2009 RICE BREEDING PROGRESS REPORT
AND
2010 RESEARCH PROPOSAL

P. O. Box 306, Biggs, CA 95917-0306
January 1, 2010

RICE EXPERIMENT STATION STAFF

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Virgilio Andaya, Ph.D. .... Plant Breeder
Jacob Lage, Ph.D. .... Plant Breeder
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)] and members are 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 includes plant breeders Drs. Farman Jodari, Virgilio Andaya, Jacob Lage, and plant pathologist Mr. Jeffrey J. Oster. Eleven career positions consisting of five plant breeding assistants, one DNA lab technician, 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 California Rice Research Board 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 and lodging resistance 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. RRT funded a $900,000 greenhouse and DNA lab construction project that was completed in 2009.

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, located at UC Davis (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, Zhongli Pan, 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 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 2009. 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, Dr. Bruce Linquist, James Thompson, Richard Plant, Chris Greer, Luis Espino, Willie Horwath, and James Hill are all doing rice research on 18 acres at RES. They are being supported by UCD staff research associate at RES, Mr. Ray Stogsdill. Dr. Larry D. Godfrey, (extension entomologist) and Mr. Evan Goldman, (staff research associate, Department of Entomology,) conducted rice insect research. Please refer to the 2009 Comprehensive Rice Research Report for information on UC, USDA and RES-UC-USDA cooperative research.

RES does provide technical input and support to the California Rice Commission.

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 has followed an 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. All test results have been non-detect and never detected in any California grown rice. Further testing required by the California Rice Commission of CCRRF foundation and basic seed samples for 2007-9 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 CRRB. 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 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 12 public rice varieties and basic seed of two Japanese premium quality varieties were produced on 140 acres at RES in 2009. 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. Utility patents have also been obtained. 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.◆

RICE BREEDING PROGRAM

INTRODUCTION

The RES Rice Breeding Program consists of four research projects. Three rice breeding projects focus on developing adapted varieties for specific grain and market types and are each under the direction of an 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. 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 also 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 2009 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 2009 breeding nursery began May 4th, and was completed May 21st. In 2009, 1778 crosses were made at RES for rice improvement, bringing the total number of crosses made since 1969 to 38,408. 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 2010, thereby accelerating the breeding process.

The 2009 RES breeding nursery occupied approximately 74 acres. Water-seeded yield tests included 2260 small plots and 3980 large plots. Small seed increase plots and cooking samples advanced breeding lines were grown on 3 acres. The nursery included about 45,560 water-seeded and 37,546 drill seeded progeny rows. F_2 populations from 2007 and 2008 crosses were grown in precision drill-seeded plots on 10 acres. An estimated 150,000 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 2010.

Headrows (1,200) of M-202, S-102, and Akitakomachi were grown for breeder seed production in 2010. 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 2008-9 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 2009-10 winter nursery of 8400 rows was planted November 4th to 6th, 2009, and 584 F_1 populations were transplanted to the nursery November 30th, 2009. Selection and harvest will occur in April, and seed returned for processing and planting in the 2010 RES breeding nursery.

Due to potential contamination concerns from the panicle rice mite infestation in UCD greenhouses, no RES material was planted at the UC Davis facilities in 2009.

The San Joaquin Cold Tolerance Nursery was planted in cooperation with two local rice growers. The 7-acre drill seeded nursery included 10,200 rows, 5 acres of F_2 populations, and two small drill-seeded yield tests were grown in cooperation with the UCCE. There were some stand establishment problems and loss of some material. Very little blanking was observed to select blanking resistant material. An additional yield test was grown in cooperation with UCCE on Twitchell Island near Rio Vista. High levels of blanking were observed in entries at that location.

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 2009 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 of 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 4th to 7th, 2009. 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. Bolero UltraMax®, Shark®/Londax® and SuperWham® were applied for weed control and one application of Lambda-Cy® was applied for rice water weevil control.

Tables 1 through 6 contain a summary of performance information from the 2009 Statewide Yield Tests. Yields are reported as paddy rice in pounds per acre at 14% moisture. Some plot yields were low due to cold water and fertilizer application problems. 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 2010. 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 (4 reps) locations in 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
4	06Y575	LR	4.8	87	104	15	5.1	10710	10870
5	08Y1009	LSR	4.7	85	91	0	5.8	10520	9910
3	06Y513	L	4.7	85	88	0	5.5	10030	9790
6	07Y508	L	4.8	81	96	0	4.7	9840	10410
2	L206	L	4.5	81	83	0	6.2	9710	9720
1	L205	LR	4.4	89	91	3	5.7	9430	9310
17	M206	M	4.8	79	96	18	5.3	8940	9840
11	04Y332-1	MPQ	4.8	85	88	4	4.9	8640	9160
8	S102	S	4.6	78	91	8	5.2	8230	9030
13	05Y471E	M	4.7	79	91	5	5.4	8170	9690
16	M202	M	4.7	83	96	38	6.0	8080	9310
14	05Y471L	M	4.7	79	93	5	5.4	8050	9530
9	04Y177	SPQ	4.7	80	88	60	4.9	8020	8980
12	07Y186	MPQ	4.9	78	91	3	5.5	7970	8850
7	CM101	SWX	4.6	79	88	28	5.5	7640	8480
10	06Y175	MPQ	4.9	80	99	75	5.3	7470	8650
15	M104	M	4.8	76	88	5	5.9	7180	9380
Mean			4.7	81	94	16	5	8740	9470
LSD (0.05)			0.1	1	5	21	1	1030	370
C.V. (%)			2	1	4	96	7	8	6

† 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 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
26	09Y026	L	4.8	86	84	0	5.6	9720	10260
22	08Y1104	L	4.8	86	81	0	5.8	9470	9820
24	09Y024	L	4.7	86	86	8	4.8	9470	9850
25	09Y025	L	4.9	83	91	8	5.2	9360	10040
30	08Y2048	SSR	4.2	79	86	0	4.7	8960	9160
20	08Y1048	L	4.6	85	89	0	5.2	8900	9400
36	08Y2049	SSR	4.6	79	84	5	4.9	8860	9640
37	07Y204	MPQ	4.8	82	94	10	5.2	8820	9050
39	07Y732	M	4.8	80	84	15	5.1	8800	9660
32	08Y2042	SPQ	4.6	80	84	0	4.4	8750	9320
46	08Y3026	M	4.9	79	91	10	5.3	8740	9690
49	08Y3117	M	4.7	79	91	15	5.3	8720	9910
18	08Y1027	L	4.6	85	91	0	4.8	8700	9570
19	08Y1047	L	4.6	81	89	0	5.1	8700	10010
47	08Y3114	M	4.8	79	89	15	5.6	8700	9920
34	08Y2044	SPQ	4.8	81	84	20	5.3	8660	9730
40	07Y843	M	4.9	78	91	0	5.7	8530	10050
33	08Y2037	SPQ	4.5	79	89	3	4.6	8330	9080
21	08Y1059	LSR	4.5	82	86	0	5.1	8280	9500
31	08Y2025	S	4.5	80	89	10	4.7	8250	9160
42	08Y3015	M	4.9	77	84	5	5.3	8240	9500
23	09Y023	LSR	4.8	84	86	5	4.4	8140	9450
50	08Y3125	M	4.8	79	94	10	5.1	8010	9680
51	M206	M	4.8	79	89	10	5.4	7980	9620
38	07Y225	M	4.8	77	86	8	5.3	7860	9300
29	M203	MPQ	4.8	80	97	100	5.6	7830	9370
35	08Y2046	SPQ	4.6	80	79	15	5.2	7770	8590
45	08Y3020	M	4.9	76	86	3	5.3	7710	9420
48	08Y3115	M	4.7	79	89	25	5.6	7580	9230
27	CH201	SPQ	4.8	85	84	15	6.2	7370	8610
41	07Y1067	M	4.8	76	91	3	5.6	7350	9610
44	08Y3017	M	4.9	77	86	5	5.3	7270	9050
28	08Y2011	MPQ	4.7	78	81	8	5.1	7000	8450
43	08Y3016	M	4.8	76	84	0	5.6	6920	9170
Mean			4.7	80	86	10	5	8350	9470
LSD (0.05)			0.2	1	4	8	1	1240	440
C.V. (%)			2	1	5	40	7	7	5

† L=long grain, LSR=long grain stem rot resistant, M=medium grain, MPQ=premium quality medium grain, SPQ=premium quality short grain and SSR=short grain stem rot.
‡ 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 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
64	08Y1092	L	4.7	82	91	0	5.3	11410	10170
66	08Y1048	L	4.7	83	97	5	5.2	11400	9690
62	L206	L	4.6	81	94	28	5.3	10840	9550
65	06Y513	L	4.8	86	91	38	5.4	10680	9510
63	06Y575	LR	4.9	84	104	65	5.3	10480	9230
68	S102	S	4.7	77	94	53	5.2	9700	8400
69	04Y332-1	MPQ	4.8	86	94	88	5.4	9590	8810
61	L205	LR	4.6	89	94	44	5.9	9570	8840
76	M205	M	4.7	86	94	30	5.3	9430	9430
72	06Y322	MPQ	4.9	84	97	91	5.7	9420	9090
78	M208	M	4.9	83	99	93	5.1	9170	8810
77	M206	M	4.8	80	94	71	5.4	9080	8780
70	04Y308	MPQ	5.0	82	91	73	5.3	9050	9140
74	05Y471L	M	4.8	78	94	53	5.4	9030	8590
75	M202	M	4.8	83	99	96	5.3	8940	8780
67	CM101	SWX	4.7	78	91	68	5.3	8700	7780
73	05Y471E	M	4.7	78	91	33	5.8	8690	8560
71	04Y177a	SPQ	4.6	82	89	92	4.8	8280	8220
Mean			4.8	82	94	57	5	9640	8970
LSD (0.05)			1	1	5	21	1	790	440
C.V. (%)			2	1	4	26	7	6	7

† 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 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
81	07Y526	L	4.5	86	94	0	5.5	10780	9870
85	08Y1009	LSR	4.9	83	86	0	5.4	10690	9530
84	08Y084	L	4.8	85	91	30	5.6	10360	9980
79	A201	LA	5.0	89	97	0	5.3	9960	8760
82	07Y599	LJ	4.9	82	84	0	5.8	9910	9430
83	08Y1109	LJ	4.7	84	89	13	5.3	9500	8180
89	08Y1167	L	4.6	86	86	0	4.8	9400	8960
86	07Y603	LA	4.8	84	86	8	5.4	9380	9080
95	07Y293	SPQ	4.8	78	81	40	4.8	9240	9120
90	CH-201	SPQ	5.0	81	84	93	5.7	9090	8000
88	07Y489	LA	4.9	80	84	5	5.7	8930	8520
91	M203	MPQ	4.8	79	97	97	5.5	8810	8550
87	08Y1115	LA	4.7	83	94	0	5.5	8740	7930
98	08Y2098	MPQ	5.0	79	99	85	5.3	8610	8610
106	07Y414	M	4.7	79	94	70	5.1	8390	8440
111	08Y3121	M	4.8	78	91	65	5.4	8350	8420
109	08Y3119	M	4.7	78	94	78	5.4	8300	8510
92	07Y369	SBG	4.2	79	94	40	5.8	8080	7220
99	08Y2089	MPQ	4.9	78	94	97	5.6	8060	8370
104	07Y257	M	4.8	77	86	60	4.8	8040	8990
102	07Y253	M	4.6	78	89	70	5.4	8010	8320
103	07Y255	M	5.3	76	89	55	5.3	8000	9010
105	07Y280	M	4.7	76	84	45	5.4	8000	8500
93	07Y350	S	4.7	80	89	70	4.1	7900	8150
96	07Y343	MPQ	4.8	81	89	75	5.2	7850	7960
112	08Y3122	M	4.7	78	91	50	5.2	7830	8440
113	08Y3126	M	4.7	77	89	80	5.7	7690	8500
80	CT202	LB	4.8	82	89	15	5.9	7650	6730
101	07Y251	M	4.8	77	91	75	6.0	7630	8350
114	M206	M	4.8	78	86	70	5.4	7490	8220
97	08Y2087	MPQ	5.0	79	89	90	6.0	7410	8110
110	08Y3120	M	4.7	77	86	70	5.1	7370	8330
100	08Y2096	MPQ	5.0	76	84	50	5.7	7220	7930
108	07Y1044	M	4.7	79	84	60	5.5	7130	8380
107	07Y832	M	4.7	81	86	40	5.2	7040	8050
94	07Y364	SLA	4.5	78	84	65	5.1	6800	7580
Mean			4.8	80	89	49	5	8340	8470
LSD (0.05)			0.4	2	7	26	1	1180	510
C.V. (%)			4	1	5	26	7	7	6

†L=long grain, LSR=long grain stem rot, LA=long grain aromatic, LJ=jasmine, M=medium grain, MPQ=premium quality medium grain, S=short grain, 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 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
129	07Y671	SSR	4.7	85	84	68	4.4	10630	10100
125	08Y1168	L	4.5	92	91	3	5.5	10240	9720
127	05Y343	SWX	4.7	90	91	93	4.8	10090	9530
122	L206	L	4.4	85	86	28	5.9	9950	9290
124	06Y513	L	4.4	93	94	3	5.4	9950	9340
123	07Y576	L	4.3	98	99	0	4.5	9630	9590
133	M205	M	4.8	86	86	80	5.3	9290	9200
128	07Y301	SPQ	4.8	89	89	51	5.5	9190	9550
121	L205	LR	4.2	97	97	10	6.0	9170	8550
126	M402	MPQ	5.0	104	104	11	5.1	9110	9240
131	07Y726	M	4.8	87	86	40	4.6	9110	9210
130	08Y2094	MPQ	4.8	83	84	98	4.9	8490	8140
132	M202	M	4.6	85	86	85	5.4	8300	8200
Mean			4.6	90	91	44	5	9470	9200
LSD (0.05)			0.2	3	3	31	1	780	390
C.V. (%)			3	2	2	49	7	6	5

† L=long grain, LR=Rexmont type, M=medium grain, MPQ=premium quality medium grain, SSR=short grain stem rot, 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 2009.

Entry Number	Identity	Type†	SV‡	Days§	Ht. (cm)	Lodge (%)	SR¶	---Grain Yield#--- RES	State
152	07Y722	M	4.9	90	89	25	5.8	10150	9440
140	08Y1154	LSR	4.7	96	97	0	3.6	9810	9490
150	07Y697	M	4.8	88	89	55	5.5	9780	9000
147	07Y477	M	5.0	86	86	55	4.8	9610	9000
154	08Y3135	M	4.6	86	86	0	4.6	9450	9170
151	07Y700	M	4.9	86	86	13	4.9	9150	8900
148	07Y691	M	4.6	86	86	70	4.7	9080	8750
137	07Y1174	LJ	4.6	99	99	0	6.2	9070	8700
146	07Y466	M	4.9	86	86	40	4.8	8740	8720
155	M205	M	4.8	87	86	25	5.4	8670	8940
153	08Y3134	M	4.5	85	84	8	5.2	8590	8530
136	08Y1114	LJ	4.5	97	97	0	6.0	8440	8220
142	08Y2103	MPQ	4.8	87	86	95	5.1	8410	9200
139	09Y139	LB	4.1	98	99	0	4.5	8280	7180
144	08Y2162	SPQ	4.9	89	89	90	5.9	8090	8130
149	07Y692	M	4.8	85	84	95	4.9	8070	8440
145	08Y2082	MPQ	4.9	83	81	100	5.7	7880	8080
141	CH201	SPQ	5.0	83	84	95	5.8	7860	7810
134	CT201	LB	4.5	92	91	0	5.9	7850	7870
143	08Y2147	MPQ	4.8	87	86	95	5.2	7710	7390
135	CT202	LB	4.4	87	86	0	5.9	7620	6960
138	08Y138	LB	4.3	98	99	0	5.0	7190	6420
Mean			4.7	89	89	39	5	8610	8380
LSD (0.05)			0.3	2	3	33	1	1190	550
C.V. (%)			3	1	3	41	7	7	6

† LB=basmati, LJ=jasmine, 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. The medium grain preliminary is only a single plot. A summary of the yields of 2009 Preliminary Yield Tests is presented in Table 7. These tests included 1262 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 2010 Statewide Yield Tests. ◆

Table 7. Summary of Preliminary Yield Tests at RES in 2009.

Test	Type	Number of Entries	All	Highest	Top 5	Check	Standard Check
			----------Average Yield (lb/acre)†----------				
Very Early							
Short grains	Conventional	25	9660	10690	10300	9290	S-102
	Specialty rice	36	9200	10240	10020	9390	CH-201
Medium grains	Advanced	35	9120	10790	10300	8980	M-104
	Preliminary	280	9090	11160	10480	8370	M-104
Long grains	Conventional	58	10970	12260	11930	11280	L-206
	Specialty rice	23	9870	12160	11500	10080	A-201
Early							
Short grains	Conventional	17	9990	11350	10670	9590	S-102
	Specialty rice	56	9830	11494	10780	9730	CH-201
Medium grains	Advanced	39	10370	11520	11180	10170	M-206
	Preliminary	510	9060	10950	10790	8960	M-206
Long grains	Conventional	54	11060	12020	11800	10940	L-206
	Specialty rice	27	9280	11260	10850	9430	CT-202
Intermediate-Late							
Short grains	Conventional	7	9870	10720	10120	8870	S-102
	Specialty rice	32	9460	10730	10500	9570	M-402
Medium grains	Advanced	22	9720	10450	10300	9850	M-205
Long grains	Conventional	15	10070	10780	10440	10170	L-206
	Specialty rice	26	9770	9990	9970	8140	CT-201

† Paddy rice yield at 14% moisture.

SHORT GRAINS & PREMIUM QUALITY

Virgilio C. Andaya

The short grain and premium quality rice breeding project 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).

Breeding goals for different grain or specialty types vary and 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.

The development of new rice varieties at RES is now making use of breeding techniques that employ advances in DNA marker technology. The new DNA marker lab routinely develops, validates and uses molecular markers to screen rice lines for grain quality and blast resistance. The impact of these advances in the short grain project is becoming more evident in breeding for premium quality, Japanese-type short grains, where DNA markers for cooking or eating quality are being used side by side with sensory evaluation.

Standard Varieties

The market for short grain and premium quality rice remains an important component of the California rice industry. Improvement in agronomic performance, grain and milling yields, grain quality and overall cooking attributes of new varieties would be of significant value to the industry. Table 8 summarizes the grain yield performance of the standard rice varieties that served as checks in the UCCE Statewide Yield Tests. The grain yields of S-102 (conventional short grain) and CM-101 (waxy type) in 2009 were low, dropping below their five-year average while the yield of CH-201 dropped by 600 lb/acre from last year's level. The premium quality medium grain check variety, M-402 registered its highest average yields in five years.

Table 8. Average over locations grains yield of check varieties from 2005 to 2009 UCCE Statewide Yield Tests.

Year	------------------------------ Grain Yield†			----------------------------------
	M-402	S-102	CH-201	CM-101
2005	8380	8690	7470	7900
2006	7850	9230	8040	8250
2007	8970	9830	6960	8760
2008	8550	9860	8880	9420
2009	9240	8720	8300	8130
5-Year Mean	8600	9270	8000	8490

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

Conventional Short Grains

In the past decade, the emphasis on breeding for conventional short grains was reduced because of the emphasis on breeding for premium quality rice. However, in the coming years, the conventional short grains will receive greater attention because of the need for better short grain materials for the development of premium quality and specialty short grain varieties. And with the narrowing of the genetic base, base broadening in the short grains are being addressed by using medium grains and Chinese rice materials in the crossing work.

S-102, a short grain variety is still in production because of its high yields, very early maturity, and blanking resistance. However, this variety is susceptible to stem rot, has a pubescent hull, and has overall low eating quality. The primary goal for the conventional short grain breeding is to develop a high yielding variety with stem rot resistance, smooth hulls, and better cooking quality.

In 2009, a total of 54 conventional short grains were entered in either the UCCE Statewide or the RES Preliminary Yield Tests. Table 9 summarized the performance of selected lines that out yielded S-102. Further evaluation will be made in 2010.

Table 9. Performance of selected conventional short grain entries in the 2009 UCCE Statewide and RES Preliminary Yield Tests.

ID	Type	Mat.†	Grain Yield ‡	SV§	Days¶	Ht. (cm)	Lodge (%)	SR	H/T#
Statewide									
08Y2025	S	VE	9160	4.9	85	3	91	4.7	62/71
08Y2049	SSR	VE	9640	4.8	83	4	84	4.9	57/69
08Y2048	SSR	VE	9160	4.7	82	1	86	4.7	65/72
07Y671	SSR	IL	10100	4.8	86	26	94	4.4	67/74
S-102	S ck		9030	4.9	81	4	91	5.2	56/72
Preliminary									
09Y2051	SSR	VE	10700	4.8	79	92	26	4.3	62/68
09Y2036	S	VE	10310	4.8	80	95	100	5.7	66/73
09Y2040	S	VE	9970	4.8	85	91	2	4.7	54/71
S-102	S ck		9280	4.9	77	91	63	5.4	60/71
08Y2130	SSR	E	10540	4.7	79	90	2	4.7	55/70
09Y2124	S	E	10030	4.8	81	92	39	5.6	65/71
S-102	S ck		9590	4.9	76	94	64	5.9	62/70
09Y2179	S	IL	10220	4.8	91	102	0	5.1	64/70
09Y2177	S	IL	9940	4.9	85	97	25	5.3	68/73
07Y672	SSR	IL	9140	4.6	86	98	0	5.3	68/72
S-102	S ck		8870	4.9	76	94	10	5.5	63/72

Type S=conventional short grain, SSR = stem rot resistant short grain, ck=check.
† 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/Total milled rice averages taken from milling plots at 18-20% harvest moisture.

Premium Quality

Premium quality rice is defined as the type of rice that when cooked is very glossy, slightly soft and sticky, has a smooth texture, tastes tender, is slightly sweet, has subtle aroma, and remains soft after cooling. These cooking characteristics are exemplified by the California medium-grain variety, M-401, and the Japanese premium short grain variety, Koshihikari. There is no unified definition of quality because of the human dimension involved. Grain quality preference varies depending on consumers or ethnic groups. Thus, breeding for locally-adapted, high-yielding premium quality rice takes into account these consumer preferences.

Premium Quality Short Grains (SPQ)

The premium short-grain rice variety Calhikari-201 (CH-201) was the first SPQ variety released in California in 1999. CH-201 was derived from a cross involving Koshihikari, a premium quality Japanese variety, and a conventional short grain variety, S-101. CH-201 is high yielding, early maturing, has good seedling vigor, and fairly lodging resistant.

In 2009, the average statewide test grain yield of CH-201 in the very early and early group combined was 8300 lbs/acre. The performance of selected entries in the Statewide Test is presented in Table 10. A total of eight premium quality short grain entries were entered in the UCCE Statewide Test in 2009.

An entry being closely evaluated for several years now, 04Y177, was entered in both very early and early group for the past two years. The average grain yield advantage across location and years over CH-201 is about 3%. Multiple taste evaluations showed that it has better eating quality, though the kernels are smaller. It is four days earlier, better stem rot resistance, and higher head rice yield. Additional quality tests are scheduled for 2010.

Table 10. Performance of selected premium quality short grain entries in the 2009 UCCE Statewide Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	SR	H/T#	Cook††
08Y2042	VE	9320	4.9	84	1	4.4	63/70	4.7
08Y2044	VE	9730	4.9	90	18	5.3	65/71	4.8
04Y177	VE, E	8600	4.7	84	38	4.8	67/71	4.9
07Y293	E	9120	4.9	82	35	4.8	54/69	4.6
CH-201	ck	8300	5.0	88	28	5.9	58/66	4.7
07Y301	IL	9550	4.9	92	20	5.5	67/71	4.8
CH-201	ck	7810	5.0	87	47	5.8	56/68	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.
SR=stem rot score where 0=no damage and 10=plant killed.
# H/T= Head/Total milled rice averages taken from milling plots at 18-20% harvest moisture.
†† Overall eating quality (gloss, taste, softness) taken 2 months after harvest, 1=poor, 5=excellent.

Twenty four premium short grain lines were evaluated in the Preliminary Yield Test at RES. Average grain yield of CH-201 at RES was about 9400 lb/acre, and had it a higher incidence of lodging and stem rot disease. Head rice yield at harvest moisture of 18-20% from the milling plots were low (55-65%).

The performance of selected premium quality short grain entries is summarized in Table 11. Notably, grain yields of some selected entries exceeded 10,000 lb/acre, with cooking and eating quality, and stem rot resistance equal to or better than the CH-201.

DNA markers are increasingly being used in the screening process for premium short grains. RM190, a microsatellite marker for the waxy gene which is associated with the amylose content and a major component of eating quality, is being used extensively in the project. In combination with other identified quality markers, RM190 is being used to select for lines that have similar marker profile with that of Koshihikari. Preliminary marker-trait association indicates that these markers may be potentially better tools in selecting for good quality lines starting in the early generation up to more advanced lines. These markers might be able to reduce the amount of materials that need to be cooked and evaluated for eating quality.

The selected lines will be candidates for inclusion in the 2010 Statewide Test pending the results of other quality data.

Table 11. Performance of selected premium quality short grain entries in the 2009 RES Preliminary Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	SR	H/T#	Cook††
09Y2049	VE	10220	5.0	78	73	5.1	61/67	4.8
09Y2046	VE	9540	5.0	77	38	4.9	60/71	4.6
CH-201	VE	9390	4.9	83	88	5.6	65/70	4.6
08Y2107	E	10600	5.0	80	100	5.9	69/71	4.6
09Y2136	E	10540	4.8	80	93	5.2	66/72	4.7
CH-201	E	9730	4.9	84	85	6.3	55/67	4.5
08Y2163	IL	10460	4.9	87	0	4.9	66/71	4.6
09Y2185	IL	10450	4.9	89	0	5.0	61/72	4.9
09Y2180	IL	10150	4.8	83	65	5.6	62/72	4.8
09Y2184	IL	10020	4.9	88	8	6.2	70/73	4.9
CH-201	IL	9200	4.9	84	90	6.4	60/69	4.6

† 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/Total milled rice averages taken from milling plots at 18-20% harvest moisture.
†† Overall eating quality (gloss, taste, softness) taken 2 months after harvest, 1=poor, 5=excellent.

Premium Quality Medium Grains (MPQ)

Breeding for premium quality medium grain rice is aimed at capturing the excellent grain and cooking characteristics of M-401. In 1999, the variety 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 and high yielding alternative to M-401 is the primary breeding goal.

In 2009, a total of 16 MPQ entries were tested in the Statewide Test. Performance of selected entries is presented in Table 12. One entry, 04Y332-1, was entered in both the very early and early group. This entry was identified in previous years of testing to have good eating quality, with grain size similar to M-401, and matured about 10 days earlier than M-402. Grain yield is similar with the M-203, but had better head rice yield and lodging resistance. However, this entry suffered severe blanking in Twitchell Island. Pending additional grain and quality data, this entry may be tested again in the Statewide Test.

A total of 69 entries were tested in the Preliminary Yield Tests at RES. The performance of selected entries is summarized in Table 13. Grain yields are high in the early group, exceeding 10,000 lb/acre. Lodging is still prevalent but the entries generally have better lodging resistance than M-203. M-203, a premium quality medium grain which is no longer in commercial production, is used as the check variety since M-401 and M-402 were too late maturing to serve as checks. Additional grain quality evaluation and cooking tests will be made on these selections.

Table 12. Performance of selected premium quality medium grain entries in the 2009 UCCE Statewide Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	SR	H/T#	Cook††
04Y332-1	VE, E	8980	5.0	94	24	5.2	67/70	4.6
07Y186	VE	8850	5.0	87	1	5.5	70/74	4.5
06Y175	VE	8650	5.0	88	25	5.3	63/70	4.8
07Y204	VE	9050	4.9	90	3	5.2	65/72	4.5
04Y308	E	9140	5.0	87	43	5.3	68/71	4.6
06Y322	E	9090	5.0	87	46	5.7	69/72	4.6
08Y2098	E	8610	5.0	85	47	5.3	66/71	4.7
M-203	check	8960	4.9	87	58	5.5	63/70	4.4
08Y2103	IL	9200	4.9	90	61	5.1	69/72	4.6
M-402	IL	9240	5.0	104	6	5.1	59/72	4.9

†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.
SR=stem rot score where 0=no damage and 10=plant killed.
# H/T= Head/Total milled rice averages taken from milling plots at 18-20% harvest moisture.
†† Overall eating quality (gloss, taste, softness) taken 2 months after harvest, 1=poor, 5=excellent.

Table 13. Performance of selected premium quality medium grain entries in the 2009 RES Preliminary Yield Tests.

ID	Mat. †	Grain Yield‡	SV§	Days¶	Lodge (%)	SR	H/T#	Cook††
09Y2023	VE	9760	4.9	80	60	5.9	66/72	4.8
08Y2014	VE	9480	4.9	83	65	5.5	67/72	5.0
09Y2019	VE	8840	5.0	79	65	5.7	59/72	4.9
M-203	VE	8430	4.9	81	100	5.7	65/73	4.5
08Y2101	E	11500	5.0	83	31	5.7	67/71	4.6
09Y2116	E	10550	5.0	83	90	5.6	70/73	4.7
09Y2102	E	10340	4.9	81	98	5.2	68/72	4.4
08Y2085	E	10210	5.0	81	78	5.5	65/71	4.8
08Y2083	E	10140	5.0	83	73	5.3	67/73	4.7
M-203	E	9460	4.9	82	100	4.8	62/73	4.5
09Y2163	IL	10100	4.9	85	15	5.1	63/72	4.9
09Y2176	IL	10040	4.9	89	20	5.9	69/73	4.8
09Y2171	IL	9690	4.9	86	80	5.1	67/71	4.7
M-402	IL	9570	5.0	97	0	6.1	60/73	4.9
M-203	IL	8910	4.8	83	95	5.3	65/71	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.
SR=stem rot score where 0=no damage and 10=plant killed.
# H/T= Head/Total milled rice averages taken from milling plots at 18-20% harvest moisture.
†† Overall eating quality (gloss, taste, softness) taken 2 months after harvest, 1=poor, 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).

Calmochi-101 (CM-101) is a waxy short-grain rice released for California in 1985. It has a high yield potential, excellent blanking tolerance, large kernels but has rough hulls. The variety Calamylow-201 (CA-201), a mutant of CH-201 released in 2006 is the first and only low-amylose variety (~7% apparent amylose content) developed for the California rice industry as a new product. Breeding for bold grain or Arborio-type variety is continuing at lesser extent. No variety has been released yet except for 89Y235 which was released as germplasm. A total of 22 waxy short grains, five bold grains, and seven low-amylose short grains were entered either in the Statewide or Preliminary Yield Tests in 2009. 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. Pending the additional grain quality data, these entries may be further tested in 2010.

Table 14. Performance of selected 2009 UCCE Statewide and RES Preliminary Yield Tests of specialty rice.

ID	Type	Mat.†	Grain Yield ‡	SV§	Days¶	Ht. (cm)	Lodge (%)	SR	H/T#
Statewide									
05Y343	WX	IL	9530	4.8	89	102	47	4.8	63/71
CM-101	ck	VE	8480	4.9	84	86	9	5.5	62/70
Preliminary									
09Y2062	WX	VE	9680	5.0	80	92	50	5.5	66/71
09Y2060	WX	VE	9140	4.9	80	97	58	5.2	68/72
09Y2058	WX	VE	8970	4.9	79	91	78	5.1	69/73
CM-101	ck	VE	8700	4.9	78	90	70	5.5	59/70
09Y2141	WX	E	10100	4.9	78	93	54	5.4	66/72
09Y2142	WX	E	9820	4.9	84	100	85	5.0	59/73
CM-101	ck	E	9140	4.9	79	91	70	5.6	60/73
07Y683	WX	IL	10370	4.8	84	98	80	5.5	68/71
CM-101	ck	IL	8570	4.8	77	90	15	5.8	65/72
09Y2156	BG	IL	9610	5.0	87	100	0	4.9	51/70
09Y2161	LA	IL	10730	4.8	92	96	3	5.8	68/72
09Y2159	LA	IL	9550	4.8	87	97	3	5.8	69/74

† 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.
SR=stem rot score where 0=no damage and 10=plant killed.
# H/T= Head/Total milled rice averages taken from milling plots at 18-20% harvest moisture.
BG=bold grain, WX=waxy, LA=low amylose, and ck=check.

DNA Marker Lab

The DNA marker lab formulates and implements procedures to identify and develop markers for traits that include cooking and eating quality, stem rot and blast resistance, and other important traits as they are discovered, and use these markers in marker-assisted selection (MAS) for all the projects at RES.

The new lab has significantly increased the capacity for MAS. The use of the marker technology is expected to expedite breeding for improved short-, medium- and long-grain varieties and to speed up the blast resistance gene introgression efforts in the medium grains project. Since early 2009, approximately 20,000 progeny lines were screened for one or a combination of markers associated with amylose content, *Pi-z* blast resistance gene, fragrance gene and markers associated with elongation of cooked basmati kernels, and markers for taste and premium quality associated with Japanese short grains.

Mapping the stem rot resistance genes from *O. rufipogon* and *O. nivara* is a continuing effort with the goal of identifying DNA markers for use as a selection tool in the future.

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 the 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. Consequently less intense cooking quality screening is required within the conventional 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 % 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 in 2009 multi-location Statewide Yield Tests averaged 9520 lb/acre (Tables 1-6). Average yields for L-205 and M-202 within the same tests were 8900 and 8760 lb/acre respectively. Yields of L-206 at colder locations of Yolo and San Joaquin have not been as competitive as M-202. Based on the results from multiple locations and multiple years, L-206 has shown good yield stability and is adapted to most of the rice growing regions of California except the coldest locations of Yolo and San Joaquin Counties. Average head rice yield of L-206 during 2005–2009 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 grain entries with intermediate (L) or high (LR) amylose contents are listed in Table 15. Entry 06Y513 has shown high yield potential in cooler than normal seasons. Compared to L-206, 06Y513 has 2 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 yield, and cold induced blanking resistance. This experimental line has shown exceptional yield potential for the second year in colder location experiments, which have traditionally been harder for long grains to be competitive with medium and short grains. Grain yield of this line in 2009 was the highest of all grain types in all 4 locations (RES, Sutter-East, Yolo, and San Joaquin tests,) averaging 10,870 lb/acre (Table 15). California grown high amylose long grains such as L-205 and 06Y575 tend to have softer cooked grain texture than those grown in Southern US. Therefore they can be used as conventional long-grain type. Both experimental lines 06Y513 and 06Y575 were purified in headrow blocks in 2009.

Table 15. Performance of selected conventional long-grain entries as compared with standard varieties in 2009 yield and milling tests.

Entry	Type**	Identity	-----Yield†----- Statewide	RES	Head Rice* (%)
Very Early Statewide					
4	LR	06Y575	10870	10710	63
6	L	07Y508	10410	9840	67
3	L	06Y513	9790	10030	63
1	LR	L-205	9310	9430	63
2	L	L-206	9720	9710	62
17	M	M-206	9840	8940	
Early Statewide					
64	LR	08Y1092	10170	11410	65
65	L	06Y513	9510	10680	--
63	LR	06Y575	9230	10480	--
61	LR	L-205	8840	9570	--
62	L	L-206	9550	10840	--
77	M	M-206	8780	9080	--
Intermediate Statewide					
123	L	07Y576	9590	9630	63
124	L	06Y513	9340	9950	66
122	L	L-206	9290	9950	65
133	M	M-205	9200	9290	
Very Early Preliminary					
1053	L	08P3068	--	12260	63
1013	LSR	08P2619	--	12010	62
1002	L	L-206	--	11280	65
Early Preliminary					
1107	LSR	08P2581	--	12020	60
1104	LSR	08P2554	--	11840	63
1083	L	L-206	--	10940	65
Intermediate Preliminary					
1183	LIM	08P3233	--	10280	65
1163	L	L-206	--	10170	64

† Grain yield in lb/acre at 14% moisture.
*Head rice yields are from solid seeded stands for statewide tests and single rows for Preliminary tests.
**High amylose type (LR), intermediate amylose type (L), Medium grain (M), Stem rot resistant (LSR), Imidazilinone herbicide resistant (LIM).

DNA markers were successfully used in 2009 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

Expanded breeding efforts in specialty long grain area continued in 2009. Specialty types include Jasmine, Basmati, and conventional aromatics such as A-201. Agronomic and milling quality of selected specialty lines is shown in Table 16.

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 at the Statewide Yield Tests. Average yield in 2009 Early and Intermediate-Late tests were 6850, 8700, and 8490 lb/acre for CT-202, L-205, and M-202 respectively (Tables 3-6).

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 that have shown a significant cooking quality advantage over Calmati-201 and Calmati-202 were tested in 2009 statewide and preliminary trials. Entries 08Y138 and 09Y139 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, good water uptake, and higher elongation ratios.

Efforts continued in 2009 to develop 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 breeding barrier. KDM was irradiated in 2008 with a higher than average dose of gamma rays. In 2009, 3,500 M_2 rows were evaluated at RES for early maturity or photoperiod insensitivity. No desirable mutants were obtained. Additional M_2 plants are currently being produced in the new green house facility at RES during the winter. Other mutants that were obtained previously are still being used as valuable germplasm source for further agronomic improvements. Fifty-five jasmine type selections were tested in 2009 Preliminary and Statewide Yield Tests. Breeding objectives for jasmine type quality include low amylose, strong aroma, a high degree of whiteness, and a smooth cooked grain texture.

Table 16. Performance of specialty long-grain entries in 2009 yield and milling tests.

Entry	Identity	Specialty Type	--------Yield†-------- Statewide	RES	Head Rice* (%)
Early Statewide					
82	07Y599	Jasmine	9430	9910	62
83	08Y1109	Jasmine	8180	9500	63
88	07Y489	Aromatic	8520	8930	61
87	08Y1115	Aromatic	7930	8740	63
79	A-201	Aromatic	8760	9960	45
62	L-206		9550	10840	63
Intermediate/Late Statewide					
137	08Y1174	Jasmine	8700	9070	56
136	08Y1114	Jasmine	8220	8440	63
139	09Y139	Basmati	7180	8280	56
138	09Y138	Basmati	6420	7190	45
134	CT-201	Basmati	7870	7850	62
135	CT-202	Basmati	6960	7620	56
122	L-206		9290	9950	63
Preliminary					
1067	08P3188	Jasmine	--	11360	62
1073	08P3202	Jasmine	--	11070	66
1059	08P3142	Jasmine	--	8930	66
1153	08P3319	Basmati	--	8820	61
1062	08P3167	Aromatic	--	10560	64
1005	A201	Aromatic	--	10080	55
1006	CT202	Basmati	--	9470	58

† Grain yield in lb/acre at 14% moisture.
* Head rice yields are from solid seeded stands for all entries.

Hybrid Vigor Evaluation

As part of preliminary studies to evaluate the degree of heterosis or hybrid vigor among long grain breeding material, a study was conducted to compare the agronomic performance of a long grain hybrid population with its parents. Crosses were made to generate sufficient hybrid seed between a long grain experimental line 06Y575 and L-206. The two genotypes are known to have distinctly different agronomic characteristics within the long grain nursery. A four replications test was conducted using evenly spaced transplants for each experimental unit. The results indicated that the hybrid line showed 3% yield advantage over the higher yielding parent. The seedling vigor of the hybrid line was also superior to both parents. Other agronomic traits as well as the milling yield of the hybrid, however, were not significantly different from the parents.

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.

In 2009, all selections in preliminary and advanced yield tests were also evaluated in special small or large solid seeded plots to obtain more accurate milling yield evaluation. Advanced lines were evaluated at 6 to 8 different harvest moistures and preliminary entries were tested at two harvest moistures.

RiceCAP Project

RES has been participating in the RiceCAP project which was a USDA initiative with the objective of applying genomic discoveries to improve milling quality and disease resistance in rice. The specific contribution from RES has been 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 final year of the project was completed in August 2009. The second round of phenotyping of the California milling population MY3 was completed in May 2009 at RES and the data was submitted to RiceCAP cooperators for association analysis with genotyping information. Genotyping of this population is being carried out at USDA genomics facility at Stoneville, MS. One hundred twenty 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 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. Twenty-five entries with a range of SR resistance were tested in 2009 Statewide and Preliminary Yield Tests. Performance of a selected number of these lines is shown in UCCE Statewide and Preliminary Yield Tests (Tables 1–7, and 16). 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 4) is an example of a combination of SR resistance, cold resistance and desirable grain and milling qualities. The long grain SR resistant selections continue to be among the highest yielding lines in the early as well as the advanced generation lines.

CALROSE MEDIUM GRAINS

Jacob Lage

Favorable rice prices play a large role in maintaining Calrose medium-grain rice as the preferred rice market type in California. Since the release of the original 'Calrose' in 1948, RES breeders have released 18 Calrose-type varieties with the latest being M-208 (rice blast resistant) in 2006. M-202 has been one of the most successful Calrose-type medium grains released from RES. However, since its release in 1985 two other varieties, M-205 and M-206, have replaced M-202 in many locations. M-205, with its high yield potential in the warmest part of the Sacramento Valley, combined with superior straw strength, and M-206, with stable yield and high level of blanking resistance, have ensured the success of these two varieties. Yet, what makes these two varieties shine compared to M-202 is their milling yield and milling stability allowing growers the option to harvest at lower moisture content with far less risk of getting penalized by poor milling appraisal.

A broad range of traits have been improved since the release of Calrose. Setting breeding goals involve identifying and improving key traits in future varieties to achieve economic productivity and satisfy the industry, consumer, and regulatory requirements. This project is continually working to improve selected key traits while not going backwards on other important traits.

Prioritizing among many potential traits is one of the most important decisions for a breeder since making gains in every trait at the same time is an impossible task. Over the past three years the Calrose medium grain program has focused heavily on earliness and milling quality.

The development of earlier varieties has been an important medium grain breeding goal for RES since the release of Calrose. Earlier varieties provide many advantages, including increase in planting dates, earlier harvest, tillage and straw management, and potential water use and cost savings. The latter being an especially important area of concern for California and other parts of the world. The challenge is to achieve the necessary economically sustainable yield and quality levels in earlier maturing varieties. The first major improvement in earliness was achieved with the development and adoption of early maturing varieties that headed more than 2 weeks earlier than Calrose. It was probably hard to imagine when M-202 was released in 1985 that 18 years later a new release, M-206 that heads 4-7 days earlier than M-202, would be better yielding and milling.

Averaged over years the improvements are not impressive which is why we have to think 10-20 years ahead each time we decide what crosses to make and hope that with every breeding cycle one additional little step is taken in the right direction. As part of that process the project is selecting for earlier maturity at the onset of the selection cycle which can take up to 6-8 years to determine progress.

The short term goal is to provide the growers with a very early medium grain alternative with superior milling quality and stability. Our current very early medium-grain variety, M-104, has its limitations, and experimental line 05Y471 shows promise and is discussed later in the report.

Variety Update

Five Calrose medium-grain 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 some parts of the southern Sacramento Valley. From Table 17 it is clear that this variety is well suited for this region (San Joaquin data) whereas the data from the RES trial is an example that the northern 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 (Table 17). For the past three years, M-206 has out-yielded M-202 by 15%, 8%, and 3% respectively, clearly indicating the strength of M-206 compared to M-202. Furthermore, M-206's improved grain and milling yield as well as its significantly better cold tolerance explains why more and more growers are replacing M-202 with M-206.

M-205 is the longest maturing regular Calrose medium grain in production (Table 17), and by far the variety with the best resistance to lodging. Like M-206 it has excellent milling quality and is becoming increasingly 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.

M-208 is the newest Calrose medium grain variety. It was developed to address the appearance of the rice blast disease 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.

Table 17. Performance of Calrose medium grain varieties and one experimental line in the very early and early statewide tests.

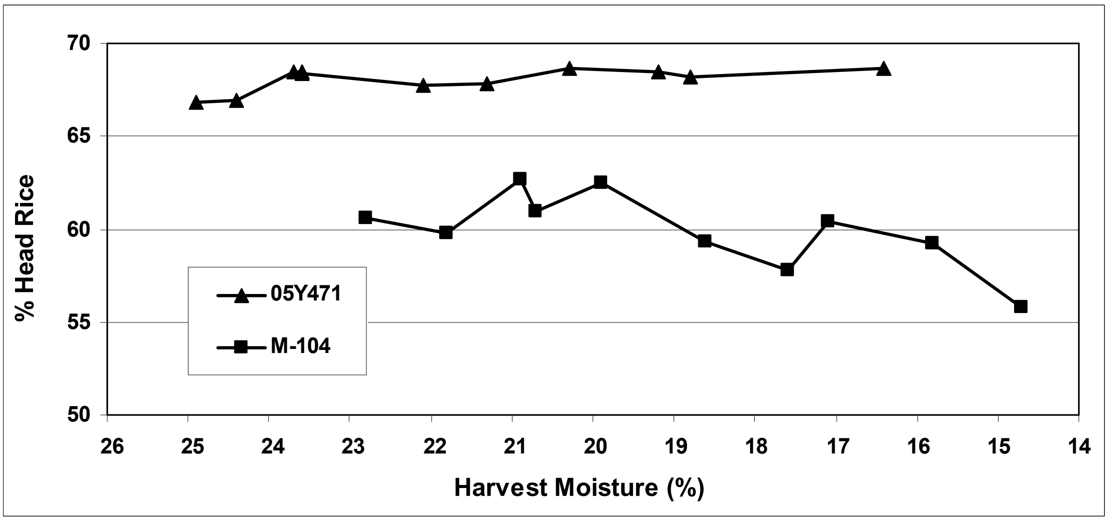
Entry	Days†	---------------------- Grain Yield‡				----------------------------
Very Early Statewide		RES	San Joaquin	Sutter	Yolo	Mean
M-104	79	7495	8680	9967	12065	9552
M-202	88	8502	8706	9028	11260	9374
M-206	84	9043	8442	9394	12554	9858
05Y471	82	8338	7953	10480	12206	9744
Early Statewide		RES	Butte	Colusa	Yuba	Mean
M-202	87	8923	9226	8845	8172	8791
M-205	91	9566	9459	9699	8631	9339
M-206	81	9134	8903	9119	8036	8798
M-208	87	9329	9418	8395	8097	8810
05Y471	79	8757	8528	8856	8496	8659

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

05Y471 is an experimental line currently being proposed for foundation seed production and subsequent release. Although it is not as early as M-104 (Table 17) this experimental line is still classified as 'very early'. 05Y471 has now been tested for two years in the very early and early advanced statewide trials totaling seven locations over two years. 05Y471 performed similar or better than M-104 in the very early Statewide Yield Test (Table 17) except at San Joaquin where M-104 clearly outperformed 05Y471 in 2008 and 2009.

Milling data from 2007 and 2008 had indicated that 05Y471's milling properties were better than those of M-104. This was tested more thoroughly in 2009 and samples of these two lines were collected from several 12x15 ft milling plots in different fields as well as from large field increases. Samples (6 to 10) from each test area were cut at declining grain moisture content in order to get detailed information of the milling performance of 05Y471. Results across all the tests were clear with 05Y471 showing far superior milling yield compared to M-104. Figure 1 shows the percent head rice of total paddy rice from two closely located field increases of 05Y471 and M-104. In this trial the milling yield of 05Y471 was five to almost ten percentage points better than M-104. Also, in this test letting 05Y471 dry in the field did not have adverse effect on the milling yield, thus opening for the possibility of savings in drying costs and increased flexibility during the harvest season.

Figure 1. Percent head rice of experimental line 05Y471 and Calrose medium grain variety M-104 from large field increases harvested at different grain moisture contents at the Rice Experiment Station.



Two years of intensive statewide yield testing of 05Y471 combined with the extensive milling studies conducted this year support the effort in promoting this as a new very early maturing Calrose medium grain variety for the Sacramento Valley. However, this data also confirms that M-104 has a very unique adaptation to the Delta region and will likely remain the preferred variety there. 05Y471 could become attractive in the warmer areas of the Sacramento Valley where M-104 traditionally has shown poor adaptation. A well adapted very early variety will provide many growers with the opportunity to diversify their rice crop in terms of maturity time. This gives potential for earlier draining and harvest. Having a high, stable milling yield over a larger range of harvest moisture will generally reduce the stress associated with harvesting large acreage of rice all maturing at the same time.

Utilizing New Greenhouse Facilities

2009 was the first year we had the newly constructed greenhouse available. The moment the contractors were out, all the benches in one of the greenhouses were filled with early generation Calrose medium grain rice. By providing extra light and heat we were able to harvest all the material in time to get the seed in the ground by June 1st. This ability to grow larger populations of rice during the winter has already become an integrated part of the Calrose medium grain rice breeding program.

The new upgraded cold tolerance screening greenhouse was also put to good use in 2009. Although we still need fine tuning on how we conduct the cold screening tests, the first run was very promising. The expensive refrigeration units provided sufficient cooling capacity to lower the nighttime treatment temperatures into the 50°F range even during the hot summer months. Traditionally we would have to rely on cold weather in the Delta region for cold tolerance screening. Although the Delta will continue to be a vital part of Calrose rice breeding, we are no longer so dependent on the weather there. In fact, both 2008 and 2009 were "poor" cold tolerance screening years for the Delta region, emphasizing the importance of the facilities at the RES.

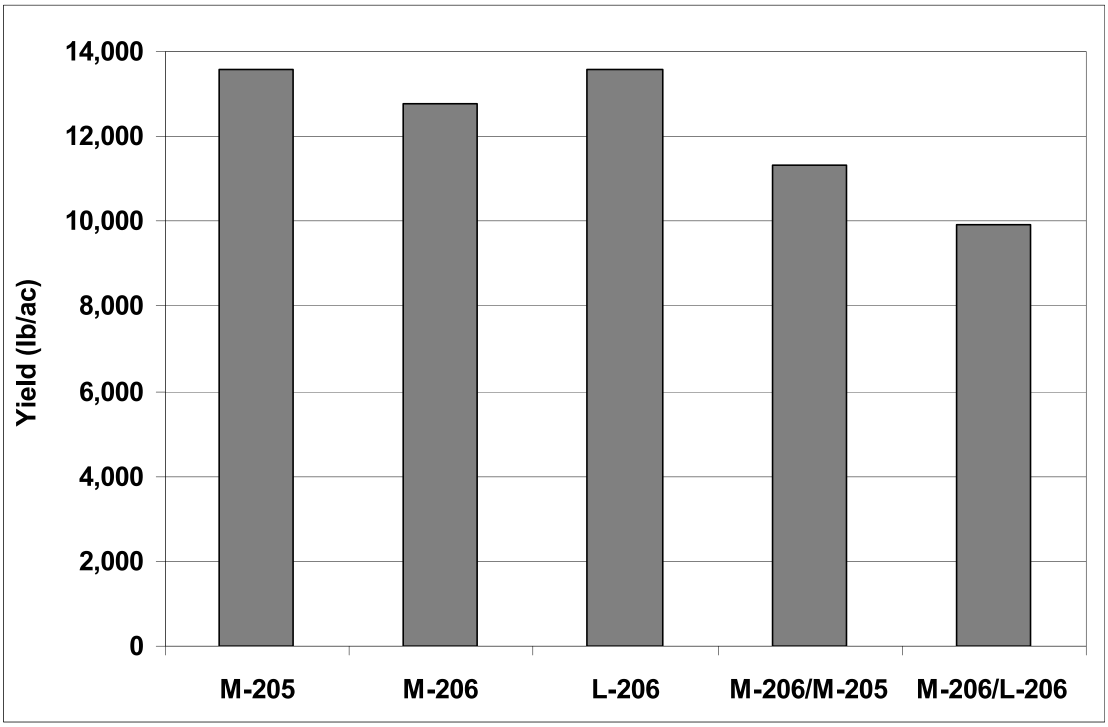
With the help of UC Davis weed specialist, Mr. James Eckert, we have commenced a screening process to identify increased tolerance to the herbicide "Granite GR®". Thousands of seedlings from irradiated M-206 are screened in the greenhouses over a period of just four weeks from planting to evaluation. The objective is to identify a mutated plant where the root system is less damaged by the herbicide than current varieties. Although this low-tech approach is like searching for the proverbial needle in a haystack, the potential benefits for rice growers in California would be significant. Nonetheless, several similar attempts in rice and other crops have produced only a few – albeit spectacular – useful results.

Hybrid Rice

Hybrid rice appears to be gaining popularity in the rice growing areas of the Southern US. Whether hybrid rice is economically feasible in California remains an unanswered question. Of particular concern is the impact on the quality of the well-established Calrose type rice, since the yield advantage often seen in hybrids may only be possible through combinations involving non-Calrose type rice. We are continually following the process in the South and elsewhere. In addition, we manually produced enough hybrid seed of M-205/M-206 and M-206/L-206 hybrids to plant small 4x4 ft test plots for our own pilot test of hybrids involving California material.

The results from this small test were nothing like the often dramatic results reported from other locations and/or crops. In fact, our manually produced hybrids yielded less than any of the parents (Figure 2). The high level of yield seen in this test is common from small plots but it does not change the fact that the hybrids yielded less than their parents. Obviously this small test does not provide enough information to dismiss the idea of hybrid rice in California and more hybrids and larger tests are planned for 2010.

Figure 2. Yield of rice varieties M-205, M-206, and L-206 together with two manually produced hybrids, M-206/M-205 and M-206/L-206 from small 4x4 ft transplanted yield plots.



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 606 crosses last year in a rapid backcrossing program (to PR1412), and screens statewide and preliminary test breeding lines and varieties (about 2000 rows per year) for stem rot resistance in the field. Blast genes are now identified with molecular markers. The rapid backcross program involves screening entries for blast, 62,000 plants for stem rot (SR) and 41,000 plants for aggregate sheath spot (SS) resistance per year with three generation advances. In addition, early generation materials derived from breeder's crosses are cycled through the disease nursery to identify and verify disease resistant lines (about 4,300 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 resistance. Conversely, the sources of SS resistance also seem to confer SR resistance in some materials.

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 4430 rows in the 2009 SR nursery.

This year, 2830 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-grain 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 in 2005. 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. Two hundred forty-nine crosses were made this year for this purpose. Some crosses for all donor parents are now at BC_6F_1.

Percentage of resistant F_1 plants used to further the backcrossing scheme has fallen dramatically for all populations except those with resistance from *O. nivara* resistance. Greater emphasis will now be placed on rapidly advancing generations from all backcrosses. It may be that the BC_6F_1 materials referred to earlier (and now in the greenhouse) will be sufficient to produce germplasm with the full disease of the donor parents.

However, since resistance derived from *O. rufipogon*, diminished as backcrossing proceeded, crosses will be made using resistant, field-screened F_5 parents from earlier backcrosses. These parents will also have been screened for SS resistance. In this way, resistance to a second disease will be added. Backcrossing will continue until BC_6 is made, and material will enter the normal yield-testing program as warranted.

Dr. Andaya is performing associative mapping using previously identified resistant lines to discover resistance gene location and candidate molecular markers for stem rot resistance from *O. rufipogon*.

In addition, 4,800 BC_1F_4 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 planted in a replicated test in 2010 for use by Dr. Andaya in mapping molecular markers to confirm/refine the associative mapping effort.

A similar population has been developed for the *O. nivara* resistance source. It will also be planted in a replicated test in 2010. Meanwhile, preliminary marker work is being conducted on these populations this fall-winter. Molecular markers would enable selection for disease resistance without having to perform the biological screening process. Such markers would allow identification of resistant seedlings before crossing, thus greatly speeding the breeding process.

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

Sheath Spot

An immediate backcross program was started in 2005 to transfer SS resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-206 (241 crosses this year). BC_6F_1 was made. Screening strategy will parallel that used for the SR immediate backcross program. RiceCAP 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 earlier backcrosses were again grown in the SR field nursery this year. As in the past, some lines (derived from all three donor parents) again showed SR resistance equivalent to that found in the wild species. These lines will be used as parents in the continuing backcross program to combine SR and SS resistance. When the backcrossing program is complete, it may be possible to combine this 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 2009, 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. All material presently advancing through the medium grain program possesses only this gene. Since molecular markers for blast resistance genes are available, they have replaced biological screening for the *Pi-z* gene. 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*, $Pi\text{-}k^h$, $Pi\text{-}k^m$, $Pi\text{-}z^5$, *Pi-9*, *Pi-40,* and $Pi\text{-}ta^2$). Seven backcrosses were made and screened for blast resistance. Theoretically, 99.6% of genes in this material are from M-206. In 2009, homozygous resistant lines were selected from the F_2 aided by molecular markers. Selections were made from these lines and brown rice has been evaluated for seed traits by the medium grain breeder. Almost all lines closely resemble M-206. The backcross program for these genes is now complete. 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_5), *Pi-2* (BC_5), and *Pi-33* ($BC_{6\text{-}7}$) genes into an M-206 background with the aid of molecular markers. This project will be completed for all genes by 2010.

One hundred and sixteen crosses were made this year to transfer blast resistance into an M-206 background.

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

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

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. Nine introductions from China (including F_1 hybrids) 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 helps 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
2009 – William V. Huffman

D. MARLIN BRANDON RICE RESEARCH FELLOWSHIP

Dr. Marlin Brandon began his career in 1966 as the UC Rice Farm Advisor in Colusa, Glenn, and Yolo Counties He later served as UC 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 2009, fellowships of $2,500 were awarded to Cameron Pittelkow, Charles Joseph Pfyl and Maegen Simmonds. A total of 19 fellowships have been awarded.

Rice Research Proposal

Rice research at RES in 2010 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 2010.

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 cooking evaluations techniques are being used that include use for DNA markers for amylose content, gelatinization temperature, and RVA profiles. 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, a 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 cold tolerance and the Hawaii winter 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 2010. 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 resistance 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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