2011 RICE BREEDING PROGRESS REPORT
AND
2012 RESEARCH PROPOSAL

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

January 1, 2012

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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, plant pathologist Mr. Jeffrey J. Oster and research scientist Cynthia B. Andaya. 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.

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, Rolfe Bryant, 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 2011. Dr. Albert J. Fischer, (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. Randall Mutters, Dr. Bruce Linquist, Chris Greer, and Luis Espino, 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 2011 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. This trait has never been detected in any California grown rice. Further testing required by the California Rice Commission of CCRRF foundation and basic seed samples for 2007-11 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, resource allocation, 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 43 improved rice varieties since the accelerated research program began in 1969. Foundation seed of 14 public rice varieties, 2 experimental increases, and basic seed of one Japanese premium quality variety were produced on 170 acres at RES in 2011. 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.

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

RICE BREEDING PROGRAM

INTRODUCTION

The RES Rice Breeding Program 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. Kent McKenzie. Dr. Virgilio Andaya is the project leader for premium quality, waxy, and short grains (see Premium Quality & Short Grains). He is also handling the early generation stages for the medium grain project. Dr. Farman Jodari is the long grain project leader (see Long Grains). Management for the DNA marker lab has been assigned to Dr. Cynthia Andaya. 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 2011 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 2011 breeding nursery began May 4th, and was completed May 27th. In 2011, 1419 crosses were made at RES for rice improvement, bringing the total number of crosses made since 1969 to 41,132. 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 2012, thereby accelerating the breeding process.

The 2011 RES breeding nursery occupied approximately 76 acres. Water-seeded yield tests included 3038 small plots and 3685 large plots. Small seed increase plots, cooking samples and advanced breeding lines were grown on 4 acres. The nursery included about 50,550 water-seeded and 31,600 drill-seeded progeny rows. F_2 populations from 2009 and 2010 crosses were grown in precision drill-seeded plots on 9 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 2012.

Headrows (3600) of M-104, M-105, M-205, Calhikari-201, 04Y177 (Calhikari-202), Calamylow-201, 06Y575, L-202, and Calmati-202 were grown for breeder seed production in 2011. 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.

Selection and harvest of the 2010-11 winter nursery was completed and seed returned to RES and planted in May. The 2011-12 winter nursery of 8400 rows was planted November 8-9, 2011, and 600 F_1 populations were transplanted to the nursery November 29, 2011. Selection and harvest will occur in April, and seed returned for processing and planting in the 2012 RES breeding nursery.

The San Joaquin Cold Tolerance Nursery was planted in cooperation with two local rice growers. The 7 acre drill-seeded nursery included 5000 rows, and 6 acres of F_2 populations. Stand establishment and weed control was good. Very little blanking was observed in the rows, but blanking occurred in the F_2 populations for selection. The nursery was very delayed due to the cool growing season. An additional yield test was grown in cooperation with UCCE on Twitchell Island near Rio Vista. High levels of blanking, and extreme delays in maturity were observed in entries at that location.

The San Joaquin Cold Tolerance nursery and Hawaii nursery 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 University of California Cooperative Extension (UCCE) and also tested at RES. The 2011 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 17th to 20th, and May 26-27, 2011. The plot size was 10 by 20 ft with the center 7 ft combine harvested (140 ft^2). Water-seeding and conventional management practices were used in these experiments. Bolero UltraMax®, and Stam80df® were applied for weed control and one application of Silencer® was applied for rice water weevil control.

Tables 1 through 6 contain a summary of performance information from the 2011 Statewide Yield Tests. Yields are reported as paddy rice in pounds per acre at 14% moisture. A cold growing season, fall rain, and muddy conditions delayed harvest in the nursery. 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 2012. 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 2011(poor vegetative growth and yield at RES test site).

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
13	08Y3076	M	4.7	90	93	0	5.1	9440	9590
12	08Y3016	M	4.8	85	97	3	5.9	9160	9440
9	M105	M	4.8	84	96	3	5.8	9020	9020
5	09Y2141	SWX	4.7	89	103	0	5.0	8850	9760
2	S-102	S	4.7	84	91	10	5.7	8780	8510
10	M206	M	4.8	87	98	3	5.1	8660	9390
11	07Y843	M	4.8	85	92	0	5.5	8620	9490
8	M104	M	4.9	83	92	4	6.0	8570	9420
7	09Y2036	S	4.7	88	99	3	5.5	8530	9090
16	L206	L	4.7	88	89	0	5.5	8290	8910
15	09Y3024	M	4.7	86	97	1	5.2	8080	8490
18	09Y1079	L	4.9	91	91	0	4.7	8060	9250
1	CM-101	S	4.8	87	93	11	5.5	8000	7890
6	08Y2049	SSR	4.6	85	85	0	4.6	7860	9050
17	06Y575	LR	4.8	94	106	0	5.8	7790	9890
4	04Y177	SPQ	4.7	89	88	0	4.9	7430	8590
14	08Y3080	M	4.7	85	96	3	5.3	7420	9100
3	CH-201	SPQ	4.9	92	87	0	5.3	7200	8800
mean			4.8	87	94	3	5.3	8320	9090
LSD(0.05)			0.2	1.6	6	4	0.7	1090	480
CV %			2	1	4	145	9	9	8

† L=long grain, LR=Rexmont type, M=medium grain, S=short 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 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 2011 (very poor vegetative growth and yield at RES test site).

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
44	10Y3286	M	4.8	83	97	8	5.2	8360	9420
43	10Y3282	M	4.9	84	93	5	5.5	7770	9280
30	09Y3059	M	4.8	84	97	5	5.4	7660	9310
24	10Y2049	SPQ	4.8	84	85	0	5.4	7630	9210
37	09Y3272	M	4.8	84	90	3	6.1	7490	9000
42	10Y3261	M	5.0	85	99	5	5.0	7490	8890
33	09Y3225	M	4.7	87	94	0	4.9	7490	9200
41	10Y3227	M	4.9	83	94	3	5.6	7480	8800
35	09Y3268	M	4.8	84	94	5	5.8	7340	8880
31	09Y3078	M	4.8	83	98	15	5.5	7320	8700
48	10Y1008	SR	4.9	90	95	0	3.9	7310	8820
23	10Y2043	S	4.7	89	89	0	4.5	7310	9430
26	10Y2158	SWX	4.8	90	92	3	4.7	7310	9290
45	10Y3290	M	4.9	85	91	3	5.3	7210	9350
39	09Y3277	M	4.8	84	90	13	5.8	7040	8780
20	10Y2115	SLA	4.7	86	90	0	5.7	7030	8350
29	09Y3048	M	4.8	81	94	13	5.9	7020	8530
32	09Y3176	M	4.8	84	89	3	5.6	6990	8860
22	10Y2123	MPQ	4.8	85	91	10	5.2	6930	8640
36	09Y3270	M	4.9	82	93	15	5.9	6820	8620
50	06Y513	L	4.9	92	95	0	5.1	6820	8180
49	10Y1178	L	4.8	96	92	0	4.9	6730	9030
40	09Y3538	M	4.9	85	94	8	5.6	6670	8950
28	09Y3043	M	4.9	83	100	8	5.6	6660	9070
38	09Y3273	M	4.8	84	92	5	6.2	6500	8560
25	09Y2060	SWX	4.9	88	92	0	5.2	6500	7750
27	09Y2063	SWX	4.8	88	90	3	5.0	6460	9010
46	10Y3305	M	4.9	80	87	3	5.4	6400	8180
21	10Y2031	SLA	4.6	88	83	0	4.8	6330	8310
47	M202	M	4.8	88	95	3	5.9	6300	8830
34	09Y3256	M	4.8	89	94	3	4.4	5850	7970
19	AKITA	SPQ	4.2	88	102	98	5.7	5310	5440
mean			4.8	86	93	8	5.3	6980	8710
LSD(0.05)			0.1	1.5	NS	5	0.7	NS	590
CV %			1.4	1.1	4.8	40	9	10	7

† L=long grain, SR=long grain stem rot, M=medium grain, MPQ=premium quality medium grain, S=short grain, SPQ=premium quality short grain and SLA=short grain low amylose, 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, NS=not significant.

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 2011.

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
67	09Y2141	SWX	4.7	91	111	35	5.3	11430	10110
66	09Y2179	S	4.7	87	105	5	6.0	10960	10360
73	08Y3269	M	4.8	93	102	0	5.3	10870	10210
76	09Y1122	L	4.8	93	98	0	5.3	10610	10400
69	M205	M	4.7	93	101	0	5.4	10610	9810
72	08Y3126	M	4.8	88	106	33	5.6	10470	9760
65	09Y2159	SLA	4.8	95	102	17	4.5	10310	9160
71	M208	M	4.9	89	107	15	5.4	10240	9820
62	S-102	S	5.0	84	103	64	5.8	10230	8670
75	06Y575	LR	4.8	98	105	0	5.8	10100	9940
70	M206	M	4.9	88	104	37	4.7	10050	9680
74	L206	L	4.6	88	98	0	5.2	10020	9790
77	10Y1025	L	4.7	96	102	0	4.9	9880	9480
64	04Y177	SPQ	4.8	90	95	50	5.3	9840	8540
68	M202	M	4.9	90	103	35	5.3	9660	9120
63	CH-201	SPQ	4.9	94	97	35	5.7	9210	7780
61	CM-101	SWX	4.8	88	101	63	5.5	8980	7630
mean			4.8	91	102	23	5.2	10200	9430
LSD(0.05)			0.1	1.5	6	NS	0.6	490	430
CV %			2	1	4	63	9	3	7

† L=long grain, LR=Rexmont type, M=medium grain, S=short grain, SPQ=premium quality short grain, SLA=short grain low amylose, 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.
NS=not statistically significant.

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 2011.

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
85	09Y2184	SPQ	4.7	94	90	0	5.1	10140	9360
96	09Y3805	M	4.9	90	106	0	5.3	10100	9800
93	09Y3665	M	4.7	92	95	0	5.2	9860	9530
86	10Y2046	SPQ	4.7	93	99	40	5.5	9630	8590
88	09Y3517	M	3.7	90	108	0	4.8	9600	9630
100	M105	M	4.8	86	100	0	5.7	9490	9030
91	09Y3600	M	4.7	94	98	0	5.2	9340	9280
94	09Y3671	M	4.8	92	102	0	4.9	8400	9100
104	09Y1067	LJ	4.8	93	105	0	5.0	8340	9420
79	09Y2171	MPQ	4.8	88	105	80	4.9	8320	8290
97	08Y3239	M	4.8	86	95	0	4.8	8280	9340
99	09Y3912	M	4.9	92	99	0	5.1	8070	9200
110	10Y1067	LIM	4.6	88	87	0	4.8	7840	8910
95	09Y3708	M	4.7	95	99	0	4.7	7800	9120
84	10Y2094	MPQ	4.8	90	111	0	4.5	7790	9010
90	09Y3580	M	4.9	91	104	0	4.3	7780	8960
82	10Y2126	MPQ	5.0	90	112	50	5.6	7700	7900
98	09Y3886	M	4.9	90	103	0	4.9	7680	8640
83	10Y2086	MPQ	5.0	90	109	30	5.8	7600	8250
92	09Y3605	M	4.8	95	100	0	4.7	7550	8920
87	09Y3005	M	5.0	86	100	0	5.3	7500	8210
89	09Y3523	M	3.9	89	96	0	5.0	7400	8880
80	10Y2082	MPQ	4.9	88	110	90	5.4	7329	7910
81	10Y2093	MPQ	4.8	89	120	50	5.6	7300	7330
105	10Y1059	LJ	4.8	91	102	0	4.7	7300	8940
78	AKITA	SPQ	3.6	88	104	90	5.4	7000	6240
108	09Y1079	L	4.9	93	103	0	4.8	6930	8670
109	10Y1162	L	4.6	94	98	0	5.7	6870	8470
107	10Y1038	L	4.6	92	104	0	4.7	6770	8420
113	10Y151	LB	4.8	95	93	0	5.3	6480	7110
101	A201	LA	4.8	99	104	0	5.6	6470	7550
111	10Y1149	LA	4.5	93	90	0	5.4	6130	7430
106	10P1433	LJ	3.7	96	105	0	3.9	6020	6660
103	10Y150	LJ	4.6	92	97	0	5.8	6020	7390
112	08Y1115	LA	4.7	94	95	0	5.0	5880	6970
102	CT202	LB	4.7	94	99	0	5.5	5410	6170
115	10P1597	LB	4.9	94	88	0	5.2	4810	5310
114	10Y153	LB	4.3	90	94	0	5.2	4200	4740
mean			4.7	91	101	10	5.2	7560	8220
LSD(0.05)			0.5	2	8	NS	0.6	1840	730
CV %			8	2	2	29	9	14	9

†L=long grain, LA=long grain aromatic, LB=basmati, LJ=jasmine, LIM=long grain imidazilinone resistant, M=medium grain, MPQ=premium quality medium grain, and SPQ=premium quality short grain.
‡ 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.
NS=not statistically significant.

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 2011.

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
129	06Y575	LR	4.8	95	103	0	5.6	10390	10310
126	M205	M	4.8	93	96	0	5.3	10270	9710
127	08Y3310	M	4.8	88	95	0	4.5	10230	9780
123	04Y177	SPQ	4.9	88	91	95	4.7	10140	9650
128	L206	L	4.8	88	89	6	5.0	9990	9560
122	CH-201	SPQ	5.0	91	91	65	5.4	9230	8850
124	09Y2176	MPQ	4.9	95	102	4	5.9	9220	9300
121	M-402	MPQ	4.9	103	102	0	4.6	9200	9000
125	M202	M	5.0	89	103	26	6.0	9160	9060
mean			4.9	92	97	22	5.2	9760	9470
LSD(0.05)			0.1	1	5.2	20	0.8	580	4.7
CV %			2	1	4	64	9	4.1	360

† L=long grain, LR=Rexmont type, M=medium grain, MPQ=premium quality medium grain, and SPQ=premium quality short grain.
‡ SV and =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 2011.

Entry Number	Identity	Type†	SV‡	Days §	Ht. (cm)	Lodge %	SR¶	---Grain Yield#--- RES	State
153	10Y1012	L	5.0	94	97	0	5.3	11170	10460
146	09Y3700	M	5.0	93	93	0	4.6	11050	10170
154	09Y1079	L	4.9	93	95	0	4.8	10810	10250
137	08Y3314	M	4.8	91	94	0	4.5	10690	9680
145	09Y3622	M	4.8	93	106	0	5.5	10680	9670
139	09Y3830	M	4.8	92	108	0	5.0	10610	9790
138	08Y3338	M	4.8	91	91	0	4.3	10560	9220
143	09Y3607	M	4.8	93	97	0	5.2	10540	9870
144	09Y3610	M	4.8	90	98	0	5.3	10370	9670
141	09Y4002	M	4.9	85	99	0	5.7	10310	9450
140	09Y3887	M	4.9	93	98	0	5.1	10220	9970
152	06Y513	L	5.0	94	99	0	5.1	9930	9780
142	09Y3502	M	4.9	91	105	5	5.0	9820	9680
135	09Y2173	MPQ	4.8	94	103	0	5.7	9750	9150
132	10Y2081	MPQ	4.7	91	103	20	5.6	9740	9430
149	09Y1067	LJ	5.0	90	98	13	5.5	9720	9190
136	08Y2163	SPQ	4.9	89	92	0	4.3	9670	9520
150	10Y1059	LJ	5.0	92	99	5	4.9	9580	8990
133	10Y2120	MPQ	4.9	92	100	0	5.3	9260	9110
130	M401	MPQ	5.0	106	122	50	5.7	8910	8870
134	09Y2174	MPQ	4.8	90	106	80	5.2	8430	8790
151	10Y1196	LJ	5.0	98	94	0	5.6	8200	8930
155	10Y151	LB	4.8	94	91	0	5.2	8150	7840
148	10Y150	LJ	5.0	90	89	0	5.6	8030	8180
157	10Y1199	LB	4.7	104	108	3	6.1	6780	7270
131	KOSH	SPQ	4.9	101	125	100	5.7	6760	6210
147	CT202	LB	5.0	96	92	1	5.4	6640	6950
159	10P1610	LB	4.9	95	97	3	5.5	6160	6450
158	10P1597	LB	4.9	95	86	0	5.6	5720	6640
mean			4.8	93	99	9	5.2	9110	8810
LSD(0.05)			0.2	1.2	7	12	0.8	700	620
CV %			2	1	5	123	9	4	6

† L=long grain, LB=basmati, LJ=jasmine, LIM=long grain imidazilinone resistant, M=medium grain, MPQ=premium quality medium grain, 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 2011 Preliminary Yield Tests is presented in Table 7. These tests included 959 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 2012 Statewide Yield Tests. ◆

Table 7. Summary of Preliminary Yield Tests at RES in 2011.

Test	Type	Number of Entries	All	Highest	Top 5	Check	Standard Check
			----------Average Yield (lb/acre)†----------				
Very Early							
Short grains	Conventional	7	10110	11880	10580	10420	S-102
	Specialty rice	69	9790	11070	10860	9110	CH-201
Medium grains	Advanced	77	9330	10220	10100	9940	M-104
	Preliminary	184	8610	11180	10770	8880	M-105
Long grains	Conventional	66	10100	11530	11390	10300	L-206
	Specialty rice	15	8730	11470	10430	6810	A-201
Early							
Short grains	Conventional	5	9900	11070	9900	8920	S-102
	Specialty rice	71	9150	11020	10620	9330	CH-201
Medium grains	Advanced	77	9180	10520	10340	9780	M-206
	Preliminary	171	9020	11540	11280	9480	M-205
Long grains	Conventional	36	10050	11390	11040	9710	L-206
	Specialty rice	45	9070	11660	11400	7590	CT-202
Intermediate-Late							
Short grains	Conventional	7	9110	11410	9490	10080	S-102
	Specialty rice	66	9330	10910	10530	9560	M-402
Medium grains	Advanced	27	10200	11310	11070	10770	M-206
Long grains	Conventional	7	10340	11360	10800	10760	L-206
	Specialty rice	29	7140	10200	9010	6880	CT-202

† Paddy rice yield at 14% moisture

CALROSE MEDIUM GRAINS

Kent S. McKenzie & **Virgilio C. Andaya**

Medium grain varieties constitute the lion's share of our efforts and are the cornerstone of California rice production. It is paramount that the medium grain project continues to be well supported and productive. Leadership for the Calrose Medium Grain Rice Project was assumed by Dr. K.S. McKenzie in 2010 to ensure continuity and evaluate the project's status and future direction, while searching for a rice breeder to fill the vacant project leader position. Beginning in August of 2011, the Director of Plant Breeding position was reinstated, having leadership and oversight responsibilities for the RES Rice Breeding Program as well as being the project leader for the Calrose Medium Grain Rice Project. Beginning in 2012, Dr. V.C. Andaya assumed this position having been working with the medium grain project for the past two years. A new rice breeder, Dr. S.O. Samonte, will join the program in February of 2012. He will work with Dr. V.C Andaya and will transition in as the project leader for the Premium Quality and Short Grain Project. RES project leaders and staff will continue their work and Dr. McKenzie's responsibilities will shift toward administrative, research direction oversight, and support.

M-105

The new very early Calrose medium grain cultivar, M-105, was released to California seed growers for foundation seed production in 2011. This variety was selected from a cross between M-104 and M-206. It combines the high stable milling yields of M-206 with some of the very early maturity of M-104. Table 8 shows the results from the UCCE Very Early Statewide Yield Test in 2011. As seen in its development, M-105 heads between M-104 and M-206. Yields in the test plot were not significantly different overall. Cause of the low yield of M-105 at the Sutter test was undetermined. Seed growers' reports were neutral and needed to evaluated it again in a more "normal year".

Yield Potential

California offers a high-yielding environment and efforts continue to take advantage of that resource by developing varieties with high yield potential. Yield increases on our current high yields will be difficult to achieve and must be made in conjunction with the needed quality and agronomic traits. Large plot yield tests (combine harvested) have been expanded for medium grains and facilitate by the new research combine in 2011.

Tables 1 to 6 show results from advanced large plot testing in 2011. In reviewing these tables there are medium grain entries that yielded more than the check cultivars, but not significantly. There are also other grain types that have shown very high yield potential. Unfortunately, transferring this yield potential to medium grains is no simple task, and experience is showing that at best they can only be achieved in small increments. This is also the case with foreign introductions or disease resistant material being used in crossing.

Hybrid rice has been under study since 2008 as a mechanism to achieve significant yield increases at RES. Hybrid rice has been successfully established commercially in China and more recently in the Southern US. In 2011, Dr. Jodari conducted a replicated transplanted small plot experiment comparing M-206 with the experimental indica hybrid LAH10 provided by Dr. S. Linscombe of the Louisiana State University Rice Research and Extension Center. Results of this small test are summarized in Table 9. The hybrid line showed good vigor and straw strength and yielded 9% more than M-206. The yield advantage, although significant, is not enough to support the hybrid system for California. There were conventional RES long grain lines in the field that yield as high as LAH10 as well. This line, like most southern long grains, was very late maturing, especially in this cool growing season. Milling performance of LAH10 was not very good with a head rice of 52 versus 68 % for M-206 (Table 9). Appearance, shape, and chalkiness of LAH10 not suitable for RES cultivars, and this, as well as cooking quality is a major obstacle for hybrid rice for California.

High Grain Quality Calrose

Improvements in yield, agronomic traits, or disease resistance, must be accompanied by acceptable quality for the market and high milling yield and stability will continue to be a priority. Visual inspection of brown and milled rice samples are part of the selection process from the earliest generation. Harvest moisture milling tests and grain measurement are routine steps in evaluation of lines reaching the yield testing levels. More than a 1200 medium grain samples were harvested by hand, milled and analyzed. Digital grain measurements and kernel weight are collect in the lab and are an integral part of determining which lines will advance. In 2011, as is usually the case, the best yielding materials frequently show weakness in head rice yield when compared to M-206 and are not suitable for further advancement.

Cold Tolerance

Resistance to low temperature induced blanking is an important trait providing “disaster insurance” in the last two cool years in California. In 2011, medium grains, although delayed, showed relatively little blanking and were much less delayed that other grain types. Selection against cool temperature delay is practiced in the San Joaquin nursery, the Hawaii winter nursery, and at cool locations in cool years. M-104 performs well in cold situations and efforts continue to bring that trait into RES breeding material. Some new cold tolerant germplasm has been identified and obtained in participating in the Temperate Rice Research Consortium, and is being incorporated into adapted medium grains.

Early Maturity & Lodging Resistance

Early maturity provides help in reducing the growing season, planting flexibility, and lodging resistance for harvest efficiency, quality, and high and stable yield. In 2011, the extremely cool summer tended to compress heading and in the nursery there were a relatively small differences in heading date. Not many lines were earlier and superior to M-104. The highest yielding lines are more often found at the M-205 maturity.

Lodging is an issue with earlier materials since they may be ready to harvest, but must be stand in the field and get over ripe while other entries mature. In addition, the highest yielding lines are commonly taller with more vegetative growth and thus more prone to lodging. Very early materials often have grain appearance problems. The combination of these issues makes selecting superior entries challenging, however, this is an area of focus in the medium grain program.

Disease Resistance

Stem rot, blast and aggregate sheath spot are all threats to productivity and quality, thus remain areas of breeding emphasis for medium grains. An intense effort is being made in SR resistance marker identification with the Pathology Project and also rice blast resistance.

In 2011 medium grain disease resistance breeding operated under the leadership of Dr. V.C. Andaya by coordinating efforts with Pathologist Jeff Oster and the marker resistant support coming from Dr. C. Andaya in the DNA Marker Lab. Their work on disease screening and marker development and pyramiding blast genes is discussed in the short grain and pathology reports. A large number of stem rot breeding lines were screened in 2011 with very few acceptable medium grain lines selected for advancement. Those selections will be screened in the advancement process including the San Joaquin nursery, RES refrigerated greenhouses, Hawaii winter nursery, quality and milling evaluation, and tested again for disease resistance by the Pathology Project. Several lines from the M-206 pathology backcrossing efforts with different source of resistant to rice blast will be available for statewide yield testing in 2012. With the persistence of rice blast in California and the issues with M-208 that is an area of emphasis for the medium grain project.

Herbicide Tolerance

Varieties show differences in tolerance to rice herbicides and this is often reflected in performance in the breeding nursery in the weed control programs. The RES Breeding Program is working with the UC weed scientists in this area to try to characterize these differences in varieties and breeding materials to ensure that existing and new products are adequately evaluated for varietal sensitivity and to develop screening and selection techniques for breeding material. Induced mutation was used very successfully by the LSU Program to recover imidazilinone herbicide resistant rice (Clearfield®). This non-transgenic trait has been incorporated into adapted material in the Long Grain Project. Medium grain materials are under development as well. However, efforts to introduce this technology to the California rice industry with involvement of the CRRB, CRC, UC and other companies have been rejected by the herbicide manufacturer.

A research effort has been made to recover plants with increased tolerance to the ALS herbicide Granite GR®. In 2009-2010 approximately 250,000 mutagenized M-206 seedlings were screened in the greenhouse and 250 putative mutants selected for advancement and further testing in 2011. DNA markers were used to identify out crosses or contaminated varieties. Approximately 86 rows were selected from a UC Weed Control nursery at Hamilton Road treated with a 3x rate of

Granite GR® in 2011. These selections will be re-tested to determine if any significant enhanced levels of herbicide tolerance has been found. Screening for tolerant mutants using some other rice herbicides is also underway using EMS and irradiated seed.

Table 8. Agronomic performance means for M-104, M-105, and M-206 in very early advanced entries in Statewide Yield Tests in 2011.

Identity	Test†	SV‡	Days §	Ht. (cm)	Lodge %	Grain Yield¶
M104	VE-SJ	5.0	98	84	1	8800
M105	VE-SJ	5.0	100	86	1	8720
M206	VE-SJ	5.0	105	89	1	9330
LSD(0.05)		0.2	4	3	NS	580
CV %		2	3	3	NS	5
M104	VE-SUT	5.0	84	94	74	10300
M105	VE-SUT	5.0	87	97	4	8270
M206	VE-SUT	5.0	90	97	1	9350
LSD(0.05)		NS	1	5	30	1390
CV %		NS	1	3	69	11
M104	VE-YOL	5.0	84	99	1	10220
M105	VE-YOL	4.9	87	104	1	10290
M206	VE-YOL	5.0	87	102	4	10230
LSD(0.05)		NS	2	5	18	650
CV %		2	2	4	190	5
M104	VE-RES	4.9	83	91	3	8570
M105	VE-RES	4.8	84	97	3	9020
M206	VE-RES	4.8	87	99	40	8660
LSD(0.05)		0.1	2	5	NS	1090
CV %		2	1	4	NS	9
M104	Over All	5.0	87	92	19	9420
M105	Over All	4.9	89	97	2	9020
M206	Over All	5.0	92	97	1	9390
LSD(0.05)		0.1	1.8	3	NS	480
CV %		3	1	4	124	8

† Test locations; VE-SJ=San Joaquin, VE-SUT=Sutter, VE-YOL =Yolo, VE-RES=Biggs
‡ SV=seedling vigor score where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ Paddy rice yield in lb/acre at 14% moisture.

Table 9. Performance of LAH10 indica hybrid and M-206 in replicated small plot test at RES in 2011.

Entry	Days to 50%	Height (cm)	Plot Yield (g)	Milling (%) Head	Milling (%) Total
LAH10	104	109	4484	52	68
M206	80	100	4052	69	72
M206†	85	99	4158	68	71
LSD(0.05)	1	5	327	--	--
CV (%)	1	3	5	--	--

†Direct seeded, others transplanted from greenhouse seedlings.

PREMIUM QUALITY & SHORT GRAINS

Virgilio C. Andaya

For the past decade, the short grains breeding project has seen four leadership changes. With every change in breeder, there are always concerns about continuity of breeding goals and procedures, smooth transfer of breeding materials, and interruption in the normal variety release process. When smooth transitions are not in place, these concerns are indeed something to worry about. In 2012, the project will undergo another leadership change. Dr. Andaya will take over the medium grain breeding project and as the Director of Plant Breeding while Dr. Stanley Omar Samonte will take over the premium quality and short grain breeding. All the breeders and support staff have been preparing for these changes to pave the way for a smooth transition and orderly transfer of responsibilities.

The short grain and premium quality breeding project continues to develop conventional, premium, waxy, and low amylose short grains, as well as Arborio-types and premium quality medium grains. The breeding goals remain the same, but putting more emphasis in improving overall grain quality, milling yields and adaptation to cold environments. As a highlight, the short grains project is releasing an advanced line, 04Y177, for the premium quality short grains market for 2012.

Release of Calhikari-202

Following its approval for foundation seed increase in 2011, 04Y177 is now approved for variety release as Calhikari-202 (CH-202) in 2012. This new variety is a semi-dwarf, early maturing, pubescent short grain rice developed as an alternative to Calhikari-201. This new variety is adaptable in areas where Calhikari-201 and Koshihikari are being planted.

Calhikari-202 originated from the cross "05P104" x "Hitomebore" designated as R20885. The cross was made at the Rice Experiment Station, Biggs, CA, on March 10, 1995. 05P104 is a premium short grain F_5 progeny line from the cross R18026 with the pedigree "Koshihikari*2/S-101//Koshihikari/S-101". 05P104 is a sister line in the F_5 generation of the progenitor of Calhikari-201 (CH-201). Officially, Calhikari-202 has the pedigree "Koshihikari*2/S-101//Koshihikari/S-101/3/Hitomebore".

Selection History

Calhikari-202 was selected from a cross made in 1995 and advanced using the pedigree breeding method. Dr. McKenzie handled the progeny selection up to the F_8 generation. Dr. Todd Campbell, then hired as the new short grain breeder, briefly continued with the selection and generation advance from F_9 to F_{10}. Dr. Junda Jiang became the third breeder to handle the breeding material from F_{11} to F_{13}. In 2007, Dr. Virgilio Andaya took over the selection and quality evaluation and head row purification until its release.

Head rows of 04Y177 were first planted in 2006 and continued through 2011. Panicles taken from selected rows and inspected for size and shape of paddy or brown rice were used to compose the next cycle of the purification process. DNA markers were also used to detect variants and mixtures. Two acres of foundation seed production fields were planted in 2011. Approximately 10,000 lbs of foundation seed was harvested for distribution in 2012.

Performance in Statewide Tests

Calhikari-202 was first entered in the UCCE Statewide Yield Tests in 2005 with experimental designation 04Y177. Starting in 2008, CH-201 and CH-202 were evaluated together in the same test locations. Comparisons for grain yield and other agronomic traits averaged by location for CH-201 and CH-202 are presented in Table 10. Overall average yields are 8750 and 8240 lbs/acre, for CH-202 and CH-201, respectively. CH-202 has an earlier heading and has comparable plant height but has poorer seedling vigor and greater tendency to lodge.

Table 10**.** Average grain yields, days to heading, plant height, seedling vigor and lodging of Calhikari-202 and Calhikari-201 in UCCE Statewide Test from 2008 to 2011.

Location/ Maturity†	Grain Yield‡		Days to Heading¶		Plant Height (cm)		Seedling Vigor§		Lodging %	
	CH-202	CH-201	CH-202	CH-201	CH-202	CH-201	CH-202	CH-201	CH-202	CH-201
Butte, E	8120	7830	85	87	95	93	4.7	5.0	37	7
Colusa, E	8010	7850	87	93	87	90	5.0	5.0	29	17
Glenn, IL	7580	8190	90	92	97	99	5.0	5.0	75	78
Biggs, E	9140	9300	86	89	91	90	4.8	5.0	81	60
Biggs, IL	9850	9750	87	91	87	87	4.9	5.0	79	47
Biggs, VE	8400	7930	88	94	97	97	4.8	5.0	82	78
San Joaquin, VE	8150	7960	107	108	79	77	4.7	5.0	1	1
Sutter, VE	8620	7520	88	92	92	93	4.8	5.0	68	40
Sutter West, IL	9950	9520	88	90	94	94	4.9	5.0	21	29
Yolo, VE	10,270	9430	92	93	94	91	5.0	5.0	38	4
Yuba, E	8820	8010	86	89	88	87	4.8	4.9	49	10

† Maturity, VE=very early, E=early, IL=intermediate-late.
‡ Paddy rice yield in lb/acre at 14% moisture content of the grain.
¶ Days to 50% heading.
§ Seedling vigor score, 1=poor and 5=excellent.

Physicochemical Grain Traits

Table 11 summarized the physicochemical grain characteristics of Calhikari-201, Calhikari-202, and Koshihikari. Overall, RVA, protein, amylose and alkali tests indicate that Calhikari-202 has an intermediate profile in between that of Calhikari-201 and Koshihikari. CH-202 grains are smaller than CH-201 and Koshihikari; however, there was no indication that the small grain size of CH-202 is a serious marketability concern.

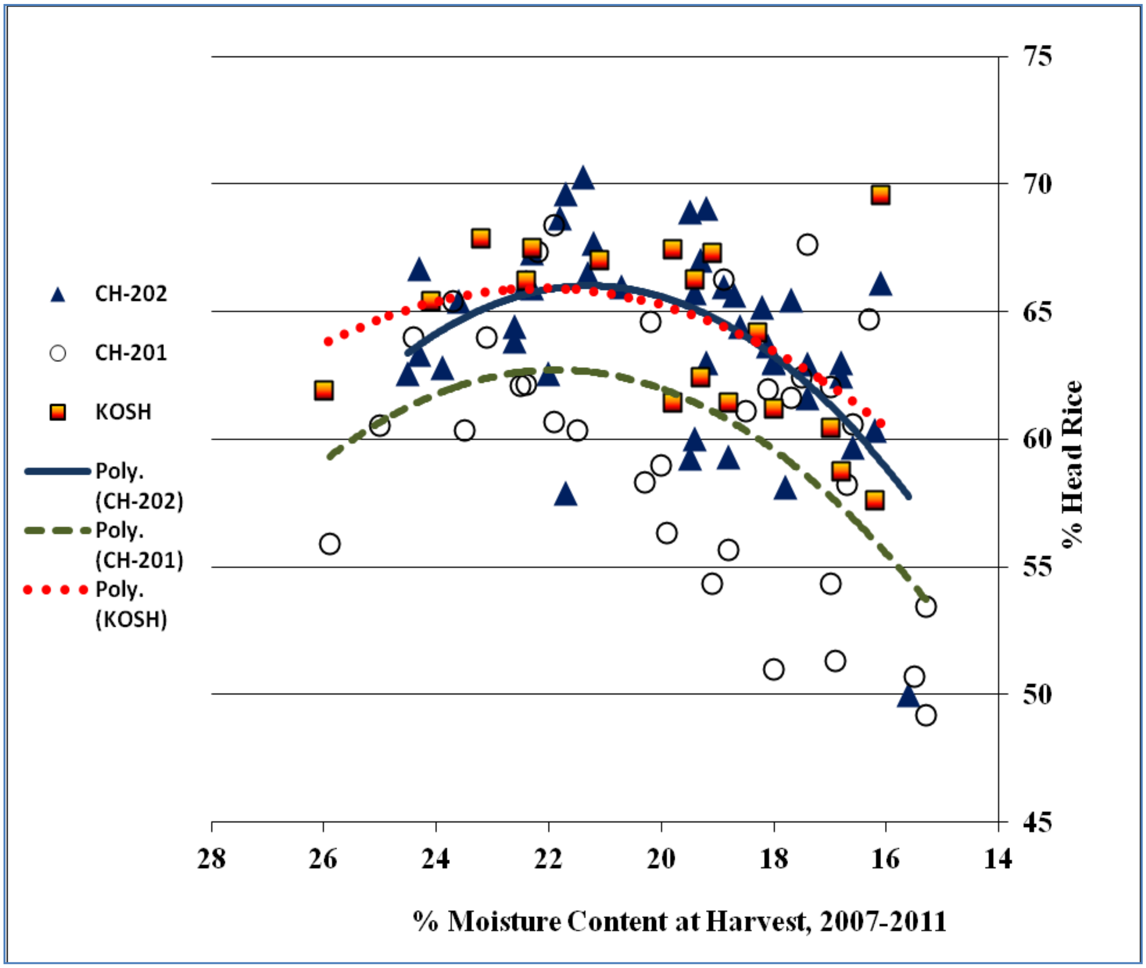
Trend analysis (Figure 1) of the average head rice percentage of Calhikari-202, Calhikari-201, and Koshihikari plotted against percent grain moisture content at harvest indicates that Calhikari-202 had a better milling (head rice) than Calhikari-201. Official milling evaluation by the Federal Grain Inspection Service, USDA, placed the milling yield (Head/Total) of CH-202 at 71/71 and 69/69 in 2010 and 2011, respectively.

Table 11. Physicochemical grain characteristics of Calhikari-201, Calhikari-202, and Koshihikari. Grain samples were taken from milling plots at RES from 2009 to 2011.

Trait†		Calhikari-201	Calhikari-202	Koshihikari
RVA	Peak	269.5	270.0	269.7
	Hot Paste	155.5	150.6	141.8
	Breakdown	114.0	119.4	127.9
	Cool Paste	259.8	252.8	237.5
	Setback	-9.6	-17.3	-32.2
	Consistency	104.3	102.1	95.7
Protein Content (%)		5.4	5.2	5.0
Amylose Content (%)		16.2	16.9	17.7
Alkali Spreading Value		6.8	7.0	7.0
Paddy	100-grain weight (g)	2.33	2.28	2.28
	Length (mm)	6.95	6.71	6.95
	Width (mm)	3.44	3.33	3.28
	Length/Width Ratio	2.03	2.02	2.16
Brown	100-grain weight (g)	1.96	1.88	1.94
	Length (mm)	5.05	4.90	5.03
	Width (mm)	2.94	2.88	2.85
	Length/Width Ratio	1.72	1.70	1.77
Milled	100-grain weight (g)	1.80	1.71	1.80
	Length (mm)	4.70	4.55	4.71
	Width (mm)	2.85	2.80	2.78
	Length/Width Ratio	1.65	1.63	1.70

† RVA, protein content, amylose content, and alkali spreading value are average of data from 2009 to 2010. Physical grain measurements are average of data from 2010 to 2011.

Figure 1. Trend analysis and scatter plot of the average head rice percentage of Calhikari-202, Calhikari-201, and Koshihikari plotted against percent moisture content of the grain at harvest. Data was taken from milling plots at RES from 2007 to 2011.



Cooking Quality

At RES, premium quality attributes of cooked rice are as follows: very glossy in appearance, slightly soft and sticky, smooth texture, tastes tender, slightly sweet, subtle aroma, and soft after cooling. Koshihikari is the standard to which everything is compared. Milled rice samples of CH-202 and check varieties were given to millers and marketing organizations in California and Japan since 2007. These outside evaluations were made in addition to extensive cooking tests performed at RES and some selected individual rice consumers.

With years of testing, CH-202 topped CH-201 in quality parameters. However, the level of cooking and eating quality is slightly below the level of Koshihikari quality. External feedbacks from California and Japan marketers were likewise favorable and drew similar conclusions.

Disease Reactions

Reactions to stem rot, aggregate sheath spot, and bakanae of Calhikari-202 and Calhikari-201 are presented in Table 12. Disease screening data from 2005 to 2011 indicate that CH-202 has a better resistance to stem rot but has poorer reaction to aggregate sheath spot and bakanae compared to CH-201.

Table 12. Stem rot, Aggregate Sheath Spot, and Bakanae screening scores of Calhikari-202, Calhikari-201 from 2005 to 2011. Screening nurseries were established by Mr. Jeff Oster, RES pathologist, in both field and greenhouse.

Year	Stem Rot†		Aggregate Sheath Spot‡		Bakanae§	
	Calhikari-202	Calhikari-201	Calhikari-202	Calhikari-201	Calhikari-202	Calhikari-201
2005	7.2	7.7	-	1.2	-	0.8
2006	5.4	6.2	2.9	2.8	0.6	0.2
2007	5.7	6.6	2.7	2.4	5.0	3.9
2008	6.2	7.7	2.1	2.2	-	-
2009	4.8	6.0	-	-	-	-
2010	5.1	6.4	-	-	-	-
2011	4.6	5.2	2.6	2.2	-	-
Average	5.6	6.5	2.6	2.2	2.8	1.6

† Stem rot score where 0=no damage and 10=plant killed.
‡ Aggregate sheath spot score where 0=resistant and 4=susceptible.
§ Bakanae score are percentage of plants infected in a row.

The Future of the Short Grains Breeding Project

The short grains market remains strong in California, especially the premium quality and waxy short grains. The market for Arborio-type and low-amylose types has relatively remained small. Nonetheless, breeding continues for these two types at a limited scale in anticipation of positive future market trends.

Breeding materials are slowly going through the pipeline for all the grain types under the project. These are being advanced with strict selection for grain quality and milling yields with the intent of coming up with better products for the rice industry.

The DNA Marker Laboratory

Leadership of DNA lab was turned over from Dr. V.C. Andaya to Dr. Cynthia Andaya, in early 2011. Dr. C.B. Andaya is a research scientist hired to perform activities in support of the different breeding programs and, in some cases, to spearhead the implementation of special projects. Dr. C.B. Andaya is managing a critical component of the RES program by continually integrating new techniques and technologies in rice research. This year, the DNA lab was involved in the following activities: 1) mapping of stem rot resistance genes, 2) pyramiding of blast resistance genes, (3) marker-assisted selection (MAS) for the different grain types, 4) fingerprinting various rice materials, and (5) herbicide resistance discovery via mutation breeding.

Mapping Stem Rot Resistance

An advanced backcross recombinant inbred line population from the cross 87Y550/M206*2 was used to map the stem rot resistance quantitative trait loci (QTL) from *Oryza rufipogon*. Microsatellite markers were screened for polymorphism in 2010 and around 100 polymorphic markers were identified and used in 2011.

Stem rot scores of the different lines comprising the mapping population were evaluated by pathologist Mr. Jeff Oster in a replicated trial at the RES. Initial locations of the stem rot resistance genes were mapped in chromosomes 4, 6, and 10. Results were verified by expanding the tests in 3 locations, Biggs, Glenn and Colusa. The trial in Colusa did not show enough disease development and was dropped in the final evaluation. Based on the two-year analysis, the QTLs in chromosome 4, 6 and 10 controlling stem rot resistance both appeared across seasons and also across locations. A QTL in chromosome 5 was detected in 2011 but not significant in 2010.

In summary, stem rot resistance QTL in chromosome 4 is between markers RM5414 and RM8213. QTL in chromosome 10 is between markers RM25633 and RM590. To narrow down and finemap the region of interest, additional polymorphic markers are being looked at and the population size being expanded. This is all aimed at finding a tightly linked marker to stem rot resistance that can be used for MAS by the different breeding projects.

Pyramiding of Blast Resistance

Rice blast disease caused by the fungal pathogen *Magnaporthe oryzae* causes considerable damage to rice. Although rice blast is not prevalent in California, it could pose a serious concern. M-208, released in 2005, contains a major blast resistance gene *Pi-z* has been observed to have blast in some fields.

RES pathologist Mr. Jeff Oster initiated a backcrossing program in 2005 to incorporate several blast resistance genes into M-206 background. In 2011, around 5600 F_2 plants from different crosses were scored using DNA markers AP5930, RM224, RM331 and RM7102. These breeding materials have resistance genes from 4 blast resistance sources: Drew (*Pi-ta2*), C101LAC (*Pi-33*), Cocodrie (*Pi-kh*) and IR65482-4-136-2 (*Pi-40*). A total of 36 plants that contain all 4 resistance genes were identified. These plants were grown in the greenhouse and will be planted in the field in 2012.

Marker-Assisted Selection

The main goal of the DNA lab is to help the breeders in their selection process. Around 1200 long grain samples were scored using three markers: Gt-alk, RM190 and Waxy Exon 6 SNP. The genotype scores for these markers give the breeder predicted quality scores in terms of gel temperature, amylose type, and viscosity.

For the medium and short grain projects, the DNA lab screened around 500 samples for the Waxy gene (RM190). RM190 is being used routinely in the short and long grain projects to assist in the selection of materials that need to be cooked and evaluated further for eating quality.

Several F_2 materials in the medium grain program were screened for Clearfield DNA markers S653F and R653F. These materials were products from the cross with CL161. In addition, around 370 samples were screened for five blast resistance markers; RM208, RM224, AP5930, RM331 and RM7102.

Fingerprinting

An important component of the DNA lab is to provide research personnel with assistance in variety identity. Several blast incidents were reported in some rice grower's fields. Plant tissues or seeds taken from blast-infected fields submitted by Dr. Chris Greer of UCD and by Mr. Timothy Blank of CCIA were fingerprinted. Using DNA markers, these plants collected in the field were identified to be M-208. In addition, the lab assisted in confirming the identity of various materials for different projects such as Koshihikari and M-401 mutant populations, M-206 putative Prowl herbicide resistant mutants, and foundation seed testing.

Herbicide Resistance

A special project at the RES is to develop rice lines that are resistant or tolerant to various herbicides being used in the rice production system. Putative Prowl mutants identified in the greenhouse were planted in the field for seed increase. Herbicide testing in the greenhouse indicated that the tolerance/resistance levels of these lines are not as dramatic as seen in the paper assay and lab test results. Validation experiments are continuing. Dr. C. B. Andaya initiated another round of Prowl selection of M-206 irradiated seeds to identify Prowl resistant lines. Several lines were rescued from this screen and are currently growing in the greenhouse. Further testing will be done on these materials.

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 1 day earlier than M-206. Plant height is 14 cm shorter than M-206. Lodging potential is significantly lower than M-206, 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 2011 multi-location, early and intermediate maturity groups, Statewide Yield Tests averaged 9680 lb/acre (Tables 3, 5, 13). Average yield for M-205 within the same tests was 9760 lb/acre. Yields of L-206 at colder locations of Yolo and San Joaquin have not been as competitive as medium grain varieties. 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 2005–2011 seasons was 62%. Kernel length of L-206 ranged between 7 and 7.3 mm.

In 2011, L-206 and 17 Southern long grain varieties that are currently in production in US were evaluated for market acceptability by 9 Southern milling organizations. This effort was sponsored by USA Rice Federation Rice Marketability and Competitiveness Task Force. Results of evaluations of 2010 crop (Table 14) indicated that L-206 was ranked 5th among the 18 varieties evaluated, with first rank being the most acceptable. Figure 2 shows the comparative category scores for L-206. The evaluation is scheduled to continue with samples from the 2011 and 2012 season crops.

Other promising conventional long grains that were evaluated in 2011 in advanced generations included 06Y575, 09Y1079, and 10Y1012. Performance results are listed in Tables 1, 3, 5, and 13. Entry 06Y575 is a high amylose/low gelatinization temperature type, with high yield potential, good milling yield, and cold tolerance. This experimental line has shown exceptional yield potential for 4 consecutive years in cooler locations such as San Joaquin as well as the warmer locations like Glenn County. The unique wide adaptability trait of this line is being incorporated to a considerable number of long grain breeding lines. This line was tested in all 8 off-station locations in 2011 statewide trials. Grain yield average over all locations was 10,050 lb/acre for 06Y575 as compared to 9420 for L-206. Yields of M-206 in 6 locations in addition to RES averaged 9410 lb/acre. (Tables 1 and 3). Potential uses for 06Y575 include canning and parboiling. Evaluation by marketing organizations is currently underway.

Table 13. Performance of selected conventional long-grain entries as compared with standard varieties in 2011 yield and milling tests.

Entry	Type†	Identity	Yield‡		Head Rice§
			Statewide	RES	(%)
Very Early Statewide					
	LR	06Y575	10580	--	64
	L	09Y1079	9640	--	66
	L	L-206	9120	--	62
	M	M-206	9640	--	--
Early Statewide					
	L	09Y1122	10400	10610	62
	LR	06Y575	9940	10100	63
	L	L-206	9790	10020	61
	M	M-206	9680	10050	--
Intermediate Statewide					
	L	10Y1012	10460	11170	65
	L	06Y575	10310	10390	63
	L	L-206	9560	9990	61
	M	M-205	9710	10270	
Very Early Preliminary					
	L	10P1222	--	11540	62
	LIM	10P1685	--	10240	62
	L	L-206	--	10300	61
Early Preliminary					
	L	10P1143	--	11330	64
	L	L-206	--	9720	60
Intermediate Preliminary					
	L	10Y1121	--	11360	63
	L	L-206	--	10760	62

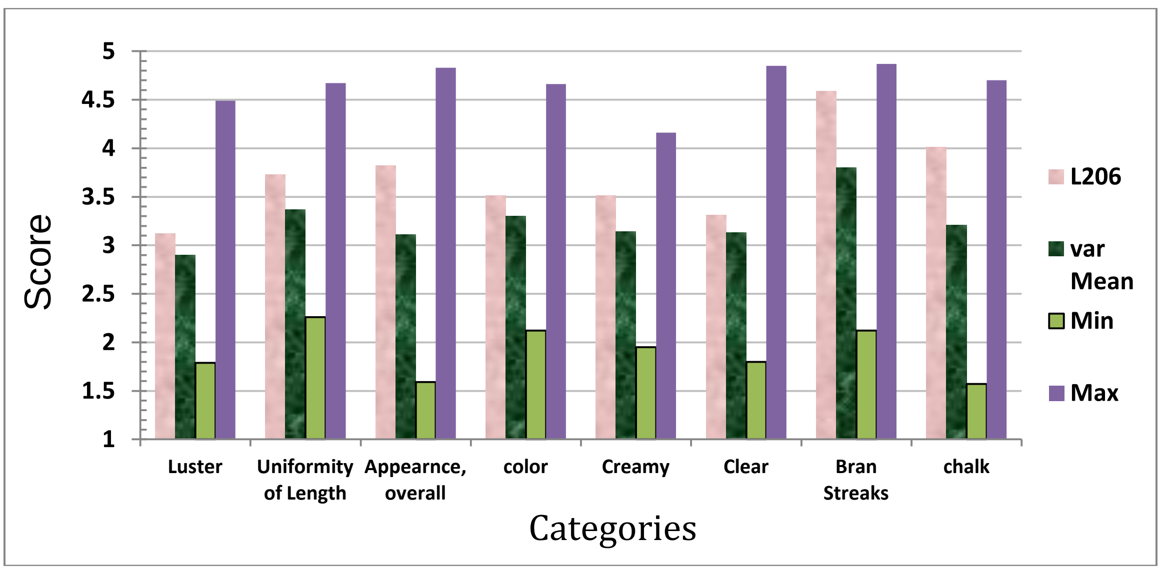
†L=long grain intermediate amylose type, LR=long grain high amylose type, LIM=long grain imidazilinone resistant, M=medium grain.
‡ Paddy rice yield in lb/acre at 14% moisture.
§Head rice yields are from solid seeded stands for statewide tests and single rows for preliminary yield tests.

Table 14. Ranking of 2010 US long grain variety samples by nine milling organizations from the Southern US.

Sample	Overall Ranking	Package Rice Approval
D	2.7	80
O	3.2	80
C	5.2	100
B	5.8	100
L-206	6.3	80
F	7.3	100
Q	9.0	60
M	9.7	80
P	10.2	80
A	10.7	80
H	11.2	60
K	11.9	80
S	12.4	60
N	12.9	20
G	13.3	0
U	14.2	60
J	14.2	20
R	14.6	40
E	14.9	20

Source: USA Rice Federation- Marketing and Competiveness Taskforce.

Figure 2. Subjective evaluation category scores for L-206 compared with overall varieties from evaluation 2010 long grain samples by nine milling organizations from the Southern US.



Source: USA Rice Federation- Marketing and Competiveness Taskforce.

Specialty Long Grains

Expanded breeding efforts in specialty long grain area continued in 2011. Specialty types include Jasmine, Basmati, and conventional aromatics such as A-201. Agronomic and quality of selected specialty lines are shown in Tables 15 to 17.

Calmati-202 is a true basmati variety released in 2006. It is an early maturing, semi-dwarf, pubescent, aromatic, elongating long grain. Susceptibility to cold induced blanking is significantly higher than standard varieties and therefore is not adapted to cold locations. Average yield of Calmati-202 in 2011 early and intermediate-late tests were 6420 lb/acre as compared to 9790 for L-206 (Tables 3 to 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 19 percent.

An improved experimental Basmati line 11Y158 was tested in 2011 Statewide Yield Tests. Cooking quality evaluations of this line in earlier generations has shown a considerable quality advantage over Calmati-202. 11Y158 is an early maturing, true basmati type, pubescent experimental line that was in the advanced purification stage in 2011. Sufficient quantities of head row seed of this line are available for use in 0.5 acre breeder seed production in 2012. Primary advantages over Calmati-202 variety include higher cooked kernel elongation, more slender grain shape, and a closer cooked grain texture to imported basmati as shown by RVA profile (Table 15). Aging of this selection by one year has increased its RVA viscosity values as shown in that table. A stronger RVA profile is expected to improve cooked grain texture resulting in more flakey cooked rice as is the case with imported basmati. Average grain yields over 6 statewide locations was 6000 lb/acre for 11Y158 and 6700 lb/acre for Calmati-202 (Table 16) Primary drawback of 11Y158 is a low milling yield of 36%. This compares with 61% for Calmati-202. Small experiments have been planned for 2012 to identify harvesting and processing procedures that can enhance milling yield and cooking quality. These factors include harvest moisture, drying rate, and milling degree. Based on the current grain and head rice yield estimates, whole grain production per acre of this line can be estimated at 2100 lb/acre. Standard long grain variety L-206, at the same time, with the current level of production can potentially yield 6200 lb/a of whole grain. The current market price differential between basmati rice and standard long grain is considerably higher than 3 to 1 ratio. Milled samples of 11Y158 from 2011 crop season will be provided to potential marketing organizations for their evaluation.

Other basmati selections with improved qualities in 2011 statewide tests include 10Y153 and 10Y1199 (Table 17).

Efforts continued in 2011 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 irradiated with a high dose of gamma ray was increased in new greenhouse facility at RES in winter of 2010. M_2 rows were subsequently produced and evaluated at RES for early maturity or photoperiod insensitivity in the summer of 2011. A few mutant lines were obtained and will be tested in 2012. Other mutants that were obtained previously are still being used as valuable germplasm source for further agronomic improvements.

In 2011, 5 jasmine type selections were tested in the UCCE Statewide Yield Tests and 42 in preliminary yield tests. Breeding objectives for jasmine type quality include low amylose, strong aroma, a high degree of whiteness, and a smooth cooked grain texture.

Efforts in the area of conventional aromatics increased in 2011 due to a need for an A-301 type variety replacement that possessed improved agronomic traits. Three experimental lines, 08Y1115, 10Y150, and 10Y1149 were tested in 2011 statewide tests and are currently being evaluated by one marketing organization. Additional selections will be tested in 2012.

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. In 2011, all selections in preliminary and advanced yield tests were 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. The goal for long grain is to maintain a minimum of 64% head rice yield in all advancing breeding lines.

Table15. Kernel and cooking quality characteristics of 11Y158.

	Milled Kernels†								RVA			
ID	Area	L	W	L/W	100 kwt	Elong ‡	Amylose Content	Gel type	Peak	Hold	Final	Setback
CT202	12.2	7.5	2.0	3.8	2.02	2.11	Int	Int	226	134	257	31
11Y158	9.4	7.1	1.6	4.3	1.44	2.32	Int	Int	137	107	235	98
11Y158 - aged 12 Months						2.33			160	115	293	133
Basmati Import-A	10.6	7.5	1.8	4.2	1.68	2.34	Int	Int	161	128	280	119
Basmati Import-B	10.2	7.2	1.8	4.1	1.54	2.31	Int	Int	121	105	287	166

†Area in mm^2, L=length in mm, W=width in mm, L/W=L/W ratio, and 100 kernel weight in g.
‡ Increase in kernel length from milled rice after cooking.

Table 16. Agronomic and milling performance of 11Y158 and Calmati-202 basmati type rice in UCCE Statewide Yield Tests in 2011.

			Yield§							HR/HM¶
Identity	SV†	HD‡	Biggs	Butte	Colusa	Yuba	Glenn	Sutter-w	Overall	(%)
CT-202	4.7	96	6640	8020	5210	6030	6770	7440	6690	61/17
11Y158	4.9	95	5720	6250	4520	5290	6900	7310	6000	36/18

† SV=seedling vigor score where 1=poor and 5=excellent.
‡ Days to 50% heading.
§ Paddy rice yield in lb/acre at 14% moisture.
¶ HR=head rice, HM=harvest moisture.

Table 17. Performance of specialty long-grain entries in 2011 yield and milling tests.

Entry	Identity	Specialty Type	Yield† Statewide	Yield† RES	Head Rice‡ (%)
Early Statewide					
104	09Y1067	Jasmine	8910	8330	61
106	10P1433	Jasmine	6660	6020	61
115	10Y153	Basmati	4920	5090	55
158	11Y158	Basmati	5360	6250	37
112	08Y1115	Aromatic	7330	7900	62
111	10Y1149	Aromatic	7860	7940	65
101	A-201	Aromatic	7910	7860	57
102	CT202	Basmati	6420	8020	61
74	L-206		9790	10020	62
Intermediate/Late Statewide					
148	10Y150	Jasmine	8180	8030	64
149	09Y1067	Jasmine	9090	9720	61
158	11Y158	Basmati	6640	5720	36
157	10Y1199	Basmati	7270	6780	48
147	CT-202	Basmati	6950	6640	61
128	L-206		9560	9990	61
Preliminary					
1094	10P1717	Jasmine	--	11590	66
1110	10P1402	Jasmine	--	9770	64
1090	10P1580	Basmati	--	7080	50
1153	10P1572	Basmati	--	6920	57
1049	10P1682	Aromatic	--	11470	63
1078	10P1064	Aromatic	--	9630	65
1145	A-201	Aromatic	--	8936	54
1147	CT202	Basmati	--	7590	61

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

Disease Resistance

SR resistance originating from *Oryza rufipogon* continues to be incorporated into an increasing number of high yielding long-grain lines. Twenty-four entries with a range of SR resistance were tested in 2011 Statewide and Preliminary Yield Tests. Performance of a selected number of these lines is shown in UCCE Statewide Yield Tests (Tables 1–6). 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. Efforts are currently underway, with cooperation of the RES plant pathologist, to modify field screening procedure for stem rot resistance based on maturity stage with the goal of increasing selection efficiency.

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, and screens statewide and preliminary trial breeding lines and varieties (about 1600 rows) for stem rot resistance in the field. Since 2005, the immediate backcross program involved screening entries for blast (1806 crosses), SR (1195 crosses) and SS (971 crosses) resistance with three generation advances per year. The objective was to transfer resistance genes into an M-206 background for use by the breeders. The crossing programs have been transferred to the breeders. In addition, early generation materials derived from breeder's crosses are cycled through the disease nursery to identify and verify disease resistant lines (about 7463 rows). Intense selection pressure is applied for important agronomic traits because sources of disease resistance have a number of undesirable characteristics. The sources of SR resistance also confer aggregate and bordered sheath spot (SS) resistance. Conversely, the sources of SS resistance also seem to confer SR resistance in some materials.

Stem Rot

Screening for SR resistance in inoculated nurseries and greenhouses usually begins 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 small percentage of the lines screened show higher levels of SR resistance than current varieties. There were about 12,000 rows in the 2011 SR nursery.

This year, 5360 rows in the stem rot nursery were drill seeded. This resulted in less seed drift, establishment of a more uniform stand, and allowed use of higher nitrogen without inducing lodging. Increased nitrogen results in greater disease severity and better screening.

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

As in the past, some lines (derived from all donor parents) again showed SS resistance equivalent to that found in sheath spot donor parents (see section below).

This year 2400 BC_1F_6 rows derived from the 2010 mapping population were evaluated for SR resistance in the field at four locations (2 at Biggs, one each in Colusa and Glenn counties). The parents were M-206 and 87Y550 (long grain with resistance derived from *O. rufipogon*). Three candidate chromosome locations that were identified in 2010 by Drs. Andaya were confirmed in 2011. Two more chromosome locations were also identified in 2011.

Molecular markers would enable selection for disease resistance without having to perform biological screening and the environmental fluctuations that come with it. Such markers would allow early generation identification of resistant seedlings before crossing, thus greatly speeding the breeding process.

Aggregate Sheath Spot

An immediate backcross program was started in 2005 to transfer aggregate sheath spot (SS) resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-206 (102 crosses this year). BC_6 has been made. Existing segregating populations from various backcrosses will now be rapidly advanced in the greenhouse, where sheath spot screening is conducted.

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.

Last March, DNA from M-206, 87Y550, and three breeding lines with sheath spot resistance derived from Teqing, Jasmine 85, and MCR10277 were sent to Dr. Jim Oard of Louisiana State University for comparison with DNA of the donor parents. These donors have been used for sheath blight resistance in the South, but also have sheath spot resistance in California. M-206 had no SNP alleles of candidate resistance genes in common with these resistance sources, while 87Y550 had 5 in common, and the breeding lines had 9-10 alleles in common. This confirms our observations that 87Y550 (stem rot resistant line) also has sheath spot resistance, but less than the sheath spot resistant breeding lines. It also confirms that sheath blight resistance is also effective against sheath spot. Several candidate genes were present in all breeding lines, and these may be the most important for transferring disease resistance.

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. Severity in 2010 was higher than most previous years, and even greater in 2011. The disease also affected a greater area than in past years. Significant blast was also present in a few RES fields for the first time. M-104 appears to be more susceptible than other varieties, followed by M-205.

Historically, 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 *Piz* gene) was released in 2005, followed by M-208 (also with *Piz*) in 2006.

Blast infection was found in M-208 fields in 2010 and 2011. DNA tests confirmed that infected plants were M-208 and DNA markers indicated the *Piz* resistance gene was present. UC Riverside researchers found that DNA patterns of all fungi isolated from M-208 are similar to each other (genetically closely related, or of the same lineage) and to the IG1 race found in 1996.

Race determination tests have been conducted at the RES. A new race has been found which is significantly different from IG1. So, even though all isolates appear to be genetically related, the M-208 isolates can infect rice with

Piz and *Pik* resistance genes, while IG1 isolates cannot.

Lines with different blast resistance genes from the M-206 backcross program (see table next column) were screened against the M-208 isolates. Again, lines with *Pik*^{h} and *Piz* genes were susceptible. However, lines with other genes were resistant.

The components of M-208 were also tested individually. They are still resistant to IG1, but not the new race isolated from M-208. It is too early to judge whether *Piz* resistance has been overcome in an epidemiological sense, since frequency of infection in M-208 fields was about 1 in 10000 plants both in 2010 and 2011. The new race may be able to attack scattered M-208 plants (it is virulent), but we do not know if it will severely damage M-208 in the future (what will be the fitness?). Fields of some resistant varieties in the southern US occasionally also have low levels of susceptible plants, but major gene resistance has not been overcome in most cases. In California, it may be difficult to determine whether the blast fungus has overcome *Piz* resistance in subsequent years if environmental conditions are not as favorable to disease as in 2010-11.

IRRI 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 IG1 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 (*Pib, Pik*^{h}*, Pik*^{m}*, Piz*^{5}*, Pi9, Pi40,* and *Pita*^{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, and some lines were entered in 4x6 yield tests in 2011. Lines with additional resistance genes (*Pi1*, *Pi2*, and *Pi33*) were grown for breeder selection in 2011.

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

Marker	Gene
RM224	*Pi1, Pik*^{h}
RM1233	*Pik*^{m}
AP5930F	*Pi2, Piz, Piz*^{5}*, Pi9, Pi40*
RM7102	*Pita*^{2}
RM208	*Pib*
RM331	*Pi33*

Pi40, Pik^h*, Pita*^{2}, and *Pib* genes from the above program have been pyramided into 4 gene lines, and are being advanced for agronomic evaluation. Presence of more than one gene in a variety should prevent rapid loss of resistance when exposed to natural blast fungus populations.

Quarantine Introductions

The building blocks for any breeding program are varieties with traits desirable in commercial production. From time to time, varieties are imported for use in the breeding program. F_1 seed from crosses made with California varieties in Korea for cold tolerance was brought through quarantine this past year using a special USDA/CDFA permit.

This permit allows brown rice to be brought directly to RES for quarantine processing.

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.◆

Rice Research Proposal

Rice research at RES in 2012 will continue toward the primary objective of developing improved rice varieties for California.

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 2011.

Quality

Efforts to identify, select, and improve culinary and milling quality in all grain types will continue to receive major emphasis. Improved cooking evaluation techniques are being used that include use for DNA markers for amylose content, gelatinization temperature, and RVA profiles. The RES quality lab is being renovated to support 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 to develop improved blast resistant varieties will continue. Materials from backcrossing efforts to transfer disease resistance have been transferred to the breeding projects for evaluation. 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 has been discontinued due to concerns about adjacent UC research activities. 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 maturity, synchronous heading, and uniformity of ripening.

Other Areas

The program will continue to look for mutants with herbicide tolerance or resistance as well as characterizing varietal differences in response to rice herbicide for screening purposes.

Cooperative Projects

Cooperative research by the rice breeding program staff with USDA, UC, The Temperate Rice Research Consortium, and others in the area of biotechnology, genetics, quality, agronomy, entomology, plant pathology, and weed control will be continued in 2012. Emphasis will be placed on applied research and more basic studies that may contribute to variety improvement for California.

Rice Research Priorities and Areas of Breeding Research

General Rice Research Objectives of Rice Experiment Station

The primary research objective of RES is the 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
- Disease resistance
- Cold tolerance and seedling vigor
- Early maturity and lodging resistance
- 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

Calrose Type Medium Grains

- Improve Calrose medium grains
- Improve stem rot resistance in medium grains
- Improve blast resistance in medium grain
- Increase yield potential, cold tolerance, and genetic diversity
- Explore opportunities to provide herbicide tolerance

Premium Quality and Short Grains Medium Grains

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

Long Grains

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

Rice Pathology

- Screening and evaluation of advanced breeding lines for blast, stem rot, and sheath spot.
- 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 germplasm introduction and pathology related research

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 2011, fellowships of $2,500 were awarded to Cameron Pittelkow and Whitney Brim-DeForest. A total of 22 fellowships totaling $55,000 have been awarded since 2000.

William Carlson	2000
Nicholas Roncoroni	2001
David P. Cheetham	2002
Jennifer J. Keeling	2002
Kristie J. Pellerin	2003
Michael S. Bosworth	2003
Kristie J. Pellerin	2004
Leslie J. Snyder	2004
Gregory D. Van Dyke	2004
Leslie J. Snyder	2005
Louis G. Boddy	2006
Rebecca S. Bart	2006
Jennifer B. Williams	2007
Mark E. Lundy	2007
Louis G. Boddy	2008
Monika Krupa	2008
Cameron Pittelkow	2009
Charles Joseph Pfyl	2009
Maegen Simmonds	2009
Mark E. Lundy	2010
Cameron Pittelkow	2011
Whitney Brim-DeForest	2011

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
2010 - James R. Erdman
2011 - Peter A. Panton