2008 RICE BREEDING PROGRESS REPORT AND 2009 RESEARCH PROPOSAL

P. O. Box 306, Biggs, CA 95917-0306
January 1, 2009

RICE EXPERIMENT STATION STAFF

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Farman Jodari, Ph.D. ....Plant Breeder
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Jeffrey J. Oster, M.S. .... Plant Pathologist

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OVERVIEW

Kent S. McKenzie

The California Cooperative Rice Research Foundation (CCRRF) is a private nonprofit research foundation [501(c)(5)] with membership consisting primarily of California rice growers. The Rice Experiment Station (RES) is owned and operated by CCRRF. RES was established at its present site between Biggs and Richvale, California in 1912 through the cooperative efforts of the Sacramento Valley Grain Association, United States Department of Agriculture (USDA), and University of California (UC). The 478-acre RES facility supports breeding and genetics research, agronomic research and foundation seed production.

Dr. Kent S. McKenzie is the station director and the scientific professional staff of CCRRF included plant breeders Drs, Farman Jodari, Virgilio Andaya, Jacob Lage, Carl W. Johnson (retired), and plant pathologist Mr. Jeffrey J. Oster. Eleven career positions consisting of five plant breeding assistants, one postgraduate assistant, a field supervisor, one mechanic and field operator, two maintenance and field operators, and two administrative assistants make up the support staff. Approximately 30 seasonal laborers are employed during crucial planting and harvest times.

Organization and Policy

Policy and administration of RES is the responsibility of an 11-member Board of Directors elected by the CCRRF membership. Directors serve a three-year term and represent geographical rice growing areas of California. They are rice growers and serve without compensation. CCRRF works to serve all California rice growers, and its policies generally reflect those of public institutions such as UC. CCRRF cooperates with UC and USDA under a formal memorandum of understanding. The UC and CRRB have liaisons to the Board of Directors. CCRRF scientists cooperate with many national and international public institutions and also with private industry. Organization and policy of CCRRF encourages active grower input and participation in RES research direction.

Research Mission and Funding

The primary mission of CCRRF is the development of improved rice varieties and agronomic management systems for the benefit of the California rice growers. The plant breeding program at RES is designed to develop rice varieties of all grain types and market classes with high and stable grain yields and quality that will sustain the profitability of rice with minimum adverse environmental impact. Important breeding objectives include the incorporation of disease resistance, high milling yield, seedling vigor, cold tolerance, early maturity, semidwarf plant type, lodging resistance, and insect tolerance into future rice varieties. Improved milling yield, grain appearance, and cooking characteristics relative to consumer preference are major components of the plant breeding program. A secondary and important objective is to address industry research needs including support of UC and USDA research by providing land, resources, and management for genetic, agronomic, weed, insect, disease, and other disciplinary research.

Rice variety development at RES is primarily funded by the CRRB that manages funds received from all California rice producers through California Rice Research Program assessments. The CRRB acts under the authority of the California Department of Food and Agriculture (CDFA). The CRRB finances approximately 80% of the RES annual budget and 20% is derived from the sale of foundation rice seed to seed growers, grants, and revenues from investments. RES does receive some grants from agribusiness and the Rice Research Trust (RRT). The RRT is a tax-exempt trust [501(c)3] established in 1962 to receive tax deductible contributions for support of rice research. RES is not government supported, but is receiving some USDA competitive grant rice research support through the RiceCAP initiative.

Cooperative Research

Cooperative research is an integral part of rice research at RES involving USDA and UC scientists. Dr. Thomas H. Tai, USDA-ARS Research Geneticist, Department of Agronomy and Range Science, UCD, is working with all project leaders to develop improved breeding and genetics methods for rice variety improvement. Rice quality and genetic research has included studies with USDA scientists Drs. Anna McClung, Bob Fjellstrom, Brian Scheffler, Georgia Eizenga, and Ming Chen. Dr. Charles F. Shoemaker and his students are pursuing research on rice quality in the Department of Food Science and Technology, UCD and material and support are provided to that effort. Statewide performance testing of advanced experimental lines and varieties was conducted by Mr. Raymond L. Wennig, UCD staff research associate, under the direction of University of California Cooperative Extension Farm Advisors Mr. W. Michael Canevari (San Joaquin), Dr. Randall G. Mutters (Butte), Dr. Chris Greer (Placer, Sacramento, Sutter, Yuba), Dr. Luis Espino (Glenn, Colusa, Yolo), and Agronomist Dr. James E. Hill, (Department of Plant Sciences, UCD). The information developed from this cooperative research is valuable to the RES Rice Breeding Program and the California rice industry. RES values and works to support a well coordinated team effort with these cooperators.

The CCRRF staff, facilities, and equipment also supported agronomic, weed, disease, and insect research of UCD scientists in 2008. Dr. Albert J. Fischer, associate professor, Department of Plant Sciences, UCD and Mr. James Eckert, UCD staff research associate at RES, conducted UC rice weed research on 18 acres. Drs. Albert Fischer, Randall Mutters, Bruce Linquist, James Thompson, Richard Plant, Chris Greer, Luis Espino, Willie Horwath, and James Hill are all doing research in a 13 acre rice systems research area. They are being supported by UCD staff research associate at RES, Mr. Ray Stogsdill. Dr. Larry D. Godfrey, extension entomologist, and Mr. Wade Pinkston, postgraduate researcher, Department of Entomology, conducted rice water weevil research. Please refer to the 2008 Comprehensive Rice Research Report for information on UC, USDA and RES-UC-USDA cooperative research.

CCRRF staff began conducting cooperative research with biotechnology companies in 1996 on transgenic rice for California. This has been a very limited area of research for CCRRF. All research is conducted under permits and in compliance with USDA-APHIS regulations and under approved protocols required by the California Rice Certification Act. It has included participants from the private and public sectors. No transgenic materials have been grown at RES since 2001. Future research in this area by RES will depend on California's needs, market acceptance, regulatory requirements, and the development of research agreements.

CCRRF initiated a voluntary and aggressive testing program of foundation seed for the presence of the Liberty Link Trait that was discovered at trace levels in Southern US long-grain rice. This included GIPSA approved third party PCR testing for the LLRice601 event, any Liberty Link trait (35S::bar), and sampling and testing by USDA-APHIS. Results involving a total of 98 pooled PCR tests were non-detect on all samples. Further testing required by the California Rice Commission of CCRRF foundation and basic seed samples for 2007-8 sales as well as all California commercial rice were all non-detect.

All research at RES is reviewed annually by the CCRRF Board of Directors, representatives of the University of California, and the California Rice Research Board. CCRRF continues to address recommendations from the 2007 Rice Breeding Program Review. This has included a major greenhouse building and renovation, DNA marker facilities and staffing, and investigating of the potential for japonica hybrid rice for California.

Seed Production and Maintenance

The production and maintenance of foundation seed of California public rice varieties and new releases is an important RES activity. The foundation seed program is a cooperative program between CCRRF and Foundation Seed and Certification Services at UCD. Its purpose is to assure availability of pure, weed free and high quality seed of public rice varieties for the benefit of the California rice industry. The California public rice breeding program of CCRRF has developed 42 improved rice varieties since the accelerated research program began in 1969. Foundation seed of 13 public rice varieties and basic seed of two Japanese premium quality varieties were produced on 170 acres at RES in 2008. Since 1988, CCRRF has protected new varieties under the Plant Variety Protection Act, Title 5 option that requires seed to be sold only as a class of certified seed. This is being done to ensure that California growers are the beneficiary of their research investments as well as assuring that clean, red rice free seed is produced. Although the foundation seed program is self-sustaining and not supported with CRRB funds, foundation seed and certified seed production provides very significant benefits to the whole California rice industry.◆

Trade names are used to simplify information. No endorsements of named products are intended or criticism implied of similar products not mentioned in this report.

RICE BREEDING PROGRAM

INTRODUCTION

The RES Rice Breeding Program (RBP) 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. Project leaders also have areas of responsibility in the operation and management of the overall program. All projects are involved in cooperative studies with other scientists from the UCD, USDA, and industry, including off-station field tests, nurseries, quality research, and biotechnology.

The Calrose medium grain project (see Calrose Medium Grains) is led by Dr. Jacob Lage who joined the staff in July 2007 and took over leadership for the from Dr. Carl Johnson who retired in July 2008. Dr. Farman Jodari is the long-grain project leader (see Long Grains). Dr. Virgilio Andaya is the project leader for premium quality, waxy, and California short grains (see Short Grains). He is providing expertise and leadership for the DNA marker lab. The rice pathology project is led by RES pathologist Mr. Jeff Oster (see Rice Pathology). All breeding program members cooperatively participate in the preparation, planting, maintenance, and harvest of the research nurseries. Staff continues to work to improve rice quality evaluation and selection for all market types. Screening, evaluation, and research in the area of DNA marker technology is progressing at RES.

Weed control in the breeding nursery can be a serious problem due to open water areas, herbicide resistant weeds, and heavy foot traffic. Aerial herbicide options are available at RES as the result of efforts of the California Rice Commission and the cooperation of Butte County Agricultural Commissioner and CDFA. These are very valuable tools for both nursery and foundation seed management.

The focus of the RES rice breeding program is on developing improved rice varieties to meet the needs of California growers now and into the future. This report summarizes the general activities of the 2008 RES Rice Breeding Program, including the various breeding nurseries, selected results from large plot yield tests, disease nurseries, greenhouse, and field experiments at RES and in growers' fields.

BREEDING NURSERIES

Seeding of the 2008 breeding nursery began April 25th, and was completed May 21st. The growing season was characterized by a dry cool spring and moderate summer temperatures. There was considerable smoke from California forest fires for several weeks but its impact on rice production was not clear.

In 2008, 1822 crosses were made at RES for rice improvement, bringing the total number of crosses made since 1969 to 36,630. Crosses made in the early spring were grown during the summer in an F_1 nursery to produce seed for the F_2 generation. Crosses made this past summer were planted in the Hawaii Winter Nursery and/or the greenhouse so the segregating F_2 generations could be grown for selection purposes in 2009, thereby accelerating the breeding process.

The 2008 RES breeding nursery occupied approximately 80 acres. Water-seeded yield tests included 3675 small plots and 3245 large plots. Small seed increase plots and cooking samples advanced breeding lines were grown on 2.5 acres. The nursery included about 56,065 water-seeded and 13,820 drill seeded progeny rows. F_2 populations from 2006 and 2007 crosses were grown in precision drill-seeded plots on 10 acres. An estimated 200,000 panicles were selected from the various F_2 populations in nurseries for further screening and advancement. Selected material is being advanced in the Hawaii Winter Nursery and greenhouse facilities. The remainder will be screened and processed for planting in 2009.

Headrows (1,200) of M-401, M-402, and Calamylow-201 were grown for breeder seed production in 2009. This headrow seed can be used for several years to produce breeder seed because it is stored under low temperature and proper humidity conditions.

The Hawaii Winter Nursery allows the advancement of breeding material and screening for cold tolerance during the winter to hasten variety development. The Hawaii Winter Nursery is a very valuable breeding tool and has been a successful and integral part of the RES Rice Breeding Program since 1970.

The 2007-8 winter nursery included 8460 progeny and an F_1 nursery of 583 crosses. Selection and harvest was completed and seed returned to RES and planted in May.

The 2008-9 winter nursery of 8460 rows was planted November 5th and 6th, 2008, and 584 F_1 populations were transplanted to the nursery December 8th to 9th, 2008. Selection and harvest will occur in April, and seed returned for processing and planting in the 2009 RES breeding nursery.

The 2008 UCD Cold Tolerance Nursery contained 8040 drill-seeded progeny rows. This was an observational nursery only, due to potential contamination concerns from adjacent UC research. The cool temperatures observed at UCD typically are not as low as those observed at the San Joaquin location. The UCD Cold Tolerance Nursery allows screening of materials for resistance blanking in that environment, however very little blank was observed in 2008.

The San Joaquin Cold Tolerance Nursery was planted in cooperation with two local rice growers. The 7-acre drill seeded nursery included 18,000 rows, 5 acres of F_2 populations, and two small drill seeded yield tests were grown in cooperation with the UCCE. Management and production were good, however, there very little blanking was observed to select blanking resistant material.

The cold tolerance nurseries remain an essential part of selecting for resistance to blanking and are used in conjunction with two refrigerated greenhouses at RES.◆

RES Rice Breeding Program Terminology

1. **Germplasm**. Breeding material used in crossing including varieties, introductions, lines, mutants, and wild species.

2. **Crossing (hybridization)**. The process of selecting parent plants and artificially cross-pollinating them. Backcrossing is crossing again to one of the parents of the original cross.

3. **F_1 generation**. The 1st generation after crossing. F_1 plants (hybrids) are grown from the seed produced by crossing. They are allowed to naturally self-pollinate to produce seed of the F_2 generation or may be used as parents (backcrossing).

4. **F_2 generation**. The 2nd generation after crossing. This is the stage that produces the maximum segregation for the different characteristics of the parents. Spaced plants from each cross are grown in large plantings and individual panicles selected, evaluated for seed quality factors, and planted to produce the F_3 generation.

5. **Progeny rows**. Selected rice lines grown in single rows for selection, generation advance, and purification. This may include lines in the 3rd through the 7th generation after crossing.

6. **Small plots**. Promising lines selected from progeny rows are grown in 4 by 6 ft or 2 by 4 ft plots for further screening, evaluation, and seed increase.

7. **Preliminary Yield Tests**. The best small plot entries are grown in replicated 12 by 15 ft plots at two seeding dates and evaluated for agronomic and quality traits.

8. **Statewide Yield Tests**. Outstanding preliminary yield test entries are grown in yield tests at several on-farm locations by UCCE and also at RES. Information on adaptability, agronomic performance, and quality traits is collected in these tests.

9. **Headrows**. Individual panicles of superior lines are planted in individual rows for purification and seed increase as potential new varieties.

10. **Breeder seed**. Headrow seed of varieties and experimental lines is grown in isolation and carefully inspected to maintain its purity to produce breeder seed. Breeder seed is the pure seed source planted each year to produce foundation seed.

STATEWIDE YIELD TESTS

Agronomic performance and adaptation of advanced selections from the breeding program were determined in multi-location yield tests. These tests are conducted annually in grower fields by UCCE and at RES. The 2008 Statewide Yield Tests were conducted at seven locations in commercial fields by Mr. Raymond L. Wennig, Dr. Randall G. Mutters, Dr. James E. Hill, Dr. Chris Greer, and Dr. Luis Espino. Advanced selections were tested in one of the three maturity groups: very early, early, or intermediate to late with standard check varieties included for comparison. Each maturity group was subdivided into an advanced and preliminary experiment. The advanced entries and checks had four replications and the preliminary entries had two replications. Plots were combine-size (10 by 20ft) and the experimental designs were randomized complete blocks.

All these advanced large plot entries were also tested at RES in a randomized complete block design. The large plot seeding dates at RES were May 5th to 8th, 2008. The plot size was 12 by 15 ft with the center 10 ft combine harvested (150 ft^2). Water seeding and conventional management practices were used in these experiments. Abolish® and SuperWham® /Grandstand® were applied for weed control and one application of Mustang® was applied for rice water weevil control.

Tables 1 to 6 contain a summary of performance information from the 2008 Statewide Yield Tests. Seedling vigor scores on the second date reflected the damage from herbicide injury. Yields are reported as paddy rice in pounds per acre at 14% moisture. At the San Joaquin location a drill-seeded system was used. Experimental yields may be higher than commercial field yields because of the influence of alleys, border effects, levees, roadways, and other environmental factors. Disease scores for stem rot (SR) are averages from the inoculated RES disease nursery. The entries that performed well will be advanced for further testing in 2009. Complete results of the UCCE Statewide Yield Tests can found in the Agronomy Progress Reports, (http://www.plantsciences.ucdavis.edu/ uccerice/main/publications.html).◆

Table 1. Agronomic performance means of very early advanced entries in Statewide Yield Tests at RES and over-location mean yields at San Joaquin, Sutter, Yolo, and RES (2 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
2	L206	L	4.6	87	98	1	8.0	11180	9850
6	07Y515	L	4.6	88	99	0	6.3	11060	9490
17	M206	M	4.8	90	104	0	6.5	10900	10140
13	05Y724	M	4.8	88	105	8	6.5	10670	10460
5	01Y655	LR	4.7	94	105	0	5.8	10600	9830
4	06Y575	LR	4.9	92	105	0	5.6	10480	10600
3	06Y513	L	4.7	91	102	0	5.9	10400	9680
10	05Y196	SPQ	5.0	90	102	43	6.9	10380	10190
8	S-102	S	4.9	80	103	38	6.8	10240	10190
11	04Y332	MPQ	4.9	89	106	3	6.4	10230	9050
16	M202	M	4.9	92	107	9	6.2	10170	9410
14	05Y471	M	4.9	85	104	4	6.9	10030	9940
1	L205	LR	4.5	93	101	0	6.6	10010	9170
15	M104	M	4.9	82	99	13	5.9	10000	9950
7	CM-101	SWX	4.9	84	103	40	5.9	9960	9820
12	06Y175	MPQ	5.0	89	108	70	6.8	9870	9070
9	04Y177	SPQ	4.8	88	99	65	6.2	9360	9670
Mean			4.8	88	102	17	6.4	10330	9790
LSD(0.05)			0.2	2	4	22	0.5	803	280
C.V. (%)			2	2	3	90	7	6	4

† L=long grain, LR=Rexmont type, M=medium grain, MPQ=premium quality medium grain, S=short grain, SPQ=premium quality short grain, and SWX=short grain waxy.
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR=stem rot score where 0=no damage and 10=plant killed.
# Paddy rice yield in lb/acre at 14% moisture.

Table 2. Agronomic performance means of very early preliminary entries in Statewide Yield Tests at RES and over-location mean yields at San Joaquin, Sutter, Yolo, and RES (2 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
40	07Y232	M	4.8	85	100	8	6.0	10630	9410
20	07Y545	LR	4.8	91	97	0	5.8	10590	9310
19	07Y534	LSR	4.7	87	99	0	5.9	10200	9490
36	07Y210	S	4.4	88	98	60	7.0	10040	10130
22	05Y547	LR	4.9	87	101	0	5.8	10040	9650
23	07Y516	LSR	4.5	89	100	0	5.3	9920	9290
34	07Y183	SPQ	4.6	83	99	60	5.5	9900	9650
24	07Y492	L	4.6	86	100	0	6.9	9870	9350
31	07Y217	SWX	4.1	82	103	45	6.2	9780	8960
48	07Y412	M	4.8	85	100	28	6.4	9690	9800
37	07Y213	S	4.7	83	96	5	5.8	9640	9920
44	07Y276	M	4.8	82	99	18	6.9	9600	9790
42	07Y262	M	4.7	87	103	15	6.7	9540	9890
21	07Y533	L	4.5	89	98	0	7.3	9490	8970
18	07Y508	L	4.8	84	105	0	5.8	9410	9990
43	07Y268	M	4.8	86	101	8	6.7	9400	9910
38	07Y225	M	4.7	81	95	3	6.2	9360	9110
49	07Y435	M	4.8	86	101	10	6.3	9360	9820
39	07Y226	M	4.6	84	99	13	6.8	9320	9640
32	07Y176	SPQ	4.7	83	98	13	6.6	9320	9410
46	07Y383	M	4.8	85	98	3	6.6	9180	9980
35	07Y186	MPQ	4.7	87	98	3	7.3	9150	9270
33	07Y163	SPQ	4.6	82	97	40	6.6	9150	10040
27	CH-201	SPQ	5	91	100	10	7.3	9110	9420
26	05Y552	LJ	4.7	84	98	3	6.1	9000	9280
47	07Y389	M	4.7	85	99	0	6.0	8930	9380
51	M206	M	4.8	87	100	5	6.4	8880	9760
29	04Y330	MPQ	4.9	85	95	45	6.0	8860	9300
25	07Y495	LSR	4.6	81	98	0	5.7	8730	8530
50	07Y440	M	4.7	83	99	5	6.9	8709	9460
41	07Y235	M	5	81	103	80	7.0	8590	9730
45	07Y277	M	4.8	84	101	30	7.0	8300	9260
30	06Y184	MPQ	5	89	105	3	6.4	8160	9050
28	06Y199	SPQ	5	85	93	60	5.3	8020	9340
Mean			4.7	85	99	16	6.4	9350	9510
LSD(0.05)			0.2	2.2	4.8	24	0.5	1480	520
C.V. (%)			2	1	2	71	7	8	6

† L=long grain, LR=Rexmont type, LSR=long grain stem rot resistant, M=medium grain, MPQ=premium quality medium grain, SPQ=premium quality short grain, LJ=jasmine, and SWX=short grain waxy.
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR=stem rot score where 0=no damage and 10=plant killed.
# Paddy rice yield in lb/acre at 14% moisture.

Table 3. Agronomic performance means of early advanced entries in Statewide Yield Tests at RES and over-location mean yields at Colusa, Butte, Yuba, and RES (4 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
61	L205	LR	4.5	91	96	0	6.7	11270	9240
73	05Y724	M	4.8	87	103	30	6.4	11050	10310
65	06Y513	L	4.8	92	99	0	6.3	11050	9960
68	S-102	S	4.8	81	100	68	6.6	10950	9530
66	07Y752	LSR	4.4	90	98	0	5.9	10920	10110
70	04Y308	MPQ	5.0	92	98	0	6.3	10870	8860
63	06Y575	LR	4.8	90	101	0	6.1	10820	10270
76	M205	M	4.7	97	100	0	5.9	10800	9900
77	M206	M	4.7	89	100	0	6.0	10620	9970
74	05Y471	M	4.7	82	101	25	6.4	10590	9850
75	M202	M	4.9	92	103	18	6.7	10580	9460
78	M208	M	4.8	93	102	10	6.3	10480	9790
69	06Y333	MPQ	5.0	93	101	25	5.7	10220	9380
67	CM-101	SWX	4.8	82	98	71	6.3	10120	9010
72	06Y322	MPQ	4.9	94	101	30	6.3	10060	9200
64	06Y599	LR	4.6	93	91	0	6.7	99120	9310
62	L206	L	4.5	86	89	0	6.8	9700	10060
71	04Y177	SPQ	4.8	87	95	90	6.0	9490	9670
Mean			4.7	89	99	20	6.2	10530	9660
LSD(0.05)			0.2	1.5	3.9	63	0.6	656	340
C.V. (%)			2	1	3	32	9	4	5

† L=long grain, LR=Rexmont type, M=medium grain, MPQ=premium quality medium grain, S=short grain, SPQ=premium quality short grain, and SWX=short grain waxy.
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR=stem rot score where 0=no damage and 10=plant killed.
# Paddy rice yield in lb/acre at 14% moisture.

Table 4. Agronomic performance means of early preliminary entries in Statewide Yield Tests at RES and over-location mean yields at Colusa, Butte, Yuba, and RES (2 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
84	08Y084	L	4.7	91	100	30	6.6	10880	9830
101	06Y696	M	4.9	91	98	15	6.2	10820	9690
102	07Y227	M	4.6	87	96	0	7.1	10770	9600
82	07Y489	LA	4.6	83	84	0	5.7	10550	9110
99	07Y293	SPQ	4.9	87	92	50	5.7	10490	9620
111	07Y460	M	4.6	88	101	20	6.0	10480	9340
103	07Y251	M	4.7	88	101	0	6.6	10480	9490
104	07Y253	M	4.8	88	99	15	6.6	10450	9730
107	07Y406	M	4.8	89	94	10	6.2	10400	9250
114	M206	M	4.7	88	101	15	6.4	10390	9970
95	07Y296	SPQ	4.7	84	95	40	5.7	10380	9430
105	07Y254	M	4.9	87	99	33	6.4	10320	9610
108	07Y414	M	4.8	88	103	10	6.6	10270	9480
97	07Y364	SLA	4.7	84	99	65	5.9	10180	9090
110	07Y447	M	4.6	90	99	10	6.4	10160	9360
92	07Y168	SPQ	4.6	80	87	40	5.5	10160	9070
81	07Y526	LJ	4.5	90	96	0	5.8	10140	9770
106	07Y259	M	4.6	87	100	43	6.2	10120	9460
113	07Y470	M	4.8	90	100	0	6.1	10100	9240
88	03Y496	LSR	4.6	90	97	0	5.2	10090	9610
93	07Y369	SBG	4.8	82	106	30	6.2	10060	8980
94	07Y182	SPQ	4.6	88	95	0	5.7	10050	9480
83	07Y559	L	4.7	87	95	0	6.3	9880	9780
96	07Y350	S	4.8	85	92	15	6.4	9860	9560
98	07Y320	MPQ	4.7	92	106	55	6.9	9860	9060
109	07Y436	M	4.7	87	96	23	6.2	9850	9300
112	07Y462	M	4.8	84	93	0	6.6	9620	9040
90	CH-201	SPQ	5.0	90	93	50	7.3	9520	8350
91	06Y629	MPQ	5.0	93	100	10	6.5	9450	8770
100	07Y343	MPQ	4.9	93	99	0	6.3	9400	8960
85	07Y599	LJ	4.7	89	95	20	6.4	9320	7470
86	07Y603	LA	4.7	92	90	0	6.6	9240	8660
89	06Y707	LJ	2.8	99	93	0	5.8	9050	7140
87	06Y545	LB	5.0	94	86	20	6.1	8880	8230
79	CT201	LB	4.8	94	95	0	6.2	8120	7290
80	CT202	LB	4.8	89	91	0	6.2	7930	6740
Mean			4.7	88	96	17	6.2	9940	9070
LSD(0.05)			0.2	2.4	4.8	NS	0.6	892	500
C.V. (%)			2	1	3		9	4	6

†LB=basmati, L=long grain, LA=long grain aromatic, LJ=jasmine, LIM= long grain IMI resistant, LJ=Jasmine, M=medium grain, MPQ=premium quality medium grain, and SPQ=premium quality short grain, SBG=short bold grain, SLA=short grain low amylose

‡ SV=seedling vigor score where 1=poor and 5=excellent.

§ Days to 50% heading.

¶ SR=stem rot score where 0=no damage and 10=plant killed.

Paddy rice yield in lb/acre at 14% moisture.

Table 5. Agronomic performance means of intermediate to late advanced entries in Statewide Yield Tests at RES and over-location mean yields at Glenn, Sutter, and RES (4 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
121	L205	LR	4.7	91	91	0	7.5	11530	8820
127	05Y343	SWX	4.8	89	93	47	5.8	11140	9870
130	07Y301	SPQ	4.9	96	94	0	5.8	11100	9700
124	08Y124	L	4.9	92	85	0	6.1	11040	9420
133	M205	M	4.7	97	98	0	6.3	10950	9270
123	07Y576	L	5.0	85	93	0	6.3	10740	9240
129	05Y346	MBG	5.0	92	96	60	6.0	10380	9140
132	M202	M	4.9	93	101	70	6.6	10310	9130
131	05Y698	M	4.8	97	97	0	5.9	9930	9070
125	04Y706	L	4.8	91	87	0	5.9	9910	8560
122	L206	L	4.8	83	85	20	7.3	9890	9090
126	M-402	MPQ	5.0	108	103	0	5.8	9220	8550
128	06Y620	SPQ	4.9	100	100	0	6.0	9110	8520
Mean			4.8	93	94	15	6.3	10400	9110
LSD(0.05)			0.1	1.9	5	NS	0.4	947	500
C.V. (%)			2	2	4		8	6	7

† L=long grain, LR=Rexmont type, M=medium grain, MPQ=premium quality medium grain, M=medium bold grain, SPQ=premium quality short grain, and SWX=short grain waxy.
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR=stem rot score where 0=no damage and 10=plant killed.
# Paddy rice yield in lb/acre at 14% moisture.

Table 6. Agronomic performance means of intermediate to late preliminary entries in Statewide Yield Tests at RES and over-location mean yields at Glenn, Sutter, and RES (2 reps) locations in 2008.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
136	07Y151	LIM	4.9	92	96	0	6.8	11070	9160
150	07Y700	M	4.8	94	99	0	6.4	10880	9400
142	07Y218	SWX	4.4	85	94	0	6.1	10820	8900
144	07Y666	SPQ	4.6	96	95	0	5.9	10710	8910
143	07Y671	SSR	4.6	84	88	50	5.4	10690	9870
149	07Y698	M	4.8	99	94	0	6.3	10390	9160
155	M205	M	4.7	97	95	0	6.2	10380	9140
153	07Y726	M	4.9	98	102	0	6.1	10190	9060
148	07Y696	M	4.7	98	102	0	6.4	10080	9350
152	07Y712	M	4.7	96	101	0	6.8	9970	9120
145	07Y646	MPQ	4.7	97	104	0	7.3	9930	8910
154	07Y729	M	4.7	96	95	0	6.4	9860	8800
151	07Y711	M	4.8	91	102	0	6.2	9840	9270
147	07Y694	M	4.9	98	103	0	6.3	9790	8690
146	07Y467	M	4.9	99	106	0	5.8	9760	9530
135	CT202	LB	5.0	90	83	0	6.0	8900	7100
141	CH-201	SPQ	5.0	91	91	70	8.0	8770	8010
134	CT201	LB	4.9	94	93	0	6.3	8400	7440
140	08Y140	LIM	4.9	97	90	0	6.6	8360	7770
139	07Y154	LB	4.9	93	93	0	6.3	7920	6690
138	08y138	LB	4.9	96	94	0	5.8	6540	5560
137	07Y152	LB	4.3	113	99	0	6.3	4430	3910
Mean			4.8	95	96	5	6.3	9440	8350
LSD(0.05)			0.3	2.7	5.6	NS	8	1640	760
C.V. (%)			3	1	3		0.4	8	8

† LB=basmati, L=long grain, LIM=long grain IMI resistant, M=medium grain, MPQ=premium quality medium grain, SSR=short grain stem rot resistant, and SPQ=short grain premium.
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR=stem rot score where 0=no damage and 10=plant killed.
# Paddy rice yield in lb/acre at 14% moisture.

PRELIMINARY YIELD TESTS

Preliminary Yield Tests are the initial step of replicated large plot testing for experimental lines. The experimental design, plot size, and production practices are identical to the Statewide Yield Tests grown at RES. Two replications are planted at the early and late seeding date. A summary of the yields of 2008 Preliminary Yield Tests is presented in Table 7. These tests included 688 entries and check varieties.

Results in Table 7 show that yields of the top experimental lines compare well with the check varieties. Agronomic and quality information will be combined with cold tolerance and disease screening information to identify superior entries for further testing and advancement to the 2009 Statewide Yield Tests. ◆

Table 7. Summary of Preliminary Yield Tests at RES in 2008.

Test	Type	Number of Entries	All	Highest	Top 5	Check	Standard Check
			----------Average Yield (lb/acre)†----------				
Very Early							
Short grains	Conventional	8	9900	10730	10190	9200	S-102
	Specialty rice	49	9200	10190	10030	7850	CH-201
Medium grains	Advanced	31	8910	10230	9910	9080	M-104
	Preliminary	68	9820	11190	10670	9940	M-104
Long grains	Conventional	46	8930	10130	9990	9080	L-206
	Specialty rice	24	8140	9710	9400	6650	CT-202
Early							
Short grains	Conventional	16	9390	10430	10140	8890	S-102
	Specialty rice	56	8600	9710	9540	7880	CH-201
Medium grains	Advanced	43	9480	10910	10480	9740	M-206
	Preliminary	162	8810	10600	9950	9360	M-206
Long grains	Conventional	52	9010	10100	9880	9340	L-206
	Specialty rice	24	7930	9470	9090	7870	A-201
Intermediate-Late							
Short grains	Conventional	14	9970	11130	10650	9410	S-102
	Specialty rice	15	9150	10030	9710	8990	M-402
Medium grains	Advanced	50	8920	10520	10070	8850	M-205
Long grains	Conventional	21	10170	11090	10800	10830	L-206
	Specialty rice	9	8410	9790	9120	8060	CT-202

† Paddy rice yield at 14% moisture.

SHORT GRAINS & PREMIUM QUALITY

Virgilio C. Andaya

The short grain and premium quality rice breeding project (SGPQ) aims to develop improved rice varieties for the following rice types: 1) conventional short grains, 2) premium quality short grains, 3) premium quality medium grains, 4) waxy short grains, 5) low amylose short grains, and 6) bold grains (Arborio-type) waxy, low-amylose, and bold grains are considered as specialty rices.

Though breeding goals do vary for the different grain and specialty types, great efforts are being exerted to meet the challenge of producing superior rice varieties that combine, among other traits, excellent grain quality, high yield potential, disease resistance, and adaptation to cold environments. Breeding priority is being given to the premium quality short and medium grains as compared to the conventional short grains and specialty rice because of their relative importance in the rice market.

The field of DNA marker technology is growing at a very rapid pace. With the establishment of a DNA marker lab at the station, molecular markers that have been developed to screen for grain quality and blast resistance are now being routinely used in all the breeding projects. DNA markers for other traits are still under development and should be online in the near future.

Standard Varieties

The market for short grain and premium quality rice remains an important component of the California rice industry. Further improvement of the agronomic performance, grain and milling yields, grain quality and overall cooking attributes of the current short grains, premium quality types and specialty rices still in production would be of significant value to the rice industry. Table 8 summarizes the grain yield performance of the standard rice varieties derived from the project and served as checks in the UCCE Statewide Yield Tests.

Table 8. Five-year average grain yield of short grain premium quality check varieties from 2004-2008 UCCE Statewide Yield Tests.

Year	---Grain Yield†---			
	M-402	S-102	CH-201	CM-101
2004	9530	9670	8530	9380
2005	8378	8688	7471	7897
2006	7850	9230	8040	8250
2007	8973	9828	6960	8758
2008	8547	9861	8645	9415
Overall average	8656	9455	7929	8740

† Paddy rice yield in lb/acre at 14% grain moisture content.

Conventional Short Grains

Throughout the years, the emphasis on breeding for conventional short grains has been significantly reduced because of the increased emphasis on the development of premium quality rice. This strategy is critically being evaluated because of the importance of having a strong conventional breeding for regular short gains and the impact it will have for the premium and specialty types.

S-102, is the dominant short grain variety in commercial production in California because of its very high yield potential, very early maturity, resistance to cold-induced blanking, and large kernel size. S-102 has been a consistent high yielding check variety in the very early and early group of the Statewide Yield Test. However, S-102 is highly susceptible to stem rot, has a pubescent hull, and low eating quality. The primary goal for the conventional short grain breeding is to develop a high yielding variety greater than S-102, incorporate stem rot resistance, with smooth hulls, and better cooking quality.

In 2008, 36 conventional (S) and short grain stem rot resistant (SR) lines were tested in the Preliminary Yield Tests at RES. A separate evaluation for stem rot resistance was conducted by the RES plant pathologist. The performance of selected lines that out yielded the check varieties are summarized in Table 9. Pending the results of the cooking evaluation and grain characterization, these lines are potential candidates for entry into the 2009 UCCE Statewide Yield Test.

Table 9. Performance of selected conventional short grain entries in the 2008 RES Preliminary Yield Tests.

ID	Type	Mat.†	Grain Yield ‡	SV§	Days¶	Ht. (cm)	Lodge (%)	SR	H/T#
08Y2024	S	VE	10729	5.0	82	93	38	5.8	68/72
08Y2049	SSR	VE	10265	4.9	82	97	8	5.9	67/70
08Y2048	SSR	VE	10069	4.8	83	90	8	5.5	67/72
08Y2025	S	VE	9793	4.9	81	98	8	6.0	67/72
07Y211	S	VE	9738	4.7	86	100	8	6.7	65/72
S-102	S	VE check	9198	4.9	80	99	30	6.8	63/72
08Y2130	SSR	E	10433	5.0	84	91	0	5.6	58/69
S-102	S	E check	8888	4.8	80	95	30	7.1	63/72
07Y667	SSR	IL	10854	4.7	96	102	0	5.7	52/71
07Y672	SSR	IL	9924	4.6	91	97	0	5.7	63/73
07Y662	S	IL	9670	4.8	88	96	20	6.6	52/70
S-102	S	IL check	9412	4.8	81	100	70	6.9	63/72

Type S=conventional short grain, SR= stem rot resistant entry.
† Maturity, VE=very early, E=early, IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
SR=stem rot score where 0=no damage and 10=plant killed.
# H/T= Head and total milled rice averages from milling rows.

Premium Quality

Premium quality rice is defined as the type whose cooked rice is very glossy, slightly soft and sticky, with a smooth texture, tastes tender, slightly sweet, with subtle aroma, 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. There is no unified definition of quality because of the human dimension involved. Grain quality preference varies depending on those desired by consumer or ethnic groups. Thus, breeding for locally-adapted, high-yielding premium quality rice that takes into account these consumer preferences continues to be a difficult challenge.

Premium Quality Short Grains (SPQ)

The premium short grain rice variety Calhikari-201 (CH-201) is the first SPQ variety released in California in 1999. CH-201 was derived from a cross involving Koshihikari, a premium quality Japanese variety, and S-101. This variety is high yielding, early maturing, has good seedling vigor, and lodging resistant. However, its grain quality did not quite equal Koshihikari, making it less acceptable for the Japanese market. Crosses that involved Koshihikari and Akitakomachi and high yielding lines from the medium grain project were and are being made to select for new and desirable trait combinations.

Thirteen premium quality short grains were tested in the 2008 UCCE Statewide Yield Tests. The agronomic attributes and results of preliminary cooking evaluation of selected entries are presented in Table 10. The grain yield of CH-201 was variable with an average grain yield of 9400 lbs/acre in the very early group to 8000 lbs/acre in the early group. The selected entries in the early group should yield advantages over 10% of CH-201. These selections will be entered again in the 2009 Statewide Yield Test to confirm yield performance in addition to being evaluated for blanking, milling, and cooking.

Last year, two premium quality short grains were rigorously evaluated for cooking quality. These entries, designated as 04Y177 and 05Y196, were purified in head rows. 04Y177 has been in the Statewide Yield Tests for 4 years and in 2008, this entry was entered both in the very early and early group. Its yield advantage over CH-201 averaged around 3%. Taste evaluations showed that it has comparable or better eating quality to CH-201. However, the kernels are smaller size which may be an issue to marketing organizations. This entry will be evaluated again in the yield tests and samples will be sent to marketing organizations for evaluation. The quality feedback for 05Y196 was not favorable and from further testing of this entry will be discontinued.

Thirty nine lines were evaluated in the Preliminary Yield Tests at RES. The performance of selected entries is summarized in Table 11. These lines will undergo further grain quality evaluations and cooking tests before they are entered for the 2009 Statewide Tests.

Table 10. Performance of selected premium quality short grain entries in the 2008 UCCE Statewide Yield Tests.

Entry No.	ID	Mat. †	Years in Test	Grain Yield‡	SV§	Days¶	BL (GH)	Lodge (%)	H/T#	Cook††
71	04Y177**	VE	4	9670	5.0	93	3	19	67/72	5.0
27	CH-201	VE check	6	9420	5.0	95	14	18	64/69	4.3
99	07Y293	E	1	9620	4.9	87	3	22	65/71	4.7
130	07Y301	E	1	9420	5.0	96	12	3	48/57	4.8
143	07Y671	E	1	9870	4.7	90	4	10	60/68	-
	04Y177	E	1	8860	4.7	85	6	81	67/71	4.8
141	CH-201	E check	6	8010	5.0	90	10	78	64/69	4.3

† Maturity, VE=very early, E=early, and IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
BL=blanking percentage in greenhouse.
#H/T= Head and total milled rice averages from milling rows.
†† Overall eating quality, 1=poor, 5=excellent.
** 04Y177 was tested in both VE and E group.

Table 11. Performance of selected premium quality short grain entries in the 2008 RES Preliminary Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	H/T#	Cook1 ††	Cook2 ‡‡
08Y2037	VE	10168	5.0	81	30	68/72	3.3	3.7
08Y2042	VE	9780	4.9	83	15	67/71	3.7	3.5
08Y2040	VE	9625	4.9	83	0	66/71	3.7	4.7
08Y2044	VE	8588	4.9	88	60	69/73	4.0	4.7
CH-201	VE check	7854	4.9	88	8	64/69	4.3	4.0
08Y2110	E	8910	4.9	89	20	64/70	3.5	3.2
CH-201	E check	7877	4.8	90	50	64/69	4.5	4.0
08Y2163	IL	10031	4.9	93	0	49/69	3.8	4.0
CH-201	IL check	7814	4.9	91	70	64/69	4.3	4.0

† Maturity, VE=very early, E=early, IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
# H/T= Head and total milled rice averages from milling rows.
†† Cook1=first cooking evaluation, 1=poor, 5=excellent.
‡‡ Cook2=second cooking evaluation during winter 2008, 1=poor and 5=excellent.

Premium Quality Medium Grains (MPQ)

Breeding for premium quality medium grain rice is aimed in capturing the excellent grain and cooking characteristics of M-401 which is a late maturing variety released in 1981. In 1999, M-402 was released as an alternative to M-401. It is about a week earlier maturing, has more translucent grains, higher milling and grain yields, but has slightly smaller kernels. The development of early maturing, better agronomic performance and high yielding alternative to M-401 is the primary goal in breeding.

In 2008, a total of twelve MPQ entries were tested in the Statewide Yield Test. Performance of selected entries is presented in Table 12. Statistical comparison of yield advantage of the selected entries with M-402 was not performed since M-402 was not entered in the very early and early trials. Nevertheless, cursory evaluation of the statewide data showed that there is yield advantage exhibited by the test entries. Whether the level of grain and cooking quality is adequate or not remains to be seen by requiring further testing.

Sixty four MPQ advanced lines were tested in the Preliminary Yield Tests at RES. The agronomic performance and milling characteristics of eleven selected advanced lines are summarized in Table 13. M-203, a premium quality medium grain no longer in commercial production, is used as check variety. Lodging for this variety is heavy in the yield plots and the milling yields are marginal. Grain yields averaged between 7900 to 8500 lbs/acre but the cooking evaluation is excellent. In general, the selected test entries exhibited higher grain yields but the yield advantage is not impressive. Rigorous grain quality evaluation and cooking tests will be made on these selections before they are advanced for the 2009 Statewide Yield Tests.

Table 12. Performance of selected premium quality medium grain entries in the 2008 UCCE Statewide Yield Tests.

Entry No.	ID	Mat.†	Years in Test	Grain Yield ‡	SV§	Days¶	BL (GH)	Lodge (%)	H/T#	Cook ††
70	04Y308	E	4	9670	5.0	91	17	21	66/70	4.5
72	06Y322	E	2	9200	5.0	93	11	27	66/71	4.3
100	07Y343	E	1	8960	5.0	92	10	8	69/72	3.7
12	06Y175	VE	2	9070	5.0	95	6	33	68/71	4.7
35	07Y186	VE	1	9270	4.9	94	23	2	69/71	4.3
126	M-402	IL	6	8550	5.0	108	20	1	60/71	5.0

†Maturity, VE=very early, E=early, and IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
BL=blanking percentage in greenhouse.
# H/T= Head and total milled rice averages from milling rows and plots.
†† Overall eating quality, 1=poor and 5=excellent

Table 13. Performance of selected premium quality medium grain entries in the 2008 RES Preliminary Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	H/T#	Cook1 ††	Cook2 ‡‡
07Y200	VE	10186	5.0	86	23	63/68	4.0	5.0
M-203	VE	8523	4.8	89	60	47/61		4.8
08Y2100	E	9309	4.8	88	20	59/69	4.5	3.7
07Y334	E	9168	4.9	95	0	64/71	4.2	4.5
08Y2103	E	9055	4.9	92	10	65/69	4.0	4.8
08Y2089	E	8422	4.8	89	0	63/70	4.2	4.5
08Y2082	E	8332	4.9	92	60	53/67	4.3	4.8
08Y2096	E	8071	5.0	89	20	59/70	3.7	5.0
M-203	E	7903	4.9	94	80	47/61		4.8
08Y2147	IL	8761	4.9	92	60	57/65	4.5	4.8
M-203	IL	8218	4.9	92	80	47/61		4.8

† Maturity, VE=very early, E=early, and IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
# H/T= Head and total milled rice averages from milling rows.
†† Cook1=first cooking evaluation, 1=poor and 5=excellent.
‡‡ Cook2=second cooking evaluation during winter 2008, 1=poor and 5=excellent.

Specialty Rice

The specialty rices are divided into three sub-groups: a) waxy short grains, b) low amylose short grains, and c) bold grains (Arborio-type). Breeding for specialty rice varieties presents unique challenges often attributed to poorly defined grain and cooking quality attributes. These make quality evaluation and selection difficult.

Calmochi-101 (CM-101) is the latest waxy short grain rice released for California in 1985. It has a high yield potential, excellent blanking tolerance, has large kernels but has rough hulls. Emphasis is given in breeding for smooth hulls, higher yields, and improved agronomic attributes. The rice variety Calamylow-201 (CA-201) is the first and only low-amylose variety (~7% apparent amylose content) developed for California and is a mutant derived from CH-201. This variety was released in 2006 as a new product for the California rice industry. Breeding for bold grain Arborio-type variety is being continued but in a lesser extent.

A total of 21 waxy short grains, 2 bold grains, and 2 low amylose short grains were entered either in the Statewide or Preliminary Yield Tests in 2008. The agronomic and yield performance of selected lines in the Statewide Yield Tests and in the RES Preliminary Yield Tests are summarized in Tables 14 and 15, respectively.

Table 14. Performance of selected 2008 specialty rice entries in the UCCE Statewide Yield Tests.

Entry No.	ID	Mat. †	Years in Test	Grain Yield‡	SV§	Days¶	BL (GH)	Lodge (%)	MC (%)	H/T#
93	07Y369	E(BG)	1	8980	4.9	83	6	8	20	48/69
97	07Y364	E(LA)	1	9090	4.9	85	23	38	17	64/70
67	CM-101	E(WX)	6	9010	4.9	83	17	43	16	66/70
129	05Y346	IL(BG)	3	9140	5.0	90	20	26	19	30/46
127	05Y343	IL(WX)	3	9870	4.9	89	11	43	18	57/67

† Maturity, VE=very early, E=early, and IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
# H/T= Head and total milled rice averages from milling rows and plots.
MC=moisture content at harvest.
BG=bold grain, WX=waxy, LA=low amylose
BL=blanking percentage in greenhouse

Table 15. Performance of selected waxy rice entries in the 2008 RES Preliminary Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Ht. (cm)	Lodge (%)	MC (%)	H/T#
08Y2059	VE	9876	4.9	85	96	23	17.7	62/69
08Y2055	VE	9785	4.9	84	101	23	15.4	57/69
07Y219	VE	8988	4.7	82	74	0	16.8	66/70
08Y2056	VE	8597	4.9	84	101	30	17.5	64/70
CM-101	VE	8524	4.9	82	96	45	16.0	66/70
08Y2137	E	9705	5.0	85	99	45	16.0	54/66
CM-101	E	9049	4.9	82	94	60	16.0	66/70
07Y683	IL	9769	4.7	90	101	10	17.7	67/73
CM-101	IL	8296	4.8	82	95	40	16.0	66/70

† Maturity, VE=very early, E=early, and IL=intermediate late.
‡ Paddy rice yield in lb/acre at 14% moisture.
§ SV=seedling vigor score where 1=poor and 5=excellent.
¶ Days to 50% heading.
# H/T= Head and total milled rice averages from milling rows.
MC=moisture content at harvest.

DNA Marker Lab

Improving the functionality of the DNA marker lab has been the primary activity in 2008. RES acquired an ABI 377 DNA sequencer to replace the mega-gel system last year. This single piece of equipment significantly increased the amount of rice materials that were tested for at least the 2 most common markers used by breeders. By full capacity, the lab can handle at least 10 fold the amount of materials processed in 2008.

More importantly, safety manuals and lab protocols were written as guide on how to safely and more efficiently utilize the supplies and equipment in the lab. As the inventory of available DNA markers grows these markers will be tested and used wherever applicable.

At least 80% of the activities in the marker lab were directly and indirectly geared towards the marker-assisted selection for the medium grain breeding project. About 4,000 early generation lines were screened for blast resistance using AP5930 microsatellite marker. In aid of the backcrossing work by the station pathologist, around 2,000 plants were processed to identify those plants that contain the desired blast resistance genes through the use of linked microsatellite markers. And for the past several, an average of 1,500 lines were evaluated for the waxy gene marker, RM190, in the long grains program.

The lab is expanding its activities by hiring a lab technician and completion of the marker laboratory facilities in the spring of 2009. Efforts will concentrate on integrating the use of markers in each of the breeding projects primarily on the use of waxy gene marker and blast resistance markers. Work on the discovery and development of stem rot resistance will also be on top of the least.

As a long term goal, the DNA marker lab will formulate procedures to efficiently identify and develop markers for traits that include cooking quality, stem rot resistance, cold tolerance, and other important traits as they are discovered, and devise ways to efficiently implement a marker-assisted selection scheme for all projects at the station.

LONG GRAINS

Farman Jodari

The long-grain breeding project continues its research and breeding efforts to develop superior long-grain varieties of four major quality types for California, including 1) Conventional long grain, 2) Jasmine, 3) Basmati, and 4) aromatic types. Milling and cooking quality improvements of conventional and specialty long-grain types remain a major priority objective in this program followed by resistance to cold induced blanking and other agronomic and disease resistance traits.

Conventional Long Grain

The long-grain rice market in US is based on quality characteristics of Southern US varieties. Cooking quality of conventional long grain types are characterized, for the most part, by intermediate amylose content (21 to 23%), intermediate gelatinization temperature (alkali spreading value of 3 to 5), and a moderate viscogram profile. Extensive cooking quality screening and selection efforts in recent years have eliminated the majority of texture softness from the California long grain breeding material. The primary focus is currently being directed toward milling yield and cold resistance improvements.

L-206, a conventional long-grain quality variety, was released for commercial production in California in 2006. Cooked grain texture of L-206 is harder than L-204 as indicated by its amylographic profile and therefore compares favorably with Southern US produced long-grains. Milling yield of L-206 is 1-2 percent lower than L-204. Recent studies, however, indicate that L-206 is significantly more resistant to grain fissuring than L-204, indicating more stable milling yield at lower harvest moisture. Primary advantages of L-206 over L-204 are improved cooking quality, higher grain yield, and earlier maturity.

L-206 is a very early to early maturing semidwarf variety. Average heading date is 4 days earlier than L-205 and M-202. Plant height is 6 cm shorter than L-205 and 11 cm shorter than M-202. Lodging potential is not significantly higher than L-205, however, due to earlier maturity plants may lean due to excessive dryness after harvest maturity. Similar to Southern long grain types, L-206 has intermediate amylose and gelatinization temperature types.

Grain Yield of L-206 averaged over nine seasons (2000-2008) has been significantly higher than M-202 at the RES location and similar to L-205 and M-202 at Sutter-Lauppe test location. Average yields were 9210 lb/acre in cooler location of Sutter-Lauppe and 10,280 lb/acre at RES (Table 16). Yields at colder locations of Yolo and San Joaquin have not been as competitive as M-202. Grain Yields of L-206 tested for 4 years in additional locations during 2005 through 2008 were similar to or higher than L-205 and M-202. Based on these results, L-206 should be adapted to most of the rice growing regions of California except the coldest locations of Yolo and San Joaquin Counties. Growing seasons in 2007 and 2008 had significantly lower overall degree days as compared to 7 previous years. In spite of this, L-206 yield was very competitive with other varieties including medium grains (Tables 1–6). Average head rice yield of L-206 during 2001 – 2008 seasons was 62 %. Kernels of L-206 are shorter than L-204 and slightly larger than L-205.

Other promising conventional long-grains that are being evaluated in detail in advanced generations include 06Y513 and 06Y575. Performance results of these lines and selected number of other conventional long grains entries with intermediate (L) or high amylose (LR) contents are listed in Table 17. Entry 06Y513 has shown high yield potential in cooler than normal seasons during 2007 and 2008. Compared to L-206, 06Y513 has 3 percent higher milling yield and similar or stronger amylographic profile as seen by RVA scores. Entry 06Y575 is a high amylose type, similar to L-205, with high yield potential, good milling, and cold induced blanking resistance. Both experimental lines were tested in Very early and Early groups of Statewide tests in 2008.(table 17) California grown high amylose long grains such as L-205 tend to have softer cooked grain texture than those grown in Southern US. Therefore they can be used as conventional long-grain type.

Table 16. Yield performance of L-206 compared to L-205 and M-202 averaged over 9 or 4 years at RES and 8 other UCCE Statewide Yield Test locations.

Maturity- Location	---------- Yield† ---------			Years tested‡
	L-206	L-205	M-202	
Very early				
RES	10280	9910	9200	9
Sutter	9210	8950	9210	9
Yolo	8500	8600	9070	9
San Joaquin	8190	7460	7550	9
Early				
RES	9660	9040	8470	4
Butte	8750	8420	7590	4
Colusa	9270	8950	9370	4
Yuba	8480	7920	8090	4
Intermediate/Late				
RES	9560	9340	9130	4
Sutter	9000	8850	8960	4
Glenn	8160	8000	8170	4

† Grain yield 10 lb/acre at 14% moisture.

‡ Very early locations were tested during 2000 – 2008 and all other locations were tested during 2005 – 2008.

Table 17. Performance of selected conventional long-grain entries with intermediate (L) or high (LR) amylose content in 2008 yield and milling tests.

Entry	Amylose Group	Identity	-----Yield†----- Statewide	RES	Blanking (%)	Head Rice‡ (%)
Very Early Statewide						
3	L	06Y513	9680	10420	12	64
4	LR	06Y575	10600	10480	8	64
18	L	07Y508	9990	9410	12	66
1	LR	L-205	9170	10010	8	65
2	L	L-206	9850	11180	15	61
Early Statewide						
65	L	06Y513	9960	11050	12	
63	LR	06Y575	10270	11270	12	
61	LR	L-205	9240	9700	12	
62	L	L-206	10060	10820	15	
Intermediate Statewide						
123	L	07Y576	9700	11530	12	59
124	L	08Y124	9240	11040	15	63
121	LR	L-205	8820	9890	8	64
122	L	L-206	9090	10740	15	60
Very Early Preliminary						
1009	LSR	07P2506	--	10130	8	66
1059	LSR	07P3207	--	10070	25	66
1070	L	L-206	--	9420	15	62
Early Preliminary						
1092	L	07P2684	--	10100	25	64
1104	L	07P2845	--	9980	8	62
1072	L	L-206	--	9380	12	62
Intermediate Preliminary						
1154	LSR	07Y761	--	11090	35	60
1167	L	07P2870	--	10660	12	62
1148	L	L-206	--	10830	15	63

† Grain yield in lb/acre at 14% moisture.
‡Head rice yields are from solid seeded stands for statewide tests and single rows for preliminary yield tests.

DNA markers were successfully used in 2008 to determine the type of amylose synthesis gene in 1300 long grain breeding lines. Use of this technology is reducing the need for starch profile characterization of certain group of long grain types through RVA analysis. Plans are underway to use 2 additional markers that identify gelatinization temperature and amylographic profile types. Although new functional markers are currently under development in major research institutions, the number of publicly available markers for rice breeding programs is still limited.

Specialty Long Grains

Breeding efforts were increased in specialty long grain area in 2008. Specialty types include Jasmine, Basmati, and conventional aromatics such as A-201. Agronomic and milling quality of selected specialty lines is shown in Table 18.

Calmati-202 is a true basmati variety released in 2006. It is an early maturing, semi-dwarf, pubescent, aromatic, elongating, and long grain. Susceptibility to cold induced blanking is significantly higher than standard varieties and therefore is not adapted to cold locations. Calmati-202 has shown significantly lower yield potential than L-205 and M-202 in the Statewide Yield Tests during 2003 to 2005, averaging 6740 lb/acre, which is 73% of L-205 and 74% of M-202 yield potentials.

Grain and cooking qualities of Calmati-202 is considerably closer to imported basmati types than Calmati-201. Due to finer grain shape, the yield potential of Calmati-202 is 10% lower than Calmati-201. Calmati-202 is not intended as a replacement for a higher yielding conventional aromatic variety such as A-201.

Milled rice kernels of Calmati-202 are longer than Calmati-201 and slightly shorter than imported basmati rice available in the US market. Grain width is more slender than Calmati-201, but not as slender as imported basmati rice. Cooked kernel length of Calmati-202 is also slightly longer than Calmati-201. The overall appearance of cooked basmati type rice is an important quality feature among basmati rice consumers. Cohesiveness of the cooked grains as well as grain shape and texture of Calmati-202 are distinguishable improvements over Calmati-201. Cooked rice of Calmati-202 that was aged nearly one year was preferred by taste panelists over Calmati-201. Grain fissuring studies have shown that both Calmati-201 and Calmati-202 are susceptible to fissuring at low harvest moistures (data not shown). 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 percent.

A new series of basmati type selections were tested in 2008 statewide and preliminary trials that have shown a significant cooking quality advantage over Calmati-201 and Calmati-202. Entries 07Y154 and 08Y138 possess true basmati qualities that are nearly indistinguishable from imported basmati types. Their primary features include higher elongation, more flaky texture, and minimal curving of the cooked grain. Both grain yield and milling yield of these lines, however, are lower than Calmati-202. Further testing is underway to determine their suitability for commercial production. Efforts are also already underway to improve both their yield and milling quality. Emphasis in basmati type breeding continues to be placed on recovering slender and flaky-cooking kernels with higher elongation ratios.

Efforts continued in 2008 to breed jasmine types through pedigree and mutation breeding. Crosses and backcrosses were made with Jasmine type material from various sources including Southern U.S. breeding programs and foreign introductions. The extreme photoperiod sensitivity of the original Thai Jasmine variety, Kao-Dak-Mali 105 (KDM), has been a significant barrier. KDM was irradiated in 2008 with a higher than average dose of gamma. The M_1 population is currently being grown in Hawaii winter nursery. The M_2 population is planned to be grown at RES in summer 2009 and evaluated for desirable mutants. Other mutants that were obtained previously are still being used as valuable germplasm source for further agronomic improvements. Forty eight jasmine type selections were tested in 2008 Preliminary and Statewide Yield Tests.

Table 18. Performance of specialty long-grain entries in 2008 yield and milling tests.

Entry	Identity	Specialty Type	--------Yield †------ Statewide	RES	Blanking (%)	Head Rice‡ (%)
Very Early Statewide						
26	05Y552	Jasmine	9280	9000	25	66
2	L-206		9850	11180	12	61
Early Statewide						
81	07Y526	Jasmine	9770	10140	12	57
85	07Y599	Jasmine	7470	9320	25	65
87	06Y545	Basmati	8230	8880	25	50
82	07Y489	Aromatic	9110	10550	25	63
79	CT-201	Basmati	7290	8120	35	62
80	CT-202	Basmati	6740	7930	15	61
62	L-206		10060	10820	12	61
Intermediate/Late Statewide						
139	07Y154	Basmati	6690	7920	50	55
138	08Y138	Basmati	5560	6540	50	52
134	CT-201	Basmati	7440	8400	45	62
135	CT-202	Basmati	7100	8900	18	61
122	L-206		9090	10740	12	61
Preliminary						
1005	07Y600	Jasmine	--	9080	25	65
1115	07P2950	Jasmine	--	9300	25	64
1186	07P3075	Basmati	--	6560	50	40
1187	07P3087	Basmati	--	6350	50	41
1127	07P3117	Aromatic	--	8540	25	56
1073	CT201	Basmati	--	7240	45	63
1074	A201	Aromatic	--	7870	15	51

† Grain yield in lb/acre at 14% moisture.

‡ Head rice yields are from solid seeded stands for statewide tests and single rows for preliminary yield tests.

Milling quality

Continued improvement in milling yield and milling stability of new long-grain varieties to the level of medium grains remains a major objective. Grain characteristics are being evaluated and selected that will lend milling yield stability to long-grain lines under adverse weather conditions and allow a wider harvest window. These may include hull cover protection, grain formation, or physicochemical properties of the grain that result in fissuring resistance. Efforts have been initiated to screen advanced breeding lines of all grain types for their resistance to grain fissuring. This effort which was initiated in conjunction with RiceCAP project will continue in a routine basis.

Information obtained from single kernel moisture meter is also being used to evaluate the uniformity of harvest maturity among advanced experimental lines that will ultimately lead to improved head rice yields. Milling yield potential of 30 of the most advanced long-grain lines from the Statewide Yield Tests were evaluated in 2008 harvest moisture studies in two maturity groups.

RiceCAP Project

RES is participating in the RiceCAP project which is a USDA initiative with the objective of applying genomic discoveries to improve milling quality and disease resistance in rice. Four breeding programs (Arkansas, California, Louisiana, and Texas) are providing phenotyping information, and several universities and research institutions are contributing genotyping and molecular research. The specific contribution from RES is providing extensive fissuring studies for 3 milling populations as well as evaluating a California long-grain population for developing molecular markers associated with milling quality. The 4th year of the project was completed in August 2008. An additional 4 months of funding was provided to RES to complete a second year of phenotyping of the California milling population, MY3. All phenotyping effort is expected to be completed by early 2009. Genotyping of this population is being carried out at USDA genomics facility at Stoneville, MS. One hundred fifty SSR markers are planned to be used in the final association analysis of the phenotypic and genotypic information. Further information on the status of this 4 year project can be found at http://www.uark.edu/ua/ricecap/.

Disease Resistance

SR resistance originating from *Oryza rufipogon* continues to be incorporated into an increasing number of high yielding long-grain lines. Thirty-two entries with a range of SR resistance were tested in 2008 Statewide and Preliminary Yield Tests. Performance of a selected number of these lines is shown in Tables 1-6, and preliminary yield test, Table 17. Despite a close linkage in the SR resistance trait with increased chalkiness and cold susceptibility, selections are being obtained that have broken such a linkage and have combined low SR score, low blanking, and high milling yield. Entry 08Y1009 (Table 17) is an example of a combination of SR resistance, cold resistance and desirable grain and milling qualities. The 2008 growing season with cooler than normal temperatures combined with heavy inoculation of breeding lines by RES pathologist provided favorable condition to select for SR resistant lines with tolerance to cooler temperatures. The long grain SR resistant selections continue to be among the highest yielding lines in the early as well as the advanced generation lines.

Modifications of cold blanking screening greenhouses that is currently underway at RES is expected to provide major improvements in cold tolerance screening of not only SR resistant long-grain lines but also RES breeding material in all projects.

CALROSE MEDIUM GRAINS

Jacob Lage

Calrose Medium Grain Rice continues to be the backbone of the Californian rice industry. Sixty years have passed since the release of 'Calrose' that set the standards for California medium grain rice which henceforth became known simply as 'Calrose Rice'. The original Calrose variety has long since been replaced by other and more productive varieties with improved milling, yield, and cooking qualities.

In 2008 the Calrose medium grain rice breeding program went through a transition with the retirement of Dr. Carl Johnson who had dedicated his entire career to the Californian rice industry. Among his most noteworthy accomplishments are the releases of M-202 and M-206 as well as being part of the efforts towards developing more cold tolerant varieties opening up for rice production in the Delta area. Despite Carl's retirement the breeding objectives will remain largely the same. Grain and milling yield will continue to be the most important traits in Calrose medium grain rice combined with resistance to cold, stem rot and lodging with the overall goal of maintaining a strong rice industry in California well into the future.

Variety Update

Five Calrose medium grain rice varieties are currently in production: M-104, M-202, M-205, M-206 and M-208. M-104 is the only very early maturing variety and is the dominant variety in the Delta region and other parts of the southern Sacramento Valley. From Table 19 it is clear that this variety is well suited for this region (San Joaquin data) whereas the data from the Rice Experiment Station trial is an example that the northern and more productive areas are not as well suited for M-104.

M-202 and M-206 are both early maturing varieties with broad adaptation throughout the rice growing area as their trademark. In the very early and early statewide tests M-206 out-yielded M-202 by 8% (Tables 1 & 3) while the difference in 2007 was 15% likely due to the lower temperatures observed that year increasing the cold blanking of M-202. Milling yield of M-206 was also far superior to M-202, especially when rice was harvested at 18% or lower harvest moisture (Figures 1 & 2). Improved grain and milling yield combined with significant better cold tolerance are the reasons why more and more growers are replacing M-202 with M-206.

M-205 is the longest maturing Calrose medium grain in production (Table 3), and by far the variety with the best resistance to lodging. Like M-206 it has excellent milling quality and is very popular in the warmer northern part of the Sacramento Valley. Its longer maturity and lack of cold tolerance prevents this variety from being grown in the colder regions of the valley. Its high yield potential and superior straw strength are convincing more and more growers in the northern counties to switch to M-205.

M-208 is the newest Calrose medium grain variety. It's a product of the appearance of the rice disease 'blast' which was first observed in Glenn and

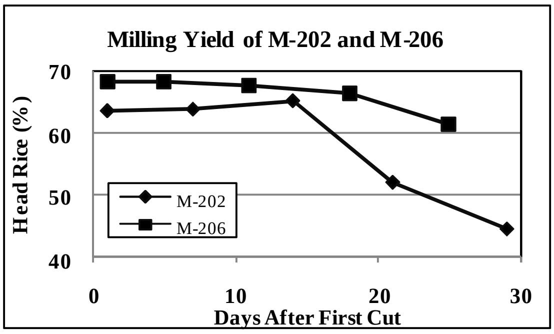
Colusa Counties in 1996. M-208 carries a single blast resistance gene, *Pi-z*, which has so far maintained its resistance to the blast race present in California. M-208 continues to be a wise choice in areas with a history of blast occurrences.

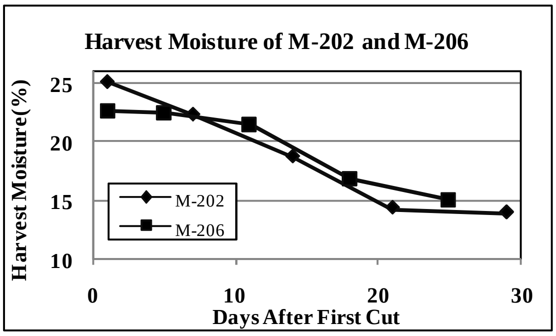
Table 19. Performance of Calrose medium grain varieties and one experimental line in the very early and early statewide trials

Test	ID	Days†	Grain Yield‡				
Very Early Statewide			RES	San Joaquin	Sutter	Yolo	Mean
	M104	82	9859	9867	9965	9927	9904
	M202	92	10035	7803	9397	10139	9344
	M206	90	11019	9440	9889	10482	10208
	05Y471	85	9738	9376	10103	10520	9934
Early Statewide			RES	Butte	Colusa	Yuba	Mean
	M202	92	10411	7290	9967	10004	9418
	M205	97	10843	7817	10073	10567	9825
	M206	89	10737	8523	10333	10699	10073
	M208	93	10244	7923	9960	10686	9703
	05Y471	82	10479	8327	9930	10194	9732

† Days to 50% heading.
‡ Paddy rice yield at 14% moisture.

Figures 1 and 2: Milling yield and harvest moisture of M-202 and M-206 from large milling plots cut at the Rice Experiment Station over a period of four weeks.



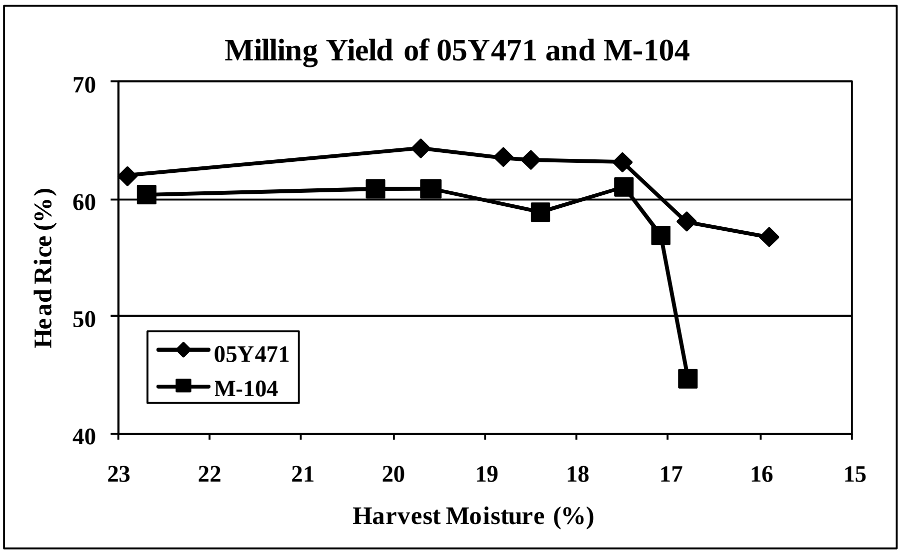


05Y471 is an experimental line under consideration for release. Although not as early as M-104 (Table 1) it is still classified as 'very early'. In the very early statewide trial 05Y471 performed similar or better than M-104 (Table 1) except at San Joaquin where M-104 clearly outperformed 05Y471. Lodging this year was less severe than 2007 where M-104 experienced almost 100% lodging at the Rice Experiment Station whereas 05Y471 suffered less with 60-70% lodging. Also from 2007 data, the blanking in San Joaquin was low for both lines, around 15% in a year where M-202 experienced 40% blanking.

The main improvement of 05Y471 over M-104 however is its milling quality. Figure 1 shows the percent head rice of total paddy rice from rows harvested at the Rice Experiment Station at different grain moisture levels. These data show that 05Y471 has two to four percentage points better milling yield than M-104 from grain moisture content 23 to about 17-18%. As the rice dries further, the milling yield of M-104 suffers tremendously dropping to 45% at grain moisture content just below 17%, whereas 05Y471 even at 16% moisture had acceptable milling yield.

05Y471 is mainly targeted towards the more productive areas of the Sacramento Valley and less so to the Delta region. A well adapted very early variety will provide many growers with the opportunity to diversify their rice crops in terms of maturity time. This will allow for earlier draining and harvest, which could result in more rice cut at the optimum harvest moisture and generally reducing the stress associated with harvesting large acreage of rice all maturing at the same time.

Figure 3. Percent head rice of experimental line 05Y471 and Calrose medium grain variety M-104 from four-foot rows harvested at different grain moisture contents at the Rice Experiment Station



Promising Advanced Experimental Lines

Several interesting advanced experimental lines were tested in the Preliminary Statewide Yield Trial in 2008. Previously Dr. Johnson made several crosses between our own best Calrose medium grain varieties and rice originated from China, the objectives being to introduce new variability of traits such as yield and cold tolerance. In 2008 we were able to test some of these 'Chinese Introgressions' for the first time in our statewide yield test. In the preliminary, early test (Table 4) six out of 13 entries (# 102-106, 108) were Chinese introgressions. Although on average across locations M-206 out-yielded all experimental lines, the Chinese introgressions yielded on average 9620 lb/acre whereas the regular experimental lines yielded 9310 lb/acre. As expected, the quality of the Chinese introgressions is no yet at the level of our Calrose medium grain varieties, but the results are nevertheless encouraging, and crossing with the most interesting Chinese introgressions is already under way.

In the group of advanced lines planted in replicated trials over two dates at the Rice Experiment Station there was a small group of lines on average yielding 5-10% above their checks (M-104 or M-206 depending on maturity). These lines, combined with promising material at less advanced stages, will be the basis of the next years Statewide Yield Tests and is proof of the viable breeding program left by Dr. Johnson.

Breeding Objectives

Yield will continue to be the most important trait in the Calrose medium grain rice breeding program, and given the current commodity prices there is a real incentive to grow high yielding medium grain rice. In the world of breeding it is widely acknowledged that the higher yield gets pushed the harder it becomes to make additional progress. Only through continuous incorporation of “new blood” combined with improved breeding technologies can we hope to push the boundaries even further. In the Calrose medium grain program we prioritize increasing the diversity of the program through crosses with non-Calrose rice such as Californian long and short grains, southern medium grains and short and medium grain rice from East Asia. In order not to compromise the well know milling and cooking quality of Calrose medium grain, much time is being devoted in maintaining these qualities in crosses with non-Calrose medium grain rice.

Second to yield is milling yield. Tremendous resources continue to be allocated to this trait, with M-206 setting the standard for selection. In comparison to M-202, M-206 not only have three to five percentage points better milling at harvest moisture between 18 and 22% it also maintains very acceptable levels of milling when harvested as low as 15% moisture (Figure 1). Another desirable trait of M-206 over M-202 is that it dries down in a more controlled manner. This is apparent in Figure 2 where M-206 maintains 21-22% moisture for ten days, whereas the moisture content of M-202 drops five percentage points in approximately the same time. This delayed drying of M-206, combined with the superior milling at lower moisture contents greatly increase the likelihood that growers will be able to harvest all their rice for optimal milling yields.

Improved milling yield at lower moisture content may eventually lead to a system where rice is harvested at lower moisture than currently advised. Should we experience a similar increase in energy costs as during the 2008 season, an only slight reduction in milling yield could become a very acceptable alternative to soaring drying costs, not only saving money but also benefitting the environment.

The importance of resistance to cold blanking increases the further south in the Sacramento Valley rice is grown. M-205 is likely our highest yielding variety in the northern part of the rice growing areas, but in test plots in the San Joaquin area blanking as high as 75% was observed in this variety in 2007. M-104 which is the preferred variety in the southern parts blanks up to 20% with M-206 only slightly better. In 2008 we experienced milder temperatures in both San Joaquin and at our test plots at UC Davis during the critical phase for cold blanking. Obviously this benefitted the growers in this region, but essentially we lost one year of research and testing for cold tolerance. The significant upgrade of our greenhouse capacity for cold tolerance testing will allow us to perform more consistent testing. However, the two cold screening locations will remain important components of our breeding efforts for more cold tolerant varieties with the realistic aim of decreasing blanking in Calrose medium grain to maximum 10% in the future.

Next on the list of important traits in Calrose medium grain rice is resistance to lodging and stem rot. These are two very difficult traits to work with and may well be interconnected, with lodging likely increased by weakening of the stem due to stem rot. A vigorous backcrossing project is underway in collaboration with pathologist Jeff Oster focusing on disease rating and keeping track of all the crosses and with Dr. Virgilio Andaya working on identifying molecular markers associated with resistance to stem rot. Success of this project will be of immense importance to growers of Calrose medium grain, and may very well result in a significant yield boost in the future

Blast luckily never became a large threat to the rice industry in California but can still be a problem locally in blast “hot-spots”. With the release of blast-resistant M-208 in 2006 rice growers in such hot-spot locations now have a very efficient way of protecting their crop against losses due to blast. Given the facts that blast is not a statewide problem and that M-208 efficiently addresses the issue breeding for future blast resistant Calrose medium grain has been down prioritized freeing resources to other focus areas. As of 2008, all selection of blast-resistant material is being done utilizing our enhanced capabilities of using molecular markers, thereby gaining precision over biological tests and reducing costs.

The tall mutant of M-206 (plant height discovery ‘phd’) was further evaluated in 2008 in collaboration with the UC Davis team lead by Dr. Albert Fischer. No apparent advantage was observed for the tall mutant of M-206 in a trial with increased water depth. However, breeding and research will continue at reduced scale to fully explore any potential of this trait.

Although Calrose medium grain is not targeted to the premium quality rice market any future Calrose rice varieties will naturally have to meet the standards for cooking and eating quality. With the introduction of new genetic variability to boost yield or increase stem rot resistance we will have to closely monitor the impact on quality to ensure we maintain the well know standards of Calrose medium grain rice.

New Technologies

Over the course of 2008 and 2009 several new technologies will be implemented in the Calrose medium grain breeding program. Already a new database system is fully implemented in the program greatly improving data accessibility and analysis thereby increasing our breeding efficiency. Electronic data capturing in the field and laboratory has been initiated and will be further developed in 2009.

Marker assisted selection is now fully functioning and with the current expansion of facilities we will be able to implement molecular markers efficiently in our breeding efforts. Already 4,000 early generation plants were tested for the presence of markers for the blast resistance gene, *pi-z*. Much emphasis will be given to the development of markers especially for stem rot resistance so that one day we will be able to incorporate this trait into Calrose medium grain rice.

The upgrading of old greenhouses and construction of a new greenhouse will open up for new possibilities for the Calrose medium grain breeding program. The improved and increased capacity for cold tolerance screening will become a cornerstone in the effort of developing Calrose medium grain especially for the part of the rice growing areas prone to cold nights during the critical growth stage of rice. Half of the newly constructed greenhouse will be dedicated to the Calrose medium grain breeding program for advancing generation during the winter. Combined with the important Hawaii winter nursery this will result in shorter development time for future varieties, as well as serve as an ideal setup for implementing large-scale marker assisted selection.

RICE PATHOLOGY

Jeff Oster

Breeding for disease resistance is a cooperative effort between the plant breeders and plant pathologist. The pathologist produces disease inoculum, conducts a disease nursery, identifies resistant germplasm, makes crosses to introduce disease resistance (about 594 crosses last year in a rapid backcrossing program), and screens statewide and preliminary trial breeding lines and varieties (about 2500 rows per year) for stem rot (SR) and aggregate sheath spot (SS) resistance in the field. In the greenhouse, screening is conducted for SS resistance (about 450 entries per year) and bakanae (450 entries). Blast genes are identified with molecular markers. The rapid backcross program involves screening about 1,300 entries for blast, and 62,000 plants for SR and 41,000 for SS resistance per year. In addition, early generation materials derived from breeder's crosses are cycled through the disease nursery to identify and verify disease resistant lines (about 4000 rows). Intense selection pressure is applied for important agronomic traits because sources of disease resistance have a number of undesirable characteristics. The objective is to transfer an improved level of disease resistance into future varieties. Most blast resistance genes have been backcrossed seven times into an M-206 background. SR and SS are receiving significant attention. The sources of SR resistance also confer aggregate and bordered sheath spot (SS) resistance. Conversely, the sources of SS resistance also seem to confer SR resistance in some materials.

Disease screening for bakanae resistance continues on all statewide yield trial entries.

False smut was found by UCCE Farm Advisor Dr. Chris Greer in 2006. This disease has been a problem in certain areas in the southern United States, and should be watched closely in California.

Stem Rot

Screening for SR resistance in inoculated nurseries and greenhouses usually begins in the F_1 generation for the immediate backcross program and in F_3 for materials provided by the breeders. Resistant germplasm often has low seedling vigor, low tillering, susceptibility to blanking, and late maturity. Only a fraction of a percent of the lines screened show higher levels of SR resistance than current varieties. There were about 6800 rows in the 2008 SR nursery.

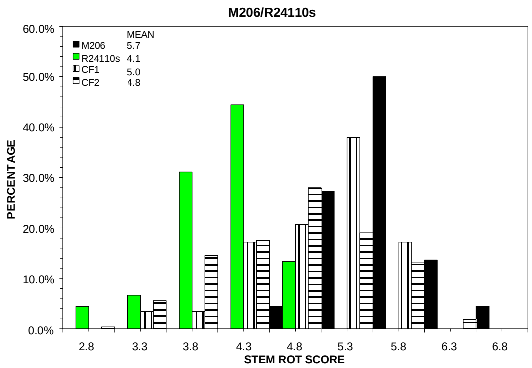
This year, 5300 rows in the stem rot nursery were drill seeded. This resulted in less seed drift, establishment of a more uniform stand, and allowed use of higher nitrogen without inducing lodging. Increased nitrogen results in greater disease severity and better screening.

Promising long and short grain resistant lines are emerging, but progress has been slow with the medium grains.

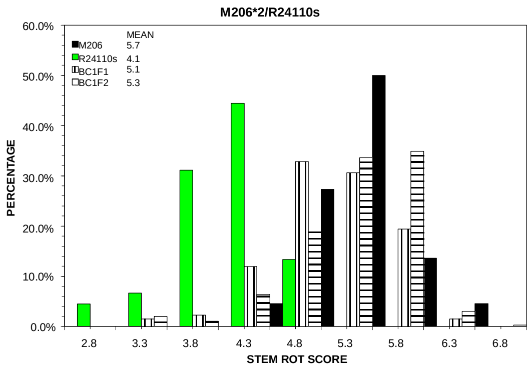
Because progress in the medium grain has been difficult, an immediate backcross program was started. Two long grain and two medium grain lines with resistance from *O. rufipogon* and two lines with resistance from *O. nivara* have been backcrossed with M-206. Because inheritance of SR resistance from *O. rufipogon* is due to more than one gene, and the error associated with single plant selection, large populations must be used. Fifty-four crosses were made this year for this purpose. Four backcrosses have been completed.

The mode of inheritance of resistance from *O. nivara* was studied in 3500 transplants last year and is shown in the figures below.

Cross



Backcross



Genetic analysis follows and is compared with that for *O. rufipogon* given by Figoni in 1981.

			O. nivara		O. rufipogon	
Trait	*O. nivara* line	Pop.	value	%gain	value	%gain
# genes	03/82661	Cross	1.5	-	2	-
	03/82661	BC1	25.7	-	-	-
	03/82664	Cross	0.94	-	-	-
	03/82664	BC1	1.4	-	-	-
h_{ns}^2	03/82661	-	0.57	-	0.91	-
	03/82664	-	0.44	-	-	-
F2/F3 regres sion	03/82661	Cross	0.42	-	0.33	-
	03/82661	BC1	0.43	-		-
	03/82664	Cross	0.24	-		-
	03/82664	BC1	0.25	-		-
h_{bs}^2	03/82661	-	0.69	-		0.91
	03/82664	-	0.64	-		-
G_s (2%)	03/82661	Cross	0.996	20.8	0.72	25.3
	03/82661	BC1	-	18.8	-	-
	03/82664	Cross	.72	14.6	-	-
	03/82664	BC1	-	14.0	-	-
h_r	03/82661	Cross	-0.12		0.32	10.4
	03/82661	BC1	0.61	12.0	-	-
	03/82664	Cross	0.25	5.1	-	-
	03/82664	BC1	0.31	6.0	-	-
a	03/82661	-	-0.43	-	0.57	-
	03/82664	-	-0.44	-	-	-
d	03/82661	-	4.09	-	-1.06	-
	03/82664	-	4.05	-	-	-
aa	03/82661	-	0.27	-	-0.38	-
	03/82664	-	-0.02	-	-	-
ad	03/82661	-	0.78	-	0.19	-
	03/82664	-	0.68	-	-	-
dd	03/82661	-	-0.67	-	0.02	-
	03/82664	-	-0.31	-	-	-

For *O. rufipogon*, dominance effects (d) were largest, additive effects (a) were next, and interallelic gene interactions were not significant (additive x additive, dominant x dominant, additive x dominant). The F_1 is as or more resistant than *O. rufipogon*, but the F_2 does not show skewing toward the resistant parent. There are only a small percentage of resistant segregants, and a lack of fit to one or two gene models. Inheritance of resistance is polygenic, apparently with some contribution from the susceptible parent. Broad sense (h_{bs}^2) and narrow sense (h_{ns}^2) heritability are 91%. F_2/F_3 regression of disease indices is 33%, and realized heritability is 32%. Predicted gain through selection (G_s, 2% level) is 25.3%, while actual gain (h_r) is 10.1%.

For *O. nivara*, dominance effects are the greatest, followed by axd, dxd, additive, and axa effects. Dominance, axd, and dxd effects are larger than values observed for *O. rufipogon*. The F_1 was intermediate to parental disease index scores, and the F_2 showed a normal distribution. There are only a small percentage of resistant segregants. Inheritance is polygenic. Broad sense heritability (includes additive and dominance effects) is 64-69%, narrow sense heritability (just additive effects) is 44-57%, and F_2/F_3 regression of disease indices is 24-43%. Predicted gain through selection (2% level) is 14-21%, while actual gain is 6-12%.

This study demonstrates that transfer of SR resistance from *O. nivara* should be possible, but may be as difficult as the resistance from *O. rufipogon.*

Crosses for all donor parents are now at BC_4F_2. Percentage of resistant F_1 plants used to further the backcrossing scheme has fallen dramatically for all populations except those derived from the 03/82664 line (*O. nivara* resistance). Greater emphasis will be placed on rapidly advancing generations from earlier backcrosses. Crosses will be made using resistant F_5 parents identified in the field (and in previous greenhouse screening), followed by one backcross and rapid generation advance. Four generations are grown per year and screened in the greenhouse. In this way, two backcrosses and advance to SR resistant F_5 will be made every two years. Backcrossing will continue until $BC_{5 \text{ or } 6}$ is made, and material will enter the normal yield-testing program.

It may be possible to combine resistance from *O. rufipogon* and *O. nivara* after the backcrossing scheme is completed.

Fifty resistant and fifty susceptible lines identified over the years in the program to transfer resistance from *O. rufipogon* were grown as transplants this year. Single plants were selected to represent these lines. These plants will be used by Dr. Andaya to perform associative mapping to discover resistance gene location and develop molecular markers for this stem rot resistance.

In addition, about 1,000 BC_1F_1 transplants were evaluated for SR resistance in the field. The parents were M-206 and 87Y550 (long grain with resistance derived from *O. rufipogon*). The best and worst scoring plants were harvested and will be used by Dr. Andaya in developing molecular markers as a compliment to the associative mapping effort.

Sheath Spot

A greenhouse screening program has been set up to test statewide yield entries (other than those with wild species resistance) for SS resistance. This is especially important for the medium grains, which do not yet benefit from SS resistance derived from *O. rufipogon*. The test revealed large differences in sheath spot resistance among these materials. Correlations between yearly results are about r^2=0.5. Sheath spot is more widespread than stem rot, and can cause significant damage. Field tests in the SR nursery are inadequate because of interference from SR and field conditions unfavorable to SS development in many years.

O. rufipogon and *O. nivara*-derived resistance also confers protection against SS. Researchers in the South have found resistance to sheath blight (caused by a similar fungus) in *O. rufipogon*, also.

In addition, an immediate backcross program was started to transfer SS resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-205 (117 crosses this year). BC_4F_2 was made. Screening strategy will parallel that used for the SR immediate backcross program. Rice CAP researchers have found one molecular marker associated with about 29% of the resistance found in Jasmine 85, and are currently developing other molecular markers to aid in transfer of these resistances.

SS resistant progeny from the first backcross were grown in the SR field nursery this year. Some lines (derived from all three donor parents) showed SR resistance equivalent to that found in the wild species. These lines will be used as parents in the continuing backcross program. If field observations are confirmed, the program will use only lines with resistance to SR and SS in the future.

When the backcrossing program is complete, it may be possible to combine resistance with that from the wild species SR resistance program.

Blast

Rice blast disease in California was identified for the first time in 1996 in Glenn and Colusa Counties. It spread over significantly more acres in 1997, and has reached Sutter (1998), Butte (1999), and Yuba (2000) counties. In 1998 to 2008, blast severity was much lower than in previous years. A few affected fields continue to be found, mostly on the west side of the valley. M-104 appears to be more susceptible than other varieties, followed by M-205. None of the Statewide Yield Tests have been affected by blast since 1997, so the entries could not be evaluated.

Major resistance genes limit blast symptom expression to small brown flecks at most, but different races of the blast fungus can overcome this resistance within several years after variety release. The first blast resistant variety (M-207, possessing the *Pi-z* gene) was released in 2005, followed by M-208 (also with *Pi-z*) in 2006. Almost all material presently advancing through the medium grain program possesses only this gene. Since molecular markers for blast resistance genes are available, biological screening for the *Pi-z* gene has stopped. If future varieties with the *Pi-z* gene are developed, they will first be subjected to a confirmatory biological screen for blast resistance before release.

IRRI recently reported development of monogenic lines each containing one major gene for blast resistance. These lines were brought through quarantine and tested to verify their blast resistance to the IG-1 race present in California. A backcross program was started in 2005 to introduce these genes into M-206.

Only genes with a wide spectrum of blast resistance in worldwide tests were chosen (*Pi-b, Pi-k^h, Pi-k^m, Pi-z^5, Pi-9, Pi-40,* and *Pi-ta^2*). Seven backcrosses were made and screened for blast resistance (270 crosses this year). Theoretically, 99.6% of genes in this material are from M-206. In 2008-9, BC_7F_1 will be screened with markers, and then homozygous lines selected from the F_2. At this point, the backcross program for these genes will be complete. These lines will be evaluated for agronomic traits, and the best lines selected. The breeders have decided not to proceed with pyramiding these genes despite the danger of resistance breakdown in varieties with only a single major gene for disease resistance.

In addition, backcrossing proceeds to transfer the *Pi-1* (now at BC_3), *Pi-2* (BC_3), and *Pi-33* (BC_6) genes into an M206 background with the aid of molecular markers (295 crosses this year). This project will be completed for all genes by 2010.

The project by Dr. Andaya to develop molecular marker screening for blast has been successful. The following table summarizes findings from this project.

Marker	Gene
RM224	*Pi-1, Pi-k^h*
RM1233	*Pi-k^m*
AP5930F	*Pi-2, Pi-z, Pi-z^5, Pi-9, Pi-40*
RM7102	*Pi-ta^2*
RM208	*Pi-b*
RM331	*Pi-33*

Bakanae Disease

Seed treatment research for control of this disease has been concluded. Backup chemicals have been identified in case bleach is no longer available.

Screening breeding lines for bakanae resistance continues. All statewide entries are screened in the field. The goal is to prevent releasing excessively susceptible varieties. This should enhance the effectiveness of seed treatments in controlling the disease.

Quarantine Introductions

The building blocks for any breeding program are varieties with traits desirable in commercial production. From time to time, these varieties are imported for use in the breeding program. No introductions were brought through quarantine this past year.

All introductions were grown under procedures developed and approved by USDA and CDFA to prevent introduction of exotic pests and rice diseases. This expedited process enables the breeding program and the industry to maintain a competitive edge in the world rice market while preventing the introduction of new pests to California.◆

THE CALIFORNIA RICE INDUSTRY AWARD

The California Cooperative Rice Research Foundation is proud to annually sponsor the California Rice Industry Award. The purpose of this award is to recognize and honor individuals from any segment of the rice industry who have made outstanding and distinguished contributions to the California rice industry. Recipients of the award are nominated and selected by a committee of rice growers and others appointed by the CCRRF Board of Directors. The California Cooperative Rice Research Foundation has been proud to recognize and honor the following individuals with the California Rice Industry Award in the past. Their distinguished service and contributions have advanced the California rice industry. ◆

1963 - Ernest L. Adams
1964 - William J. Duffy, Jr.
1965 - Florence M. Douglas
1966 - Fred N. Briggs
1967 - Loren L. Davis
1967 - George E. Lodi
1968 - Karl I. Ingebretsen
1969 - Glen R. Harris
1970 - Milton D. Miller
1971 - James J. Nicholas
1972 - George W. Brewer
1973 - Johan J. Mastenbroek
1974 - Leland O. Drew
1975 - Marshall E. Leahy
1976 - Fritz Erdman
1977 - Carroll W. High
1978 - B. Regnar Paulsen
1979 - W. Bruce Wylie
1980 - Robert W. Ziegenmeyer
1981 - Maurice L. Peterson
1982 - Jack H. Willson
1983 - James G. Leathers
1984 - Francis B. Dubois
1985 - Morton D. Morse
1986 - Chao-Hwa Hu
1986 - J. Neil Rutger
1987 - Howard L. Carnahan
1988 - Narval F. Davis
1989 - Duane S. Mikkelsen
1990 - Melvin D. Androus
1991 - Albert A. Grigarick
1992 - Ralph S. Newman, Jr.
1993 - Carl M. Wick
1994 - David E. Bayer
1995 - Gordon L. Brewster
1996 - Phil Illerich
1997 - D. Marlin Brandon
1998 - Shu-Ten Tseng
1999 - Robert K. Webster
2000 - Lincoln C. Dennis
2001 - Alfred G. Montna
2002 – Dennis O. Lindberg
2003 – John F. Williams
2004 – Carl W. Johnson
2005 - James E. Hill
2005 – Don Bransford
2006 – Michael Rue
2007 – Lance Tennis
2008 – Charlie Mathews

D. MARLIN BRANDON RICE RESEARCH FELLOWSHIP

Dr. Marlin Brandon began his career in 1966 as the Rice Farm Advisor in Colusa, Glenn, and Yolo Counties, Rice Extension Agronomist, LSU Professor of Agronomy, and Director and Agronomist at RES until passing away in 2000. He was a mentor and teacher of rice production science to colleagues, students, and growers everywhere.

In tribute, the California Rice Research Board and the Rice Research Trust established a fellowship in his memory that is awarded at Rice Field Day. Recipients will be known as D. Marlin Brandon Rice Scholars.

In 2008, fellowships of $2,500 were awarded to Louis Boddy and Monika Krupa. A total of 16 fellowships have awarded.

Rice Research Proposal

Rice research at RES in 2009 will continue toward the primary objective of developing improved rice varieties for California. Two new breeders joined the Rice Breeding Program in 2007 and considerable effort was made on their integration into the program, incorporating their new skills and ideas, and the transitioning with the retirement of Dr. Johnson in July 2008.

Project leaders will concentrate efforts on developing rice varieties for the traditional medium, short, and long-grain market classes. Research efforts will continue to improve and develop specialty rice such as waxy (mochi or sweet) rice, aromatic rice, and others as an adjunct breeding effort. Major breeding emphasis will continue on improving grain quality, yield and disease resistance. Efforts will be made to effectively use new as well as proven breeding, genetic, and analytical techniques. RES staff will expand DNA marker screening capabilities. Following are the major research areas of the RES Rice Breeding Program planned for short, medium, and long-grain types in 2008.

Quality

Efforts to identify, select, and improve culinary and milling quality in all grain types will continue to receive major emphasis. The RiceCAP project is cooperating with RES to develop genetic markers for milling quality. Improved techniques for cooking evaluations are being used that include use for DNA markers for amylose content, gelatinization temperature, and RVA types. The RES quality lab is supporting quality evaluation and research for variety development.

Resistance to Disease

The RES Rice Breeding Program is continuing efforts to improve disease resistance in our California varieties. Evaluation and screening for stem rot and sheath spot resistance will be conducted by the plant pathologist on segregating populations, advanced breeding lines, and current varieties. Rice blast disease presents an additional threat to California. Research and breeding activities to address rice blast have been implemented and greenhouse screening for resistance is continuing. M-208, an improved medium grain with resistance to blast race IG-1, was released in 2006 and efforts to develop improved blast resistant varieties will continue. The Pathology Project is proceeding forward on large scale backcrossing efforts to transfer disease resistance into selected varieties, primarily medium grain. Marker-aided selection will be a part of this effort as will the use of new sources of resistance. New resistant sources and foreign germplasm will continue to be evaluated as potential parental material. Foreign germplasm will be introduced through quarantine for use in breeding and research.

Yield

Yield is a complex character that results from the combination of many agronomic traits. Emphasis will continue on breeding varieties with high grain yield potential, minimal straw for high yield, and more stable yields while maintaining and/or improving grain quality.

Tolerance to Low Temperature

Tolerance to low temperature remains an essential character needed at seedling and reproductive stage in California rice varieties. Segregating populations and advanced experimental lines will continue to be screened in the San Joaquin nursery for resistance to blanking, normal vegetative growth, minimum delay in maturity, and uniform grain maturity. Selection at UCD may be discontinued due to concerns about adjacent UC research activities. Expanded large plot yield testing is being considered at the San Joaquin nursery site. Cold tolerance data will include two seeding dates of advanced material at RES, UCCE Statewide Yield Tests, refrigerated greenhouse tests, and data from the UCD, San Joaquin, and Hawaii nurseries.

Lodging and Maturity

Improved lodging resistance will receive continued emphasis in all stages of variety development. Efforts will continue to develop improved varieties that have a range of maturity dates with major emphasis placed on early, very early rice, synchronous heading, and uniformity of ripening.

Seedling Vigor

Selection and evaluation for seedling vigor will continue on all breeding material.

Cooperative Projects

Cooperative research by the rice breeding program staff with USDA, UC, RiceCAP and others in the area of biotechnology, genetics, quality, agronomy, entomology, plant pathology, and weed control will be continued in 2008. Emphasis will be placed on applied research and more basic studies that may contribute to variety improvement.

Rice Research Priorities and Areas of Breeding Research

General Rice Research Objectives of Rice Experiment Station

The primary research objective of RES is development of high yielding and quality rice varieties of all grain types (short, medium, long) and market classes to enhance marketing potential, reduce cost, and increase profitability of rice. Rice breeding research priorities at RES can be divided into general priorities, that are applicable to all rice varieties developed for California, and specific priorities, that may differ between grain types, market classes, special purpose types, and the special interests of the plant breeding team members.

A secondary but important objective is to support and enhance UC and USDA rice research through cooperative projects and by providing land, water, and input resources for weed control, insect, disease, and other disciplinary research.

General Rice Breeding Priorities Applicable to All Public California Rice Varieties

- High and stable yield potential
- Cold tolerance
- Lodging resistance
- Resistance to blast, stem rot, and aggregate sheath spot diseases
- Seedling vigor
- Early maturity
- Synchronous heading and maturity
- Improved head rice milling yields
- High quality rice consistent with grain type, market class, or special use
- Develop and utilize DNA marker assisted selection

Specific Rice Breeding Priorities by Grain Type, Market Class, and Special Use

Short Grains and Premium Quality Medium Grains

- Improve California short grain rice
- Develop superior premium quality short and medium grain varieties
- Improve waxy, low amylose, and bold grain rice
- Discover and develop DNA markers for grain quality and disease resistance

Calrose Type Medium-Grains

- Improve conventional medium grains
- Improve stem rot resistant in medium grains
- Increase genetic diversity
- Utilize DNA markers for selection for blast resistance genes
- Utilize rapid generation advance

Long Grains

- Superior quality for table and processing
- Improve head rice milling yields and fissuring resistance
- Improve basmati types
- Develop Jasmine types
- Develop aromatic types
- Improve cold tolerance
- Improve SR and blast resistance

Rice Pathology

- Screening and evaluation of advanced breeding lines for blast, stem rot, sheath spot, and bakanae.
- Facilitate transfer of stem rot and aggregate sheath spot disease resistance from wild species of rice and disease resistance genes identified in RiceCAP
- Mapping of stem rot resistance genes and marker aided selection for stem rot and blast
- Facilitate transfer of wide spectrum blast resistance genes to adapted medium grains using accelerated backcrossing, screening, and selection for resistance.

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