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, no conventional short grain materials are entered in the Statewide Test. Adjustments in the use of parental materials for crossing work and the strategies for selecting desirable materials are being made to keep the conventional short grain varietal development on track.

The development of premium quality short and medium grain rice varieties remains the main focus of this project. Premium quality is defined as the type of rice that cooks very glossy and slightly sticky, with a smooth texture, tastes tender with subtle aroma, slightly sweet, and remains soft after cooling. These cooking characteristics are exemplified by the California medium-grain cultivar M-401 and the Japanese premium short grain varieties Koshihikari and Akitakomachi. Premium quality is culturally defined and breeding for locally-adapted, high-yielding premium quality rice varieties continues to be a difficult challenge.

The rice variety Calhikari-201 is the first released premium quality short grain (SPQ) variety for California and was derived from a cross using Koshihikari and S-101 as parents. Released in 1999, this variety has high yield potential, good seedling vigor, early maturity, lodging resistance and has a smooth hull. However, its grain quality did not equal Koshihikari making it less acceptable for the Japanese market. It is also susceptible to stem rot and blanking. 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. Twelve premium quality short grains are being tested in the Statewide Tests this year. The premium quality short-grain experimental lines 04-Y-177 and 05-Y-196 are being closely monitored in the Statewide Tests for yield potential and agronomic characteristics. These lines are being purified in headrows and will be evaluated for their milling and cooking qualities.

Breeding for premium quality medium grain types (MPQ) is focused on capturing the excellent grain and cooking characteristics of M-401. Lines are selected agronomically based on early maturity, seedling vigor, resistance to blanking and lodging, synchronous flowering, and milling yields. Cooking tests are given heavy emphasis in the selection process. This year, a total of sixteen 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 rice varieties are divided into three groups: a) waxy short grain, b) low amylose short grains, and c) big-grains Arborio-type. Calmochi-101 is the latest (released 1985) waxy/mochi rice developed at the station. It has a high yield potential and resistance to blanking but has rough hulls. Emphasis is given in breeding for smooth hulls, larger kernels, and improved agronomic attributes. Four advanced experimental lines are being tested statewide. 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. Improvements on the agronomic characteristics of Calamylow-201 are being made. Breeding for big-seeded grains similar to the Italian variety Arborio is on-going. 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 breeding for water weevil tolerance will be continued by the short grain breeding project. Incorporation of stemrot and blast resistance remains an important breeding goal. There is also a growing interest in using DNA markers to tag genes for disease resistance and grain quality at the station. The use of DNA markers is routinely performed in the long grain project for the waxy gene and soon a marker for the blast resistance gene (*Pi-z*) can potentially be used routinely to screen for blast resistance.

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 BC_3). 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 made in 2007 to determine mode of inheritance. Crosses using a new technique have been made with the distantly-related wild rice *O. officinalis* 101399. This rice has much higher stem rot resistance than *O. rufipogon*. Three plants with resistance equal to *O. officinalis* have been recovered, and additional crosses will be made. In the past, crosses made at the station with this wild species have not produced fertile offspring, but crosses made at IRRI using embryo rescue have been brought through quarantine. None of these lines were resistant. 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.

Disease resistance screening continues on advanced entries for sheath spot and seedling diseases, including new greenhouse tests for sheath spot and bakanae susceptibility. New sources of sheath spot resistance are being used in a rapid backcross scheme (now at BC_3).

About 7500 entries were screened for blast resistance in the last year. The form of resistance controlled by a single gene almost completely suppresses this disease, but this type of resistance tends to break down in varieties after several years. A rapid backcross program has been started (now at BC_5) 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 a good marker to identify the *Pi-z* and related genes. Hopefully, markers for other genes can also be identified. 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.

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 2003-7 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. Field research with present varieties is summarized in the Bakanae Research Update article. 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.

New Insecticides under Development for Managing Rice Water Weevil in Rice (L.D. Godfrey, UC Cooperative Extension and Extension Specialist and Entomologist in Agricultural Experiment Station)

Studies continued in ring plots to evaluate experimental materials versus registered standards for rice water weevil (RWW) control and to modify the use patterns of the existing products to facilitate management. The ring plots are an ideal method to compare several products under similar, controlled conditions especially unregistered products that would require crop destruction. The ultimate evaluation is in grower fields and this is needed before the product can be deemed effective but initially the ring plot evaluations are helpful. Effective controls in rice are in place with the pyrethroid active ingredients, lambda-cyhalothrin and zeta-cypermethrin, receiving the most use (90-95% of the insecticide applications in rice involve a pyrethroid). Diflubenzuron is also registered in California rice. Reliance on one class of chemistry for managing an important pest is always undesirable due to the possibility of resistance, interference due to regulatory actions, and other unexpected occurrences. Given the re-evaluation of pyrethroid registrations due to possible off-site movement by California regulatory agencies, it is important to continue to develop alternative active ingredients and classes of chemistry.

In 2006, twenty-four treatments (a total of ten different active ingredients) were established in ring plots to accomplish this research. In 2007, 20 treatments are being compared and research is progressing. Registered standards, Warrior®, Mustang®, and Dimilin®, all effectively controlled RWW. Research continued on three experimental insecticide active ingredients; etofenprox, indoxacarb, and clothianidan all appear to have significant potential for RWW management. All these products are a few years from any possible registration with their progress in this regard being approximately in this listed order (from nearest to farthest from registration). Etofenprox had a Section 18 (emergency) registration is Louisiana in 2006 and could be used in grower fields. Indoxacarb registration in California is being pursued with the aid of the IR-4 organization. Indoxacarb is active via a post-flood application whereas clothianidan has the most flexibility in terms of application timing showing good RWW control with a seed treatment, soil, pre-flood application and 3-leaf stage application. Results with pre-flood application of etofenprox have been erratic from year-to-year but the 3-leaf stage application efficacy has been consistently excellent. The re-evaluation of pyrethroid registrations, challenges with mosquito management, possibilities of exotic, new pests, etc. emphasize the importance of developing alternative active ingredients and classes of chemistry. In 2006, these three experimental products applied with various rates and application methods provided as high as 95%+ RWW larval control and excellent protection of grain yield. However, all three products showed only moderate RWW control when improper rates or suboptimal application procedures were used. A high infestation was achieved in the ring plots to adequately assess these products (~5.5 RWW per sample in untreated plots). Two additional active ingredients, DPX-E2Y45 and V10194, were evaluated against RWW for the first time in my studies and both showed good performance albeit somewhat less than the previously mentioned products. Pre-flood applications of Warrior and Mustang Max were evaluated and found effective against RWW. Registrations are being discussed and pursued for this use timing.

Work on a biological insecticide, azadirachtin, was de-emphasized in 2006 with only one greenhouse tested conducted. This product may have potential and would be especially useful for organic growers. This greenhouse study was intended to provide a second year of data on this product as well as to perhaps provide some explanation of the poor field results obtained in 2005. In summary, the foliar application was more effective against RWW than the pre-flood application, a liquid formulation (Aza-Direct®) was more effective than a granular product, and the 0.01 lb. AI rate of Aza-Direct was highly effective and about 4 times more of the granular formulation was needed to reach comparable levels of control to that seen with Aza-Direct.

Finally, studies evaluated the effects of insecticide treatments in rice on populations of invertebrate non-targets. This information is useful in order to develop best management practices for mosquito control with rice production. These invertebrates are part of the aquatic agro-ecosystem and some of these feed on aquatic stages of mosquitoes. Similar procedures and results were seen from 2005 and 2006 field studies; the pre-flood applications of Warrior had minimal effects on the number of aquatic insects and the number of invertebrates in 2005. For the post-flood applications, seven treatments were compared. For the first two weeks after application, there were some slight to moderate effects of the treatments on populations of aquatic insects. Reductions were most severe with dinotefuron and Mustang Max and intermediate with indoxacarb, etofenprox, and Warrior on aquatic insects for the first 2 weeks. Dimilin and azadirachtin had no effects in aquatic insect populations. Levels of other aquatic invertebrates, i.e., insect relatives, were even less severely affected by the treatments. Dinotefuron was the only product which reduced populations for more than one week; this treatment showed a 3 week reduction in invertebrate populations. Although some of the reductions were in the 70% range, the populations quickly recover and were not affected the rest of the season. Warrior was evaluated as a representative material that could be applied against armyworms in mid-July. In 2005, numbers of aquatic insects were reduced by ~70% by the Warrior application at 1 week after treatment but no effects were seen thereafter.

In summary, the registered insecticides of pyrethroid chemistry and diflubenzuron continue to be very effective and useful products for rice arthropod pest management. The key insect pests, rice water weevil and armyworms, are well controlled with these products. Rice water weevil levels, based on light trap captures, continued to increase in 2007 as in 2006; this rebound was from low levels in 2004 and 2005. New insect pests continue to plague rice production in the southern states and several other very damaging insect pests of rice occur world-wide. Care must be taken to keep these pests out of California. Insecticides are going to continue to play a role in IPM of rice pests and research to find alternatives to pyrethroid insecticides is ongoing and important.

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 III, James E. Hill, Rice Extension Specialist, L. Boddy and C. Marchesi are PhD. students, and M.O. Ruiz is a postdoctoral researcher under A.J. Fischer, UCD. J. Lang and S. Johnson are Junior Specialist and SRA I, respectively).

Our field program includes the testing of herbicides, their mixtures and sequential combinations for the rice growing systems that currently prevail in California. Thus we have conducted experiments for water-seeded continuously flooded rice, pinpoint systems and drill-seeded rice. 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 herbicide-resistant 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. 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. This year we have also included activities to elucidate the weed emergence patterns, morphological observations for distinguishing ducksalad (*Heteranthera limosa*) from monochoria (*Monochoria vaginalis*) and a typification of the red rice accessions found in California.

Continuous flooded rice

In this system, flood water is maintained at 4 inches throughout the season except when drainage is necessary for 70% weed exposure to apply foliar herbicides. Important advantages with this system are the suppression of watergrass by deep water, which is particularly relevant when there is resistant watergrass, and the virtual elimination of Sprangletop as a problem provided a uniform water depth of 4 inches is maintained. Our site was heavily infested with early and late watergrass, but also ricefield bulrush and the complex of ducksalad/monochoria was present. The system is particularly suited for early into-the-water treatments and granular formulations become excellent tools. Thus sequences with Cerano (12 lb/a) at day of seeding (DOS) followed by either Granite GR applied at 15 lb/a, 2-3 leaf stage rice (lsr), Regiment applied at 0.66 oz/a; 1-3 tiller rice (till), or propanil (6 lb a.i./a; 1-3 till) resulted in excellent broad-spectrum control. Some stunting and dark green color of rice could be noticed after the Granite GR treatment. Also, the program can begin with Granite GR (15 lb/a; 2-3 lsr) applied into the water followed by either propanil (6 lb a.i./a; 1-3 till) or by Clincher (15 oz/a; 1-3 till) resulted in very clean plots. The sequence of Granite followed by propanil is adequate to protect Granite from the evolution of resistance to ALS inhibitors. Shark applied into the water is also a typical herbicide for broadleaf and sedge control in water seeded and continuously flooded rice. However, short residual activity and a rather narrow window of activity against ricefield bulrush often results in escapes of this weed. Combinations of Shark (8 oz/a; 2-3 lsr) followed by Granite GR (15 lb/a; 2-3 lsr) provided good broad-spectrum control. This is also an adequate sequence for protecting Granite against the evolution of ALS-resistant weed biotypes. Finally, a classical and very effective treatment was the new granular Bolero ultramax formulation (26.6 lb/a; 1-2 lsr) followed by propanil (6 lb a.i./a; 1-3 till).

Pinpoint flood management

The pinpoint system in California rice needs to be drained at early stages (2-4 lsr) to expose weed foliage to foliar herbicides. This early drain allows good contact and control of germinated weeds, but extended exposure of soil to air favors the establishment of weeds like sprangletop, barnyardgrass and smallflower. For this reason it is important that fields are rapidly re-flooded beginning 48 hours after application. At 1-2 tiller stage, fields are not drained, but water is usually lowered to expose 70% of weed foliage to the herbicide application.

Once the fields are permanently flooded the aquatic conditions favor weeds like bulrush and ducksalad/monochoria. Therefore, later in the season, at the early tillering stage of rice a second herbicide treatment is needed for full spectrum weed control that spans the period when rice is most susceptible to weed competition.

We used broad-spectrum herbicides like Granite, propanil or Regiment in combination with specific herbicide for sprangletop control (Clincher, Abolish or low rates of Whip). In addition, Abolish contributes some residual control that can protect from weed emergence during the period up to re-flood.

The best broad-spectrum treatments were: Clincher 15 oz/a, 3-4 lsr) fb. propanil (6 lb a.i./a, 1-2 till); propanil + Abolish (4 lb a.i. + 2qt/a respectively, 3-4 lsr); sequences including Granite SC (2 oz/a) in tank mix with either Clincher (15 oz/a) or propanil (4 lb a.i./a) at 3-4 lsr and fb. propanil (4 lb a.i./a) or Clincher (15 oz/a) at 1-2 till respectively. Since propanil in tank mix with Clincher may occasionally exhibit antagonism, we used a tank mix of propanil (4 lb a.i./a) plus a low rate of Whip (6 oz/a) applied at 3-4 lsr to obtain excellent broad-spectrum control including sprangletop. Granite SC (2 oz/a) at 3-4 lsr was an excellent broad-spectrum herbicide but needs a compliment of Clincher to control sprangletop infestations characteristic of this system. Granite SC can cause some stunting and darkening of rice. Regiment (0.66 oz/a), applied between the 4 leaf and 1-2 tiller stage of rice is a good watergrass herbicide with activity on ricefield bulrush, although sprangletop and smallflower will escape control. Activity of Regiment on smallflower is improved when applied at the 3-4 leaf stage as opposed to 1-2 tiller stage of rice.

New herbicides

Strada is a new broad-spectrum ALS inhibiting herbicide. In a pinpoint system, Strada (0.67 oz/a) can be tank mixed or followed in sequence (1 till) by propanil (4 lb a.i./a) to obtain good broad-spectrum control; sprangletop is not controlled. This combination is also adequate to protect Strada from resistance to ALS inhibitors. To achieve sprangletop control with Strada fb. propanil sequence, a low rate of Whip (6 oz/a) can be tank mixed with either Strada or propanil. Best control occurs when sprangletop has not begun tillering. There is a granular formulation suited for into-the-water applications in water seeded and continuously flooded rice. This is a safe, broad-spectrum herbicide that can be applied at the 1-2 leaf stage of rice. Although this formulation is not yet available, we obtained promising results with Strada GR (13.3 lb/a; 1-2 lsr) following an early application of Cerano (12 lb/a; DOS), or Strada (13.3 lb/a; 1-2 lsr) followed by propanil (6 lb a.i./a; 1-3 till). A triple combination of Bolero ultramax (27 lb/a) plus Strada GR (13.3 lb/a) applied at the same 1-2 lsr timing followed by propanil (6 lb a.i./a; 1-3 till) gave excellent broad-spectrum control with protection against the eventual presence of sprangletop. Combining Strada with herbicides with another mode of action is important to protect this herbicide from ALS resistance. Overall, Strada appears to be very safe on rice in its different modes of application.

Herbicide resistance management

Experiments were conducted at a Glenn county grower's field heavily infested with herbicide-resistant late watergrass ("mimic"), which in addition to the usual resistance pattern to most grass herbicides, also control escapes have been noted by Cerano and Granite. However, in a continuously flooded system Granite GR (15 lb/a; 2-3 lsr) applied into-the-water was very suppressive of all weeds. Sequences of Granite followed by propanil (6 lb a.i./a; 4-5 lsr) or by Regiment (0.79 oz/a; 4-5 lsr) resulted in complete control of weeds present (resistant late watergrass, ricefield bulrush and ducksalad). When Cerano (12 lb/a; DOS) was used alone only about 70-80% control of resistant late watergrass was obtained, confirming previous field and laboratory observations of low-level resistance with this product. Combinations of Cerano followed by Granite SC (2.4 oz/a; 4-5 lsr), or propanil (6 lb a.i./a; 4-5 lsr), or by Regiment (0.79 oz/a; 4-5 lsr) controlled resistant late watergrass and resulted in good broad-spectrum control.

In a pinpoint experiment where early treatments were applied on drained plots at the 3-4 lsr and sequential treatments included applications at the 1-3 tiller stage of rice, we had several options for excellent resistant late watergrass and broad-spectrum control. As observed in previous years, a single well-timed application of propanil (6 lb ai.i/a; 1 till) gave total control of resistant late watergrass, smallflower umbrellasedge and ducksalad, which were the main weeds present in this experiment. Other excellent programs were: Clincher (15 oz/a; 3-4 lsr) followed by propanil (6 lb a.i./a; 1 till), Clincher tank mixed with Granite SC (15 oz/a + 2 oz/a, respectively; 3-4 lsr) followed by propanil (6 lb a.i./a; 1 till), Regiment (0.79 oz/a; 3-4 lsr) followed by propanil (6 lb a.i./a; 1 till), or a tank mix of Regiment plus Abolish (0.66 oz/a + 1.5 qt/a, respectively; 4-5 lsr) followed by propanil (6 lb a.i./a; 1 till).

Drill-seeded rice
This trial was drill seeded with M-206 and flushed with water three times for establishment (May 21, June 4, and June 8), then a final permanent flood (3-4 inches) was applied when rice was at the 5 leaf stage (June 15). Aquatic weeds are not generally such a problem initially in drill seeded rice, while the main weeds in this system were watergrass and sprangletop.

Residual herbicides are particularly suited to this system to provide weed control until permanent flood can be installed. The two residual herbicides used in this trial were Abolish and Prowl; the residual ability of Prowl diminishes rapidly after rice is flooded. Both herbicides should be applied as delayed pre-emergent herbicides (this is right after the germination flush before rice emerges). Both herbicides are active on grasses (including sprangletop) and have activity on smallflower umbrellasedge, although control of watergrass at this timing may be more consistent with Prowl. Prowl (2 pt/a, DPRE[1]) followed by propanil (6 lb a.i./a, 4 lsr) provided excellent broad-spectrum control, as well as the sequence of Abolish (2 qt/a, DPRE) followed by propanil (6 qt a.i./a, 4 lsr). Abolish can also be followed by Regiment (0.22 oz/a, 4 lsr), or by the tank mix of Regiment (0.45 oz/a) plus Abolish (1.5 qt/a) at the late watergrass resistant site. Other good treatments for this system were: Shark (6 oz/a, 5 lsr) followed by Clincher (15 oz/a, Post permanent flood, 1-3 tiller stage of rice); Clincher (13 oz/a, 5 lsr) with sprangletop at the 3 leaf stage followed by propanil (6 lb a.i./a, PPF[2]); and the tank mix of Granite (2 oz/a) plus Clincher (13 oz/a) at the 3 leaf stage of rice followed by propanil (6 lb a.i./a, PPF).

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[1] DPRE, pre-emergence application after rice seeds have imbibed water 7days after initial irrigation flush; rice had not yet emerged and watergrass was at the 0.5 leaf stage).
[2] PPF, post permanent flood; post emergence application after permanent flood is established.

Herbicide Resistance Weed Management Systems in Rice using Alternative Stand Establishment Techniques.
The following alternative rice establishment systems have been developed and evaluated since 2004: 1) conventional water-seed rice, 2) conventional drill-seeded rice, 3) water-seeded rice after spring tillage and a stale seedbed, 4) water-seeded rice after a stale seedbed without spring tillage, and 5) drill-seeded rice after a stale seedbed without spring tillage. These systems have demonstrated their potential for manipulating the kinds of weed species that emerge with rice. Thus problematic weeds can be avoided or, alternatively, controlled by new herbicides for which they do not have resistance. Pendimethalin and glyphosate are not used in water-seeded rice, but can control weed biotypes resistant to herbicides used in conventional water-seeded rice. Data averaged across four years show drastic differences in weed recruitment among systems, thus aquatic sedge and broadleaf weeds dominated the water-seeded systems, while the aerobic seedbeds of the drill-seeded systems favored grasses (*Echinochloa* spp. and sprangletop). The stale seedbed technique (promotion of weed emergence with irrigation flushes, fb. pre-plant burn-down application of glyphosate at 1.2 lbs. a.e./a) had been very useful in depleting weed populations from the upper soil layer and, thus, markedly diminishing the amounts of weeds emerging with the crop. If this technique was followed by no or limited soil disturbance (to prevent new weed recruitment) prior to water-seeding rice, very little weed control was needed thereafter. Thus, the stale-seedbed technique reduced weed recruitment in water-seeded rice by about 40%, and by 70% if spring tillage was eliminated (no-till). Conventional drill-seeded systems typically result in heavy weed recruitment, and although using stale-seedbed and minimum soil disturbance reduced weed recruitment by 40%, there were still many weeds present in System 5 (no-till drilled rice with a stale seedbed treatment).

Success with the stale-seedbed technique depends on the patterns of weed emergence and, very importantly, upon being able to keep the seedbeds moist and to allow sufficient time for most weeds to emerge prior to glyphosate application. These techniques were successful in suppressing the earlier emerging weeds, particularly *Echinochloa* spp. and smallflower umbrellasedge in dry and water-seeded rice, respectively, since substantial weed emergence was achieved prior to glyphosate application, which resulted in very limited weed emergence thereafter. However, aquatic weeds have delayed emergence respect to rice and other weeds and little emergence had occurred by the time glyphosate was applied, thus a substantial proportion of these weeds emerged later in the season in water-seeded rice. To control these weeds using a stale seedbed technique a longer period of very moist conditions would be required to promote substantial emergence and thus deplete the top layer of soil of germinable weeds. In dry-seeded rice a delayed emergence of sprangletop with respect to *Echinochloa* spp. was also observed. The patterns of weed infestation over time illustrate how although the mostly grass weed infestations in the no-till drill-seed rice increased over time, the system was successful in reducing recruitment of these grasses everytime the stale seedbed technique was adequately timed such that glyphosate could be applied once most weeds had emerged. In water-seeded rice, the stale-seedbed technique was successful in reducing recruitment of the mostly smallflower composed infestations, essentially also because substantial weed emergence was achieved prior to seeding rice, which could be eliminated with glyphosate to reduce subsequent weed emergence. Weed dynamics in the no-till systems was different. Although substantial amounts of weeds are eliminated with the glyphosate application, a significant proportion of sprangletop (in no-till drill-seeded rice) and of the aquatics redstem and ducksalad occurs late in the season and infestations by these weeds have gradually increased over time. Being able to expose weeds to the action of glyphosate (or other non-selective herbicide for which resistance has not evolved) is an essential aspect of implementing alternative stand establishment techniques in order to control herbicide-resistant weeds.

Subsequently, the drill-seeded systems were treated with Clincher (13 oz/a) + propanil (4 lb a.i./a) + Prowl H_2O (2 pt/a) applied at the 3 lsr, and the water-seeded systems received propanil (lb a.i./a) + Granite SC (2 oz/a) at the 4-5 lsr. Weeds were thus controlled from all plots. Rice yields in previous years did not differ among these establishment systems. Therefore, the alternative rice establishment systems evaluated in this study may be used to effectively manipulate weed species recruitment and enable the use of herbicides that may control weed biotypes resistant to herbicides used in conventional water-seeded systems. Success in weed suppression is maximized if sufficient weed emergence is promoted prior to burn-down in the stale seedbed technique, and if spring tillage is avoided to prevent stirring up new weeds from the soil. Modeling of weed recruitment and growth is being evaluated to identify rotation options that may reduce the seed-banks of problematic weed species. Results from this research will be used to develop innovative integrated weed management programs for California rice by breaking weed life cycles through rotation of stand establishment methods, alternating herbicide modes of action, as well as effective crop interference.

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[1] Sptp., bearded sprangletop; bulrush, ricefield bulrush; smallflower, smallflower umbrellasedge.
[2] Values in parentheses are standard errors of the mean.

Herbicides used, percentage of their active ingredient and concentration

	% ai	lb ai/gal
Abolish	84	8.0
Bolero Ultramax	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
Strada GR	0.5	NA
Londax	60	NA
Prowl H_2O	42.6	3.8
Regiment	80	NA
Shark H_2O	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

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Valent (Bolero®)
BASF (Prowl H2O®)