2015 RICE BREEDING PROGRESS REPORT

CALIFORNIA
COOPERATIVE
RICE
RESEARCH
FOUNDATION

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Rice Experiment Station
P.O. Box 306, Biggs, CA 95917-0306
www.crrf.org ricestation@crrf.org

RICE EXPERIMENT STATION STAFF

Administration

Kent S. McKenzie, Ph.D. .... Director

Plant Breeding

Virgilio C. Andaya, Ph.D. .... Director of Plant Breeding
Farman Jodari, Ph.D. .... Plant Breeder
Stanley Omar PB. Samonte, Ph.D. .... Plant Breeder
Paul L. Sanchez, Ph.D. .... Plant Pathologist
Cynthia B. Andaya, Ph.D. .... Research Scientist

Plant Breeding Support

Matthew A. Calloway .... Breeding Nursery Manager
Baldish K. Deol .... Plant Breeder Assistant
Ravinder Singh Gakhal .... Plant Breeder Assistant
Davinder Singh .... Plant Breeder Assistant
Christopher A. Putz .... Plant Breeder Assistant
Michael J. Lynch .... Plant Breeder Assistant
George B. Yeltatzie, M.S. .... DNA Lab Technician

Field Operations and Maintenance

Burtis M. Jansen .... Field Supervisor
Joseph E. Valencia .... Mechanic and Operator
Randall C. Jones .... Maintenance and Operator
Shane A. Odekirk .... Maintenance and Operator

Clerical and Accounting

Lacey R. Stogsdill .... Administrative Assistant

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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.

The RES scientific professional staff includes a director, director of plant breeding, plant breeders, a plant pathologist and research scientist. Eleven career positions consisting of a, breeding nursery manager, five plant breeding assistants, one DNA lab technician, a field supervisor, one mechanic and field operator, two maintenance and field operators, and one administrative assistants make up the support staff. Approximately 30 seasonal laborers are employed during crucial planting and harvest times.

RES Rice Breeding Program

The RES Rice Breeding Program encompasses 5 research projects. Three rice breeding projects focus on developing adapted varieties for specific grain and market types and are each under the direction of a plant breeder. The rice pathology project supports the breeding projects through screening and evaluating varieties for disease resistance, rice disease research, and quarantine introduction of rice germplasm for variety improvement. The DNA marker lab provides support to all projects. All projects are involved in cooperative studies with other scientists from the UC, USDA, and industry, including off-station field tests, nurseries, quality research, and biotechnology. All breeding program members cooperatively participate in the preparation, planting, maintenance, and harvest of the research nurseries. 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.

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. CCRRF cooperates with UC and USDA under a formal memorandum of understanding. The UC and California Rice Research Board (CRRB) have liaisons to the Board of Directors. CCRRF scientists cooperate with many national and international public institutions and also with private industry. Organization and policy of CCRRF encourages active grower input and participation in RES research direction.

Research Mission and Funding

The primary mission of CCRRF is the development of improved rice varieties and agronomic management systems for the benefit of the California rice growers. The plant breeding program at RES is designed to develop rice varieties of all grain types and market classes with high and stable grain yields and quality that will sustain the profitability of rice with minimum adverse environmental impact. Important breeding objectives include the incorporation of disease resistance, high milling yield, seedling vigor, cold tolerance, early maturity, semidwarf plant type 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 donations from agribusiness and funds from the Rice Research Trust (RRT). The RRT is a tax-exempt trust [501(c)3] established in 1962 to receive tax deductible contributions for support of rice research. RRT has been the primary funding source for capital improvements at RES.

RES Breeding Program is reviewed annually by the Board of Directors, representatives of the UC, and the CRRB. All research is conducted under permits and in compliance with USDA/CDFA regulations and under approved protocols required by the California Rice Certification Act. CCRRF continues to make investments in facilities, equipment and staff to maintain a vibrant and productive rice research program.

Cooperative Research

Cooperative research is an integral part of rice research at RES involving UC and USDA scientists. 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, Placer, Sacramento, Sutter, Yuba), Dr. Luis Espino (Glenn, Colusa, Yolo), and Specialist in Cooperative Extension, Dr. Bruce A. Linquist, (UCD). The information developed from this cooperative research is valuable to the RES Rice Breeding Program and the California rice industry. 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, Georgia Eizenga, Rolfe Bryant, and Ming Chen.

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 2015. Dr. Albert J. Fischer, (professor, Department of Plant Sciences, UCD) and Whitney Brim-DeForest, (Ph.D. student) transferred weed control research to Drs. Kassim Al-Khatib (professor, Department of Plant Sciences, UCD) and Amar Godar, (UCD staff research associate). Drs. Randall Mutters, Bruce Linquist, and Luis Espino, are all doing rice research on 18 acres at RES. They are being supported by a UCD staff research associate at RES, Mr. John Ray Stogsdill. Dr. Larry D. Godfrey, (extension entomologist) and Mr. Kevin Goding, (staff research associate, Department of Entomology), conducted rice insect research. RES does provide technical input and support to the California Rice Commission (CRC).

CCRRF staff began conducting cooperative research with biotechnology companies in 1996 on transgenic rice for California. This was very limited, included participants from the private and public sectors, and 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.

Seed Production and Maintenance

The production and maintenance of foundation seed is an important RES activity. The foundation seed program is a cooperative effort with the California Crop Improvement Association to assure availability of pure, weed free and high quality seed for the benefit of the California rice industry. Forty-seven improved rice varieties have been released since an accelerated research program began in 1969. Foundation seed of 16 rice varieties, 2 experimental increases, and basic seed of one Japanese premium quality variety were produced on 144 acres at RES in 2015. 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.

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 results from the initial 2006 USDA tests and annual foundation and basic seed test from 2007 through 2015 by CRC have been non-detect.

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 10 by 10 ft plots for further screening, evaluation, and seed increase.

7. **Preliminary Yield Tests**. The best small plot entries are grown in replicated 10 by 20 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.

RICE BREEDING PROGRAM

The RES Breeding Program consists of three major rice varietal improvement projects namely: 1) Medium Grains, 2) Short Grains and Premium Quality, and 3) Long Grains. The medium-grains project is working on the development of superior Calrose-type rice varieties with high and stable grain yield, superior grain quality and milling yield, improved seedling vigor, wide adaptability, and with tolerance to cold temperature and resistance to diseases. The short-grains project develops regular short grains as well as those with low amylose content, waxy or sweet rice types, Koshihikari-type premium short grains, M-401-type premium medium grains, and Arborio-type or large-seeded rice. The long-grains project, aside from its emphasis on developing high quality conventional long grain rice, is also developing Jasmine-type, Basmati-type, and aromatic long grain rice to cater to the needs of the domestic specialty market. Each of the breeding projects are under the leadership of a rice breeder and overseen by the Director of Plant Breeding.

The breeding projects are supported by the Rice Pathology Lab through greenhouse and field disease screening and the DNA Marker Laboratory through DNA marker-assisted selection, genetic fingerprinting, and development of mutant populations.

The breeding program as a whole is composed of outstanding technical senior staff with specialized scientific capabilities. Dr. Virgilio C. Andaya is the Director of Plant Breeding whose role is to provide leadership and guidance and build an effective rice breeding team and is in charge of the medium-grains breeding project (see Calrose Medium Grains). Dr. Stanley Omar Samonte is in charge of the short-grains project (see Premium Quality and Short Grains). He is also in charge of overseeing the RES database and the station website, and provides expertise in statistical design and analyses. Dr. Farman Jodari provides leadership of the long-grains project (see Long Grains) and serves as the liaison to the Southern US Breeding Programs. He had been working at RES since 1999 and will be retiring in 2017 after a productive and dedicated service to the Rice Industry in California. Dr. Cynthia Andaya is the research scientist in charge of the marker lab (see DNA Marker Laboratory). She provides leadership in marker-assisted breeding efforts, DNA fingerprinting, genetic mapping of stem rot resistance, and generating mutants for special projects. Dr. Paul Sanchez was hired in June, 2015, as the new plant pathologist in charge of the pathology lab (see Rice Pathology) bringing expertise in rice genomics, wild rice utilization, and genebank management. He overlapped with rice pathologist Mr. Jeff Oster who retired in July 2015 after 30 years of service

RES is owned, funded, and supported by the California rice growers. The rice varieties developed at RES are well-known internationally for their excellent grain quality. RES also collaborates with scientists from the UC, USDA, and the Rice Industry, in conducting on- and/or off-station trials, grain quality studies, and genetic research.

CALROSE MEDIUM GRAINS

Virgilio C. Andaya

Overview

The predominant rice varieties planted in California are medium grains, commercially and internationally known as Calrose rice. The Calrose brand is famous for quality, earning a reputation of being one of the most recognizable brands in the international market, and was awarded the 2015 "World's Best Rice" award during the 7th TRT World Rice Conference in Kuala Lumpur, Malaysia.

The breeding goals in the medium-grains project are to develop varieties with high and stable grain yield, superior milling or head rice yield, excellent grain quality, with tolerance to cold temperature induced blanking, good seedling vigor, and resistance to rice blast and stem rot diseases. Most of the breeding materials such as F_2 populations, progeny rows, and advanced breeding lines are planted at the RES breeding nursery. A cold location nursery in San Joaquin is used to screen for cold tolerance, specifically cold-induced sterility or blanking, to complement refrigerated greenhouse low temperature screening at the station. The most promising selections are planted in the winter nursery in Lihue, HI, for seed increase, generation advance, and additional screening for blanking.

The medium-grains project employs both traditional and marker-based breeding methods. The DNA markers used for marker-assisted selection are mostly microsatellite markers, and effectively used for fingerprinting and purity testing, breeding for blast resistance and grain quality.

Breeding Highlights

Performance of Check Varieties

Commercial medium grain varieties are routinely used as check varieties in preliminary yield trials and UCCE Statewide Tests at the RES location. Included in these tests are varieties still in production in California. M-202 is a 30 year old variety and will no longer be used as check in 2016. Its overall grain yield was around 10% lower compared to newer cultivars. M-206 is widely-grown variety with excellent milling yields, high and stable grain yield, and adaptable even in cold rice areas. M-205 is a variety with high yield potential but has a more restricted area of production. It is very resistant to lodging, and has superior grain and milling yields. M-105 was released in 2011 as an alternative to M-104, both very early varieties. M-105 was noted for superior milling yield. An early blast resistant variety, M-208, carries the *Piz* gene which confers resistance to IG1 but not the IB1 blast pathogen now present in California. Its acreage is limited due to lower yield potential and sensitivity to cold temperature. M-209, a new early variety released in 2015, has high yield potential and bigger grains. It is adapted in areas where M-205 is grown.

Table 1 summarized the overall agronomic and yield performance of the check varieties from pooled data of the three maturity groups of the UCCE SW test in 2015 at the RES location. M-209 registered the highest overall yield of 9610 lbs./acre compared to M-205 with average yield of 9080 lbs./acre, a 5.8%

yield advantage. Both of these varieties registered the best lodging percentage of 3%. As expected, M-202 had the lowest yield among the checks of 8180 lbs./acre, while M-206 remained among the top yielders reaching average yield of 9560 lbs./acre.

The 5-year combined averages of the check varieties from 2011 to 2015 are summarized in Table 2. In the last five years, 2015 was the warmest causing the rice varieties to head about 5 days earlier compared to 2014. The average plant height is shorter but there was higher incidence of lodging. Average grain yield has increased in the past three years, reaching 9330 lbs./acre in 2015.

Table 1. Performance of medium grain varieties used as checks at the RES location of the UCCE Statewide Yield Tests in 2015.

Variety	Grain Yield#	MC at Harvest (%)	SV‡	Days§	Lodging (%)	Height (cm)
M-104	8580	16.0	4.9	71	13	84
M-105	8800	16.9	4.7	75	26	91
M-202	8180	15.8	4.9	79	27	95
M-205	9080	16.7	4.8	81	3	91
M-206	9560	17.3	4.8	76	30	94
M-208	8980	15.9	4.9	78	40	96
M-209	9610	17.4	4.8	79	3	94

Paddy rice yield in lbs./acre at 14% moisture;
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent;
§ Days to 50% heading; MC=Moisture Content

Table 2. Five-year combined averages of medium grain varieties* used as checks at the RES location of the UCCE Statewide Yield Tests.

Year	Grain Yield#	MC at Harvest (%)	SV‡	Days§	Lodging (%)	Height (cm)
2011	9550	17.2	4.8	89	11	100
2012	10290	21.6	4.8	85	6	97
2013	9080	14.6	4.8	84	17	99
2014	9220	16.8	4.9	83	8	95
2015	9330	16.7	4.8	78	20	93

* M-104, M-105, M-202, M-205, M-206, M-208, and M-209;
# Paddy rice yield in lbs./acre at 14% moisture;
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent;
§ Days to 50% heading; MC=Moisture Content

Release of M-209

M-209 (formerly 08Y3269) was approved for release by the CCRRF Board of Directors in early 2015. It is a high yielding, early maturing, semi-dwarf, glabrous, lodging tolerant Calrose-type medium grain.

Table 3 summarized the performance of M-209, M-205 and M-206 for each location of the SW Test based on the pooled data from 2011 to 2015. Five-year average at RES yield test was 10,010 lbs./acre or 2.9% and 4.1% advantage over M-205 and M-206, respectively. Its registered grain yield advantage over M-205 is 3.7%, 6.1%, 3.9%, and 5.5% in Butte, Colusa, West Sutter and East Sutter, respectively. Though it out-yielded M-205 by 17.9% in San Joaquin, M-209 is not recommended for planting in colder rice growing areas. Overall, M-209 is slightly earlier and taller and similar lodging compared to M-205. It is recommended for areas where M-205 is normally grown.

M-209 was grown by seed growers for the first time in 2015. The grain yields on a dry weight basis recorded in their seed production fields were better than expected, with yields ranging from 98 to 108 cwt/acre. This registered seed will be available for planting by the rice growers in 2016.

Table 4 summarized the grain characteristics, milling quality and RVA attributes, disease reaction, and blanking scores of M-209, M-205 and M-206. The milled rice grains of M-209 are heavier and slightly longer compared to M-205 and M-206. The length/width ratio is 2.13, 2.09, and 2.17 for M-209, M-205, and M-206, respectively. Because of the bigger grain size, M-209 is best harvested above 18% grain moisture content; and unlike M-205, M-105, and M-206, milling yield may drop when harvested below that moisture. M-209 is best when harvested around 20% grain moisture. The average milling yield of M-209 is 68/73 (head/total), compared to 67/73 and 69/72 for M-205 and M-206, respectively. The percent chalkiness of M-209 is slightly lower than M-205 and M-206, and is similar in clarity and whiteness to both. Based on the results of the RVA, M-209 has a similar profile as the other medium grains, including the apparent amylose and protein content. Milled rice samples of M-209 were evaluated by milling and marketing organizations for visual, cooked rice, and taste quality and was judged to be superior in grain quality and acceptable to the rice market.

Blanking tests in refrigerated greenhouse at RES for three years (Table 4) showed that M-209 is more susceptible to low temperature induced sterility with score of 16.7% compared to 15.5% for M-205 and 13.1% for M-206. However, the 3-year blanking score in San Joaquin, unseasonably warmer in the past years, is actually lower for M-209 than M-205 and M-206. Nonetheless, M-209 may sustain greater damage from cold temperatures thus not recommended for planting in cooler rice areas of California.

Results indicate that M-209 average reaction to stem rot and aggregate sheath spot was comparable to M-205 but better disease reaction compared to M-206 (Table 4). However, M-209 may be slightly more susceptible to blast compared to M-205 and M-206.

Table 3. Agronomic performance of M-209 compared to M-205 and M-206 per location of the UCCE Statewide Tests from 2011 to 2015.

Location/ County	Variety	Grain Yield#	M-209 Yield Adv. (%)	MC at Harvest (%)	SV‡	Days§	Lodge (%)	Height (cm)
RES Biggs	M-205	9730	2.9	17.7	4.8	86	2	94
	M-206	9620	4.1	17.4	4.8	80	28	97
	M-209	10010		17.6	4.8	85	2	97
Butte	M-205	8870	3.7	21.1	5.0	91	3	98
	M-206	9150	0.5	21.1	5.0	82	27	101
	M-209	9200		21.1	5.0	89	4	99
Colusa	M-205	9450	6.1	19.5	5.0	95	7	98
	M-206	9690	3.5	18.0	5.0	85	25	101
	M-209	10030		18.8	5.0	92	6	101
Yuba	M-205	9450	0.4	21.5	5.0	95	14	103
	M-206	9610	-1.2	19.9	5.0	87	48	105
	M-209	9490		20.6	5.0	92	29	103
Glenn	M-205	8910	0.2	15.6	4.7	94	1	102
	M-206	9090	-1.8	14.3	4.9	84	5	101
	M-209	8930		15.2	4.8	91	1	103
Sutter (West)	M-205	8610	5.5	20.6	5.0	92	50	102
	M-206	9050	0.3	22.3	5.0	84	59	103
	M-209	9080		20.0	5.0	90	50	104
San Joaquin	M-205	7200	17.9	21.8	5.0	114	1	80
	M-206	9450	-10.2	18.0	5.0	101	1	89
	M-209	8490		20.0	5.0	110	1	84
Yolo	M-205	8990	1.6	20.4	5.0	92	45	98
	M-206	9050	0.9	20.4	5.0	86	46	102
	M-209	9130		20.0	5.0	90	40	102
Sutter (East)	M-205	9300	3.9	19.1	5.0	92	12	91
	M-206	9640	0.2	19.5	5.0	84	36	95
	M-209	9660		19.3	5.0	89	11	91

Paddy rice yield in lbs./acre at 14% moisture;
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent;
§ Days to 50% heading; MC=Moisture Content

Table 4. Summary of grain, disease, and blanking performance of M-209 compared to M-206.

Trait	-----Variety-----		
	M-205	M-206	M-209
Grain Trait+			
Paddy, Length (mm)	8.70	8.42	8.81
Width (mm)	3.25	3.26	3.29
1000-seed wt. (g)	30.8	29.8	32.1
Brown, Length (mm)	6.17	6.03	6.32
Width (mm)	2.85	2.84	2.85
1000-seed wt. (g)	24.8	24.1	25.6
Milled, Length (mm)	5.87	5.77	5.99
Width (mm)	2.76	2.76	2.76
1000-seed wt. (g)	22.9	22.2	23.6
Length/Width Ratio	2.13	2.09	2.17
Milling++			
Harvest Moisture (%)	19.6	20.4	20.3
Head rice (%)	67	69	68
Total rice (%)	73	72	73
Chalkiness (%)	8.8	9.3	8.4
Vitreousness	119.3	119.0	119.4
Whiteness	124.7	124.6	124.5
RVA+++			
Peak	270	272	262
Trough	150	148	144
Breakdown	120	125	118
Final Viscosity	260	257	252
Setback	-9.7	-15.4	-9.9
App Amylose Content (%)	16.9	17.3	17.1
Protein (%)	6.4	6.8	6.3
Gel Type	Low	Low	Low
Disease Score#			
Stem rot	4.8	5.4	4.9
Aggregate Sheath Spot	1.9	2.5	1.9
Blast	2.6	2.4	2.8
Blanking Score*			
Greenhouse Blanking (%)	15.5	13.1	16.7
San Joaquin Blanking (%)	5.0	4.8	4.3

+ Mean of 2-year data from 3 field sources

++ Mean of 4-location strip trial test data

+++ Mean of 2-year data, Stem rot score (0-10), 3=all but 1 leaf sheath penetrated, 4=all penetrated, 5=all penetrated+ but not culm, 6=penetration of culm surface layer, 7=25% of culm girdled; Aggregate Sheath (0-4), 0= none of 4 uppermost leaves damaged, 2=bottom 1 of 4 damaged, 3=bottom 2 of 4 damaged; Blast score (0-4), 0=no symptoms, 1=pinhead, 2=<25% leaf area with susceptible, lesions,3=>25% but <75% leaf area with, susceptible lesions, 4= plants dead.

* Mean of 3-year data

Disease Resistance

Rice Blast

Breeding for rice blast resistance in the medium-grains project has received renewed attention in response to the breakdown of blast resistance in M-208 due to the presence of a new blast strain, IB-1. Ten near-isogenic lines (NILs) of M-206, each containing different blast resistance genes from various donors, were developed from marker-assisted backcrossing work initiated in 2005 in the rice pathology project. Some of these NILs were initially tested in small plots for yield at RES and the better ones were later evaluated in SW test for yield performance, and in milling plots for milling quality and grain evaluation. Among the NILs, 12Y113 containing the *Pi-z5* gene and 12Y3097 containing the *Pi-b* gene performed the best and were selected and tested further in the SW test from 2013 to 2015.

Table 5 summarizes the yield and agronomic data from the 2015 yield tests at RES and statewide. Grain yield of 12Y113 ranged from 9590 to 9800 lbs/acre at RES and 9150 to 10,230 lbs/acre in statewide tests. On average, 12Y113's yield advantage over M-208, is about 8% and 7%, at RES and statewide, respectively. Its yield advantage over M-206 is 1.4% at RES and 2.6% statewide. On the other hand, the grain yield of 12Y3097 ranged from 9470 to 9960 lbs./acre at RES and 9000 to 9890 lbs./acre, statewide. Average yield advantage over M-208 was 8% and 4% at RES and statewide, respectively; while yield advantage over M-206 is 1.4% at RES but 0.5% lower yield statewide. The seedling vigor and plant height of 12Y113 is similar to M-206 and heads in between M-206 and M-208. It has a higher tendency to lodge and has a slower grain dry-down rate compared to M-206. 12Y3097 is slightly shorter than M-206 but similar in heading and has a slightly better lodging score. However, it has lower seedling vigor.

Table 6 summarized the milling and grain data taken from samples in milling plots at RES in 2015. The grain attributes of 12Y3097 in terms of chalkiness, seed weight, milling yield and grain dimension is comparable with M-206, though sometimes the grain may be slightly longer and lighter. The grains of 12Y113 are heavier, more plump, but narrower relative to the grains of M-206. One drawback of 12Y113 is the higher percent chalk and low degree of milling, both in total and head rice percentage. For that matter, 12Y113 is dropped for further testing. About 300 lbs. however, will be stored in cold storage.

Stem Rot

The medium-grains project is working with Dr. C. Andaya and Dr. P. Sanchez on mapping the stem rot resistance quantitative trait loci (QTL). Studying the genetics of stem rot resistance has been a very challenging work because of issues in phenotyping or disease screening both in the greenhouse and in the field. Equally challenging is the breeding portion because of the linkage drag and the undesirable agronomic traits associated with the wild species resistance donor, which are oftentimes very hard to break even with several cross and backcrosses.

There were stem rot resistant rice lines isolated during the mapping population development. One of those lines was 14Y3060. Table 7 and 8 summarized the yield, agronomic performance and grain attributes of 14Y3060 compared with the check varieties M-205 and M-206. Though the line appears promising agronomically, the level of resistance is low. Further evaluation will be performed on the material and other lines will be evaluated as well.

Breeding Challenge

Conventional breeding methods alone, to be realistic, will not result in the next significant grain yield jump without using the newest tools in genetics and DNA technology. And even with modern techniques like the use of molecular markers, the challenge of breeding new varieties that combine better grain quality with superior grain yield is enormous, to say the least. Not only that yield and grain quality are both genetically complex, combining two complex traits is a magnitude more difficult than tackling each trait individually, becoming even more challenging if improving seedling vigor and cold tolerance, disease resistance, earliness, or better milling, are added.

The medium-grain project is focused on setting goals that are achievable short term, but keeping sight of more ambitious goals in the long term. These goals can be attained by increasing efficiency in breeding, measuring more traits faster using new equipment and better facilities, and improving nursery and yield plot management. There is no justification to drastically overhaul the breeding procedures, but rather build upon the proven methods that have worked successfully for a long time.

Table 5. Agronomic characteristics of blast resistant (MB) lines 12Y113 and 12Y3097 and the check varieties, M-206 and M-208, in 2015 Statewide Yield Test.

Entry	Type	Grain Yield#		MC at Harvest (%)	SV‡	Days§	Lodge (%)	Height (cm)
		RES	Statewide					
Very Early SW								
12Y113	MB, *Piz5*	9590	9150	20.0	5.0	89	11	94
12Y3097	MB, *Pib*	9470	9000	19.4	4.8	87	3	91
M-206	M	9350	9180	19.5	5.0	87	4	94
M-208	MB, *Piz*	9090	8780	18.5	5.0	90	6	94
Early SW								
12Y113	MB, *Piz5*	9800	10230	19.2	4.9	82	54	102
12Y3097	MB, *Pib*	9960	9890	18.3	4.6	81	26	99
M-206	M	9620	9700	18.8	4.9	80	32	99
M-208	MB, *Piz*	8850	9330	17.0	4.9	85	35	102
Intermediate-Late SW								
12Y113	MB, *Piz5*	9680	9910	15.1	4.9	79	1	99
12Y3097	MB, *Pib*	9650	9500	14.9	4.8	78	7	97
M-206	M	9710	9660	14.8	5.0	77	4	99
M-208	MB, *Piz*	8990	9200	14.4	5.0	80	19	99

Paddy rice yield in lbs./acre at 14% moisture;‡ SV = seedling vigor score, where 1 = poor and 5 = excellent;
§ Days to 50% heading; MC=Moisture Content; CV=Coefficient of Variation; LSD=Least Significant Difference

Table 6. Milling and grain characteristics of 12Y113, 12Y3097, M-206 and M-208.

Entry	MC at Harvest (%)	H/T*	%Chalk	Length (mm)	Width (mm)	LW Ratio	1000-seed wt.
12Y113	21.9	63/69	19.6	5.78	2.65	2.18	22.3
12Y3097	19.2	66/71	16.7	5.81	2.55	2.28	21.2
M-206	20.3	64/70	16.3	5.77	2.56	2.25	21.2
M-208	19.1	66/71	13.3	5.99	2.58	2.32	23.7

*Head Rice/Total Rice; MC=moisture content

Table 7. Performance of stem rot resistant line, 14Y3060, compared to M-205 and M-206 in preliminary yield test at RES from 2013 to 2015.

ID	Grain Yield#	Days§	SV‡	Lodge (%)	Height (cm)	Stem Rot Score+
Overall Mean, 2013-2015						
14Y3060	11010	81	4.8	5	94	5.0
M-205	10480	87	4.8	4	89	5.2
M-206	10250	78	4.9	45	94	5.8

Paddy rice yield in lbs./acre at 14% moisture;
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent;
§ Days to 50% heading; MC=Moisture Content
+ Stem rot score where 0=no damage, 10=all plants killed

Table 8. Milling yield and milled grain characteristics of 14Y3060 compared to M-205 and M-206 in 2015 milling plots at RES.

Entry	MC at Harvest (%)	H/T*	%Chalk	Length (mm)	Width (mm)	LW Ratio	1000 wt. #
14Y3060	18.4	65/71	11.1	5.68	2.58	2.20	21.40
M-206	17.2	62/71	18.5	5.77	2.60	2.22	21.50
M-205	18.2	60/69	17.3	5.91	2.54	2.33	21.70

*Head Rice/Total Rice; MC=moisture content; # Milled 1000 wt. in g.

PREMIUM QUALITY AND SHORT-GRAINS BREEDING PROJECT

Stanley Omar PB. Samonte

Introduction

The Premium Quality and Short-grains Breeding Project encompasses the varietal improvement of the following types:

- Short grain, conventional (SG)
- Short grain, low amylose (SLA)
- Short grain, waxy (SWX)
- Short grain, premium quality (SPQ)
- Medium grain, premium quality (MPQ), and
- Arborio or bold grain (BG).

All new lines are bred and selected for improved and stable grain yield and yield-related traits, milling and cooking quality, reduced delay in maturity and blanking due to cold temperature, lodging resistance, very early to early and uniform maturity, short flowering duration, and resistance to diseases (stem rot, aggregate sheath spot, and blast). In addition, specific trait parameters are required to qualify a line into a specific grain type. Experimental lines in nurseries and yield tests are compared against check varieties, which include S-102 for SG types, Calamylow-201 (CA-201) for SLAs, Calmochi-101 and 203 (CM-101 and CM-203) for SWXs, Calhikari-202 (CH-202) and Koshihikari for SPQs, M-402 and M-401 for MPQs, and 87Y235 for BGs. Selected lines show improvements over their respective checks.

In 2015, major nurseries and tests conducted included:

- Crossing Nursery (2014-2015 Winter and 2015 Summer)
- F_1 Nursery (2014-2015 and 2015-2016 Hawaii, 2015 Summer)
- F_2 Population Nursery (2015 Summer at RES and San Joaquin)
- F_3 to F_4 Nursery (2015 Summer)
- F_5 Nursery (2014-2015 and 2015-2016 Hawaii Winter, 2015 RES)
- 10 x 10 Yield Test (2015 RES)
- Preliminary Yield (PY) Test (2015 RES)
- Statewide (SW) Yield Tests (2015 at multi-locations)
- Cooking Strip Tests (2015 Summer)
- Milling Yield Tests (2015 Summer)
- Cold Tolerance Tests (2015 San Joaquin and 2015 Greenhouse).

Collaborations were conducted with pathologists Jeff Oster (until June 2015) and Dr. Paul Sanchez (to determine the reactions of rice lines that were entered into SW and PY tests to stem rot, aggregate sheath spot, and blast) and with Dr. Cynthia Andaya (to determine blast resistant F_5 plants through marker-assisted selection).

Waxy Short Grains

The Rice Experiment Station released Calmochi-203, formerly designated as 09Y2141, as a new variety in 2015 (Fig. 1). It is a stable, high yielding, semi-dwarf, early-maturing, glabrous, waxy, short grain rice. Prior to its varietal release, CM-203 had significantly higher grain yields than CM-101 in all 38 SW test environments from 2010 to 2014. Averaged across environments, grain yield was 9650 lbs./acre for CM-203 and 7590 lbs./acre for CM-101, for a 27% yield advantage. Further comparisons with CM-101 indicated that CM-203 was similar in seedling vigor, taller by about 5 cm, it required one more day to reach heading and 11 more days to reach maturity (20% MC), and it lodged slightly more. CM-203 had higher head rice percentages (65 vs. 63%), larger grain size dimensions, heavier 1000-grain weights, and lower viscosity than CM-101. Blanking, based on the San Joaquin Trials, was about 3% higher in CM-203 than CM-101. A detailed comparison of CM-101 and CM-203 (09Y2141) conducted from 2010 to 2014 is presented in the 2014 Rice Breeding Progress Report that is available online at the Station's www.crrf.org website.

In SW and milling tests conducted in 2015, CM-203 continued to show its superior patterns of trait parameters that it had established in the previous years. It yielded significantly higher than CM-101 in all SW test locations (Fig. 2). Grain yields, averaged across locations, were 10,060 lbs./acre for CM-203 and 7660 lbs./acre for CM-101, which was a 31% yield advantage for CM-203. Both varieties showed equally high SV ratings (Table 9). Compared to CM-101, CM-203 headed a day later, it was taller, lodged less, had similar low blanking percentages at San Joaquin, and had higher head rice percentage at 69%.

Premium Quality Short Grains

Calhikari-202, which was released in 2012, has continued to show its advantages over Koshihikari and CH-201 (released in 1999) in yield, agronomic traits, quality, and taste. In the SW Tests from 2010 to 2015, which included 63 test environments, CH-202 had a 6-year yield average of 8520 lbs./acre and a 4.3% yield advantage over CH-201, which averaged 8,170 lbs./acre (Fig. 3). When compared to Koshihikari in 2015, CH-202 had a 57% yield advantage, lower seedling vigor, earlier heading (14 days earlier), 53% less lodging, and higher head rice percentage (2% higher at 69%). CH-202 was shorter in plant height by 27 cm and had 30% lower lodging, despite is higher yield.

In premium quality short grain types, lower head rice protein concentration is associated with better taste rating. Head rice samples from milling tests in 2013, 2014, and 2015 showed that CH-202 had lower protein concentrations and higher Satake Taste Analyzer ratings than Koshihikari.

In 2015, four SPQ lines were evaluated in the SW Tests. SPQ 13Y2031, which was evaluated in the very early maturing group of SW Tests for the first time, was the top selection. Its average grain yield was 9400 lbs./acre, which was 15% and 19% higher than CH-201 and CH-202, respectively. In comparison with CH-202, 13Y2031 had higher seedling vigor, later heading by 3 days, taller height by 3 cm, and less 25% less lodging. It had a 64% head rice percentage, which was similar to CH-201 (63%), but lower than CH-202 (69%). Average Satake Taste Analyzer scores for 13Y2031, CH-202, and Koshihikari, were 83, 81, and 79%, respectively. SPQ 13Y2031 has glabrous seed (smooth hull), unlike CH-202, CH-201, and Koshihikari, which are pubescent. SPQ 13Y2031 will be advanced to the Experimental Seed Increase Nursery in 2016.

Premium Quality Medium Grains

There were nine MPQ lines entered in the SW Tests in 2015, and 12Y2175 and 11Y2183 were the outstanding selections. Both lines produced higher grain yields than the standard MPQ varieties M-402 (Fig. 4) and M-401.

Based on six SW test locations, 12Y2175 yielded an average of 10,120 lbs./acre while 11Y2183 averaged 9,540 lbs./acre Yield advantages of 12Y2175 over M-402 and M-401 were 30 and 9%, respectively, while 11Y2183 had yield advantages of 23 and 2%, respectively. Trait parameters of M-402, M-401, 11Y2183, and 12Y2175 estimated from yield and milling tests conducted in 2015 are shown in Table 10. M-401, M-402, and 12Y2175 exhibited high SV ratings (4.95, 4.95, and 4.90, respectively, in a 1-5 rating scale), unlike 11Y2183 with its low 4.65 rating. Early heading is essential in saving irrigation water, and both 12Y2175 and 11Y2183 headed at least 9 days earlier than the MPQ varieties. Furthermore, 11Y2183 and 12Y2175 had higher head rice percentages than the MPQ varieties. However, because of its higher grain yield and SV rating, 12Y2175 replaces 11Y2183 as the top MPQ line and it will be entered into the Experimental Seed Increase Nursery in 2016.

Conventional Short Grains

Five conventional short-grain lines were evaluated in the SW Tests in 2015, with 10Y2043 at the forefront and being evaluated in both the very early and the early maturity groups. Grain yield of 10Y2043 (averaged across 8 test locations in 2015) was 10,700 lbs./acre, which was 19% higher than S-102 (Fig. 5). Its 5-year average from 2011 to 2015 was 10,110 lbs./acre, which was 18% higher than S-102. Compared to S-102 in 2015, 10Y2043 had slightly lower seedling vigor, it headed 4 days later, was 4 cm shorter in plant height, and had lower chalky area percentage (Table 11). Head rice percentage of S-102 was higher than that of 10Y2043 in 2015, but their 3-year average across 2013 to 2015 was 65% for 10Y2043 and 64% for S-102. Furthermore, 10Y2043 was glabrous (smooth hull), unlike S-102 which was pubescent. SG 10Y2043 will be advanced to the Experimental Seed Increase Nursery in 2016.

Low Amylose Short Grains

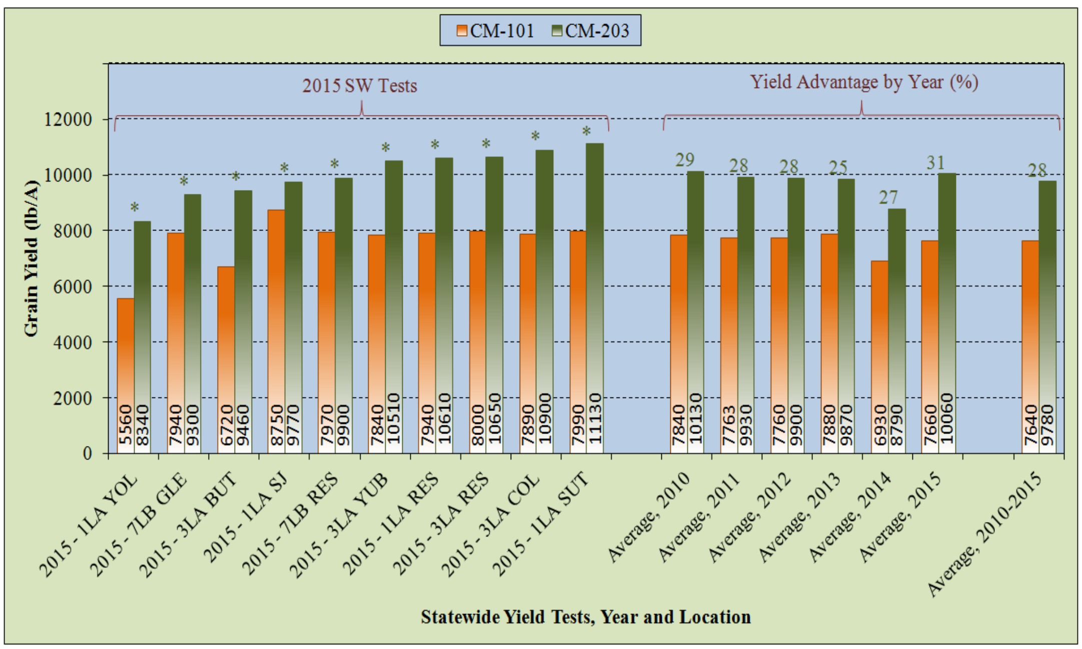
In 2015, 14Y2110 was the lone SLA entry in the SW Tests. Compared with the pubescent CA-201, the glabrous 14Y2110 had the following advantages: higher grain yield (8640 lbs./acre, 45% yield advantage); lower panicle blanking percentage in San Joaquin (4 vs. 29%); and lower lodging (1 vs. 21%). CA-201 and 14Y2110 had similar SV ratings and head rice percentages. However, 14Y2110 had the unattractive trait of heading 9 days later than CA-201.

Arborio or Bold Grains

RES has not yet released a bold-grain variety, although it has released 87Y235 as a germplasm in 1994. The development of new BG lines is a first step to promote interest in this type of rice. In 2015, the most advanced BG lines were being evaluated in the Preliminary Yield Tests. The top BG line 15Y2002 is glabrous and is being evaluated for grain yield, quality, and agronomic performance data to determine its advancement into the SW Tests in 2016.

Fig. 1. Waxy short grains Calmochi-101 and Calmochi-203, released by the Rice Experiment Station, at grain filling stage.

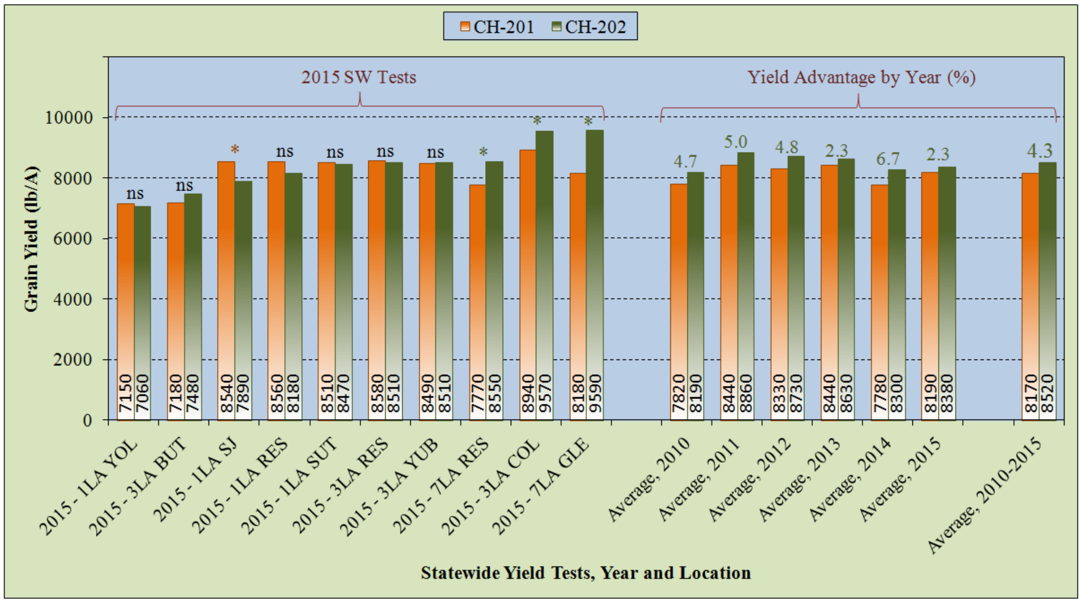
Fig. 2. Grain yields of waxy short grains Calmochi-101 and Calmochi-203 in Statewide Tests in 2010 to 2015.



* - Significant difference at the 5% level.

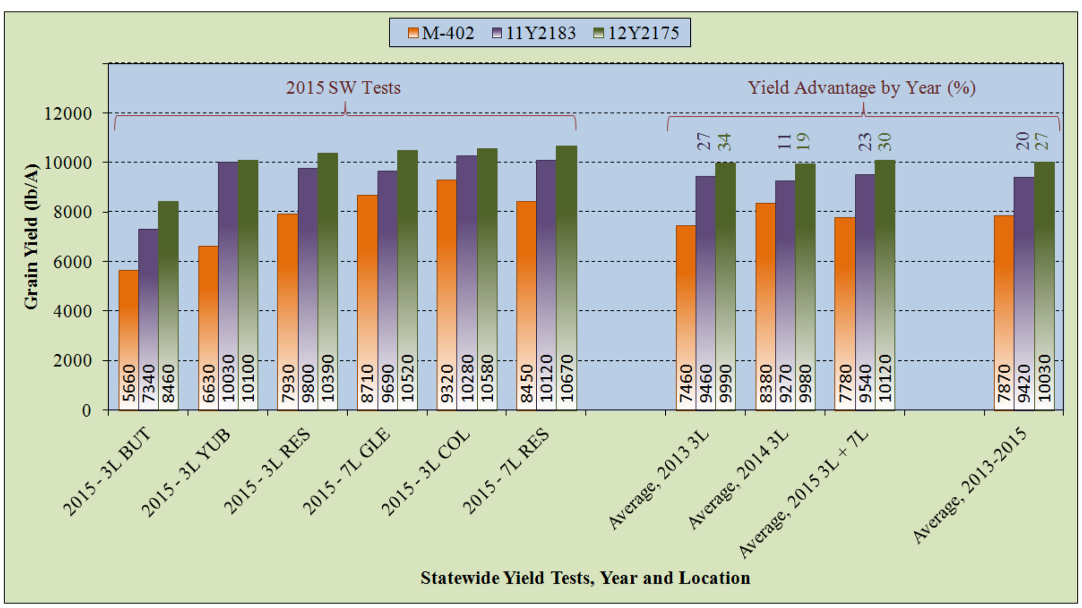
Abbrev.: 1LA – very early maturing, advanced group; 3LA – early maturing, advanced group; 7LA – intermediate/late maturing, advanced group; BUT – Butte County; COL – Colusa County; GLE – Glenn County; RES – Rice Experiment Station; SJ – San Joaquin County; SUT – Sutter County; YOL – Yolo County; YUB – Yuba County

Fig. 3. Grain yields of premium quality short grains Calhikari-201 and Calhikari-202 in Statewide Tests in 2010 to 2015.



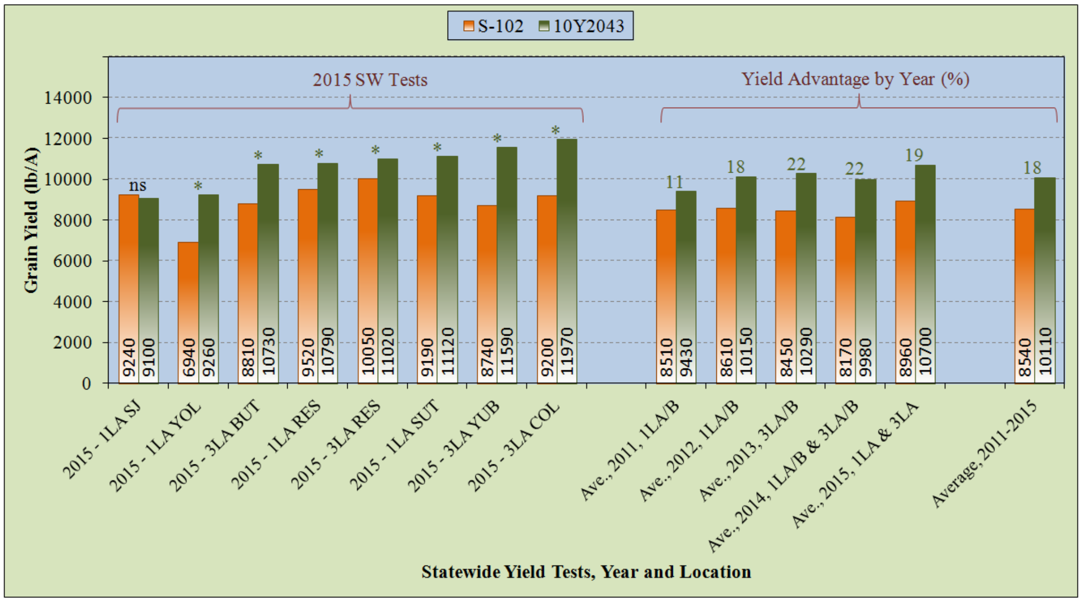
* - Significant difference at the 5% level.
ns - Non-significant difference at the 5% level.
Abbrev.: 1LA – very early maturing, advanced group; 3LA – early maturing, advanced group; 7LA – intermediate/late maturing, advanced group; BUT – Butte County; COL – Colusa County; GLE – Glenn County; RES – Rice Experiment Station; SJ – San Joaquin County; SUT – Sutter County; YOL – Yolo County; YUB – Yuba County

Fig. 4. Grain yields of premium quality medium grains M-402, 11Y2183, and 12Y2175 in Statewide Tests in 2013 to 2015.



Abbrev.: 3L – early maturing group; 7L – intermediate/late maturing group; BUT – Butte County; COL – Colusa County; GLE – Glenn County; RES – Rice Experiment Station; YUB – Yuba County

Fig. 5. Grain yields of short grains S-102 and 10Y2043 in Statewide Tests in 2011 to 2015.



* - Significant difference at the 5% level.
ns - Non-significant difference at the 5% level.
Abbrev.: 1LA/B – very early maturing, advanced group/preliminary group; 3LA/B – early maturing, advanced group/preliminary group; SJ – San Joaquin County; YOL – Yolo County; BUT – Butte County; RES – Rice Experiment Station; SUT – Sutter County; YUB – Yuba County; COL – Colusa County

Table 9. Trait parameters of waxy short grains Calmochi-101 and Calmochi-203 estimated from yield and milling tests in 2015.

Trait	Waxy Short Grain Variety	
	CM-203	CM-101
Seedling Vigor (1-5 rating) †	5	5
Heading (d) †	81	80
Height (cm) †	100	94
Lodging (%) †	35	44
Blanking at San Joaquin (%)	5	6
Head Rice Percentage (%) ‡	69	66

† Source: SW 1L, 3L, and 7L – Very Early, Early, and Intermediate/Late Maturity Groups of the Statewide Tests
‡ Source: Milling Yield Test

Table 10. Trait parameters of medium premium quality (MPQ) rice varieties and lines estimated from yield and milling tests in 2015.

Trait	MPQ Variety or Line			
	M-402	M-401	11Y2183	12Y2175
Seedling Vigor (1-5 rating) †	4.95	4.95	4.65	4.9
Heading (d) †	102	107	88	84
Height (cm) †	94	104	97	104
Lodging (%) †	1	1	1	1
Blanking at San Joaquin (%)	5	9	8	7
Head Rice Percentage (%) ‡	63	57	65	65
Chalky area (%) ‡	10	13	15	14

† Source: SW 7L – Intermediate/Late Maturity Group of the Statewide Tests
‡ Source: Milling Yield Test and Cooking Source Plots

Table 11. Trait parameters of short grain rice S-102 and 10Y2043 estimated from yield and milling tests in 2015.

Trait	Short Grain Variety or Line	
	S-102	10Y2043
Seedling Vigor (1-5 rating) †	5.0	4.8
Heading (d) †	81	85
Height (cm) †	95	91
Lodging (%) †	40	47
Blanking at San Joaquin (%)	4	8
Head Rice Percentage (%) ‡	69	64
Chalky area (%) ‡	20	14

† Source: SW 1L and 3L – Statewide Very Early and Early Maturity Groups
‡ Source: Milling Yield Test

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 overall 2015 statewide test locations, excluding San Joaquin, averaged 9420 lbs./acre (Tables 12 and 13). Average yield for M-206 within the same tests was 9330 lbs./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 2006–2015 seasons was 62%. Average kernel length of L-206 is 7.1 mm.

12Y20

Experimental line 12Y20 is a new conventional long grain selection that has shown grain yield and milling yield advantages over L-206. This line is being proposed for release as L-207. Yield performance and quality characteristics data obtained in 2015 supported the results of testing in 2012 and 2013. 12Y20 is a high yielding, intermediate height, and early maturing selection with Southern long-grain cooking quality. It is 3 to 4 days later and 6 in. taller than L-206. Average grain yield in very early statewide tests during 2012, 2013, and 2015 was 8% higher than L-206 (Table 12). In 2015 it was also tested in early and intermediate maturity locations, where it showed 6 and 4% higher yields respectively over L-206 (Table 13). Of special importance is the performance of 12Y20 at Yolo test location, during 2012-2015, where it compared favorably with L-206 and M-206. Cooler conditions at Yolo site have been a challenge for many long-grain selections and varieties in the past. Consequently, areas of adaptation for it include most areas excluding San Joaquin. Agronomic characteristics of 12Y20 are listed in Table 14.

Despite taller plant heights, no significant lodging has been observed. Milling yields at sequential harvest moistures (Table 15) were tested during 2012 to 2015. Within a span of 7 to 10 days, head rice yields remained stable ranging between 63 to 67%.

Cooking quality of 12Y20 as tested by USDA Rice quality lab, is similar to Southern long grains, with intermediate amylose, intermediate gel type, and moderate RVA profile (Table 16). In 2012 and 2013 tests, 12Y20 showed significantly lower stem rot disease, compared with L-206 (Table 17). No significant differences were observed, however, during the following years. Aggregate sheath spot resistance was also tested at RES greenhouse facility during 2012–2014. Significantly higher resistance was observed in 2013 and 2014. Limited foundation seed was produced in 2015.

Agronomic and milling characteristics of other conventional experimental lines with improved quality traits are listed in Table 18. Experimental line 14Y1006, tested in very early and early maturity state-wide locations, performed significantly better than check varieties.

Table 12. Yield performance of Experimental 12Y20, L-206 and M-206 at very early statewide test locations, excluding San Joaquin, during 2012, 2013, and 2015.

Year	Entry	RES	Sutter	Yolo	Mean	Yield Adv. L-206
2015	12Y20	9740	10880	8670	9760	11%
	L-206	8910	9820	7740	8820	
	M206	9350	9900	7490	8910	
2013	12Y20	9880	10350	10490	10240	7%
	L-206	9970	9700	9000	9560	
	M206	8610	9710	9790	9370	
2012	12Y20	10290	10040	10710	10350	8%
	L206	10020	9570	9060	9550	
	M206	10420	9320	9900	9880	

Table 13. Yield performance of Experimental 12Y20 as compared to L-206 and M-206 at Early and Intermediate statewide test locations during 2015.

	Entry	RES	Colusa	Yuba	Butte	Mean	Yield Adv./L-206
Early	12Y20	10550	11160	10480	9130	10330	6%
	L-206	9360	9940	9840	9810	9740	
	M206	9620	9850	9940	9370	9700	
	ID	RES	Glenn	Mean			Yield Adv./L-206
Intermediate	12Y20	9450	10830	10140			4%
	L-206	9520	9910	9710			
	M206	9120	9620	9370			

Table 14. Agronomic characteristics of Experimental 12Y20 at statewide test locations averaged over 2012-13, and 15. (Colusa, Yuba, Butte, and Glenn are 2015 data only)

Trait	Entry	Avg.	RES	Sutter	Yolo	Colusa	Yuba	Butte	Glenn
Seedling	12Y20	5.0	4.9	5.0	5.0	5.0	4.8	5.0	5.0
Vigor	L206	4.9	4.8	4.9	4.5	5.0	5.0	5.0	5.0
Score	M206	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0
Days to	12Y20	85	82	88	86	83	89	87	83
50%	L206	81	78	84	84	82	82	78	78
Heading	M206	81	79	86	82	83	83	78	79
Plant	12Y20	40	39	38	41	40	40	42	42
Height	L206	34	33	32	34	35	36	37	34
(in.)	M206	39	38	36	39	40	40	40	40
Lodging	12Y20	2	3	0	4	0	6	0	0
%	L206	11	2	3	0	0	71	0	0
	M206	18	30	17	24	0	48	8	0

Table 15. Milling yield and harvest moisture (in parentheses) comparisons in sequential harvests of 12Y20 and L-206 during 2012-2015.

Year	Entry	% Head Rice (% Harvest Moisture)			
2015		18-Sep	22-Sep	25-Sep	29-Sep
	L206	59 (21)	62 (18)	59 (17)	
	12Y20		63 (18)	61 (15)	67 (14)
2013		13-Sep	17-Sep	20-Sep	24-Sep
	L206	59 (17)	57 (15)	54 (15)	51 (16)
	12Y20	63 (17)	63 (16)	60 (14)	59 (15)
2012		1-Oct	6-Oct	10-Oct	15-Oct
	L206	60 (20)	59 (19)	62 (17)	61 (15)
	12Y20	60 (19)	63 (19)	64 (18)	66 (17)

Table 16. Cooking quality and grain dimensions of 12Y20 as compared with L-206 and commercial brand rice

			RVA				Kernel			
Entry	Amylose	Alk.	Peak	Trough	Final Visc	Setback	Length	Width	Area	100 wt (g)
12Y20	23.2	4	251	130	265	14	7.12	2.05	11.72	1.9
L206	22.3	3.7	267	148	293	26	7.04	2.10	11.68	1.9
Mahatma Brand	22.6	4	275	152	290	15	6.59	2.21	11.77	2.0

Table 17. Stem Rot and Aggregate sheath spot resistance of 12Y20 compared with L-206. (2012 – 2015) (Lower ratings indicate higher resistance).

Entry	Stem Rot				--Aggregate Sheath Spot--		
Year	2012	2013	2014	2015	2012	2013	2014
12Y20	4.6	5.3	4.1	4.5	2.2	1.3	2.1
L206	5.2*	7*	4.6	5.5	2.2	2.1*	3.1*
LSD 0.05	0.6	0.7	NS	NS	0.4	0.4	0.4
Mean	4.8	6	4.6	3.7	2.2	1.8	1.6

* Significantly higher at the 0.05 level.

Table 18. Performance of selected conventional long-grain entries as compared with standard varieties in 2015 yield and milling tests.

Entry	Type†	Identity	Yield‡		Head Rice§
			Statewide	RES	(%)
Very Early Statewide					
18	L	14Y1006	9620	10290	65
20	L	14Y1104	9170	9120	63
1	L	L-206	8720	8910	62
13	M	M-206	9180	9350	
Early Statewide					
62	L	14Y1006	11170	11090	65
88	L	14Y1104	10070	9560	63
61	L	L-206	9740	9360	62
74	M	M-206	9700	9620	
Very Early Preliminary					
1021	L	15Y1021	--	11450	62
1070	L	15Y1070	--	11520	62
1001	L	L-206	--	10800	60
Early Preliminary					
1102	L	15Y1102	--	11830	58
1154	L	15Y1154	--	11720	61
1082	L	L-206	--	10340	60

†L= conventional long grain type, and M=medium grain.
‡ Paddy rice yield in lbs./acre at 14% moisture.
§Head rice yields are from solid seeded stands for statewide and preliminary yield tests.

Specialty Long Grains

Expanded breeding efforts in specialty long grain area continued in 2015. Specialty types occupy 50% of the long grain nursery and include Jasmine, Basmati, and conventional aromatics such as A-201. Agronomic and quality of selected specialty lines are shown in Table 19.

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 2015 early tests were 6690 lbs./acre as compared to 9730 for L-206 (Table 19).

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%.

In 2015 several basmati lines were tested in statewide trials (Tables 19, and 26-31). These selections were advanced through screening for several basmati quality attributes. Cooking quality evaluations of these lines in earlier generations has shown considerable quality advantages over Calmati-202. 14Y149 is an early basmati line with a significantly closer amylographic profile to imported basmati types (Table 31). Quality evaluations are currently underway to determine aging effects on elongation and texture of cooked grains of basmati types. This includes two advanced selections 11Y158 and 10Y1199 that were tested previously (RES annual reports 2012 and 2013). Primary advantages of these lines 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. A stronger RVA profile is expected to improve cooked grain texture resulting in more flakey cooked rice as is the case with imported basmati. Small experiments are being conducted to identify harvesting and processing procedures that can enhance milling yield and cooking quality. These factors include harvest moisture, drying rate, and milling degree. Efforts are underway to continue to improve both grain and milling yields without losing any basmati quality attributes.

Efforts also continued in 2015 to develop jasmine types through pedigree and mutation breeding. Crosses and backcrosses were made with jasmine type material from various sources including Southern US 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. Pedigree and mutation breeding efforts are generating breeding lines with diverse and unique quality combinations. Primary objective is to incorporate imported jasmine quality into adapted breeding lines.

In 2015, 8 jasmine type selections were tested in the UCCE Statewide Yield Tests and 45 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. Two jasmine type entries 15Y84 and 15Y136 have shown good jasmine quality attributes and acceptable agronomic characteristics (Table 19). Advanced experimental line 11Y106 is being discontinued from further testing due to blanking susceptibility as well as excessive aroma content.

Efforts in the area of conventional aromatics also continued in 2015. One conventional aromatic type, 12Y1022 was tested in early statewide tests (Table 29). A considerable number of aromatic types are being generated from the populations that were originally intended for jasmine or basmati quality types.

A-202

A-202 is a conventional aromatic variety that was released in January 2014. It is intended as a replacement for A-301. Compared to A-301, A-202 is 9 days earlier, 4 in. taller, and has a significantly higher seedling vigor score. Average yield overall for early and intermediate locations in 2015 was 9180 for A-202 and 9730 for L-206 (Table 19). Three year average head rice yield of A-202 is 61%. A-202, similar to A-301, is susceptible to cold induced blanking and therefore not recommended for cold locations. Aroma volatilization of A-202 is slightly less during cooking process. Flavor sensory, however is similar to A-301. Milled kernels of A-202 are slightly bolder than A-301, with average length of 7.36 mm and average width of 2.27 mm. Amylose content, gelatinization temperature type and RVA profile of is typical conventional long-grain type similar to A-301 and L-206. Subjective evaluations of cooked grain texture indicate that A-202 is slightly softer than standard variety, L-206.Areas of adaptation for A-202 include Butte, Colusa, Yuba, Glenn, and Sutter counties.

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 2015, 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.

Disease Resistance

SR resistance originating from *Oryza rufipogon* continues to be incorporated into an increasing number of high yielding long-grain lines. In 2015, 2 entries were tested in statewide tests and 18 in preliminary tests with a range of SR resistance. Performance of a selected number of these lines is shown in UCCE Statewide Yield Tests (Tables 27 and 29). 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.

Table 19. Performance of selected jasmine and basmati type long-grain entries in 2015 Statewide Yield and RES milling tests.

					Yield (in lbs./acre at 14% moisture)							
					-------------Early-------------				--Intermediate-			
Entry	Type	SV†	DH§	HT‡	RES	Butte	Colusa	Yuba	RES	Glenn	Avg.	HR¶
L-206	L	4.7	80	35	9360	9810	9940	9840	9520	9910	9730	62
A-202	A	4.9	85	37	8340	9220	9510	9320	8840	9860	9180	60
15Y84	J	4.9	86	35	9560	10470	10800	10450	-	-	10320	60
15Y136	J	4.9	82	39	-	-	-	-	9290	9340	9320	64
CT-202	B	4.8	86	35	6790	6370	6660	6950			6690	57
14Y156	B	4.8	87	43					8410	6990	7700	46

† SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Number of days to 50% heading.
‡ Height in cm.
¶ Head rice yields are from solid seeded stands for all entries.

RICE PATHOLOGY

Paul L. Sanchez

Breeding for disease resistance is a cooperative effort between the rice breeders and pathologist. Pathologist produces disease inoculum, maintains a disease nursery, identifies resistant germplasm, and screens statewide and preliminary trial breeding lines and varieties (about 3000 rows) for stem rot (SR) resistance in the field and aggregate sheath spot (ASS) and blast (BL) in the greenhouse.

Since 2005, the immediate backcross program involved screening entries for BL, SR and ASS. Advancing generations from those crosses have been screened for both SR and ASS resistance (439 rows in the field plus greenhouse ASS screening).

Surviving materials have been stored for future reference. In addition, early generation materials derived from breeder's crosses are cycled through the disease nursery to identify and verify disease resistant lines (about 3726 rows). Intense selection pressure is applied for important agronomic traits because sources of disease resistance have a number of undesirable characteristics.

Stem rot resistance has been derived from wild rice species, *O. rufipogon* (IRRI Acc. No. 100912). The source of SR resistance also confers aggregate and bordered sheath spot (ASS) resistance. Conversely, the sources of ASS resistance also seem to confer resistance in some RES germplasm materials (Oster, J. unpublished data). Plants exhibiting resistance to SR will be cross-screened against ASS to combine resistance to ASS and SR. Further greenhouse and field evaluation is underway to confirm SR and ASS resistance and understand the mechanism of damages in selected RES breeding lines.

A few crosses were made to generate materials with both SR and blast resistance. Generations were advanced with blast and SR screening done in alternate generations. ASS screening was also performed on the purified lines. The RES DNA laboratory, headed by Dr. C.B. Andaya is using molecular markers to evaluate parental and advanced lines with blast resistance genes.

Stem Rot

Screening for SR resistance in inoculated nurseries and greenhouses usually begins in F_3 generation for materials provided by the breeders. Resistant germplasm often has low seedling vigor, and is low tillering, susceptible to blanking, and late maturing. Only a small percentage of the lines screened show higher levels of SR resistance than current varieties. The SR resistant line, 14Y3060, was found high yielding in preliminary yield plots. However, there are still some grain quality issues in SR resistance breeding. About 6428 rows were screened in the 2015 field SR nursery.

This year, 2700 rows in the stem rot nursery were drill seeded. This resulted in less seed drift, an establishment of a more uniform stand, and allowed the use of higher nitrogen without inducing lodging. Increased nitrogen results in greater disease severity and better screening. However, aerial nitrogen application was neither uniform nor at the desired rate. This resulted in poor screening results. A new planting method and screening evaluation will be used in 2016.

Promising long and short grain resistant lines have emerged. In 2013, some high yielding medium grain lines were identified, but resistance was not confirmed in some of them in 2015. As in the past, some lines (derived from all donor parents) again showed ASS resistance equivalent to that found in ASS donor parents.

In addition, 660 BC_3F_5 rows of a population established for mapping and fine mapping of SR resistance genes from *Oryza rufipogon* (originally identified in a BC_1F_5 mapping population) were evaluated for SR resistance in the field at two sites at RES. Some materials identified as resistant in 2014 were again resistant in plots and rows, but many others gave inconsistent scores. The inconsistency in resistance scores could be attributed to lack of nursery uniformity. Fine mapping populations should not be planted in tiers running the length of the field, but rather blocked in groups with tiers perpendicular to the length of the field. In addition, the first 50 feet of the field adjacent to the water inlet should be avoided. Mapping populations should be solid seeded as well as row seeded in the future. Once SR resistance genes are identified and mapped, the need for space-consuming solid seeding could be reduced.

Variations in stem rot ratings in 2015 were observed between and among lines in the mapping population. Intensive phenotypic evaluation will be conducted in 2016 under controlled environment conditions inside the greenhouse to confirm the degree of susceptibility and resistance of selected lines that were evaluated in different field locations in California. Aside from plant maturity of each entry, environmental factors that affect the SR disease rating such as: amount of N application, amount of SR inoculum (*sclerotia*) applied per plant, and timing of inoculation, will be given greater consideration in the evaluation. Increasing the amount of inoculum beyond the minimum 200 *sclerotia* per plant will be applied to confirm SR resistance and susceptibility of each plant.

In general, very early maturing plants were found to be more susceptible to SR than late maturing plants under field conditions. Very early maturing and tall plant entries were more prone to stem disintegration and lodging, thereby reducing yield and making mechanical harvesting difficult in the field.

A modified stem rot rating scale and scoring system will be used for SR phenotyping in 2016 (Table 20). The new scoring system will allow us to simplify the phenotyping and will aid in identifying lines with SR resistance gene.

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

The combined SR phenotypic and genotypic data will allow us to identify and map the gene(s) or QTLs controlling SR resistance in the mapping population.

Table 20. Modified stem rot rating scale and scoring system.

Old SR Scale	SR Severity of Damage	New SR Scale	SR Rating
0	No symptoms	0	Resistant
1	All but 3 leaf sheaths penetrated	1	Resistant
2	All but 2 leaf sheaths penetrated	1	Resistant
3	All but 1 leaf sheaths penetrated	1	Resistant
4	All leaf sheaths penetrated	1	Resistant
5	All leaf sheaths penetrated, Culm not visibly penetrated but with mycelial growth	2	Moderately Resistant
6	Infection(penetration) of surface layers of culm	2	Moderately Resistant
7	25% of culm girdled	3	Susceptible
8	50% of culm girdled	3	Susceptible
9	75% of culm girdled	4	Very Susceptible
10	Culm completely girdled and penetrated, *sclerotia* usually present inside the culm	4	Very Susceptible

Aggregate Sheath Spot

An immediate backcross program was started in 2005 to transfer aggregate sheath spot (ASS) resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-206 background. Existing segregating populations from various backcrosses have been advanced in the greenhouse, where sheath spot screening is conducted. In addition, these same materials were grown in the SR field nursery. Some lines (derived from all three donor parents) again also showed SR resistance equivalent to that found in the wild species. These materials have been stored and conserved in cold storage for future reference and use.

Sheath spot screening in the greenhouse of advanced lines was expanded from just the statewide entries to include preliminary trial entries.

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. From 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 and extent of affected acres in 2010 was higher than most previous years and even greater in 2011. Significant blast was also present in RES fields for the first time in 2011. Blast was lower in severity and incidence in 2012-2014. M-104 appears to be more susceptible to blast than other varieties, followed by M-206. Seedlings of all statewide entries were screened against a mixture of IG1 and IB1 races this year in the greenhouse. This test should confirm presence of major genes in candidate lines and perhaps provide some information on relative susceptibility of lines without major genes (almost all are highly susceptible). However, a seedling test will not necessarily predict adult plant disease resistance.

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. Symptoms were noted on M-208 at low frequency in 2009.

IRRI developed monogenic lines containing major genes for blast resistance. These lines were brought through quarantine and tested in the greenhouse and dew chamber 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 after seven backcrosses. In 2009, homozygous resistant lines were selected with the aid of molecular markers. Selections were made from these lines and brown rice has been evaluated for seed traits by the medium grain breeder.

Four lines (containing *Pi40*, *Piz^5*, *Pikh*, *Pib* genes) were entered in the early statewide trial in 2012-2014, and they yielded more than M-208, and were comparable to M-206's yield. These lines were again evaluated in 2015 and yield data are indicated in Table 5.

Blast infection was found in M-208 fields in 2009-2013. 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.

A new blast race has been found which is significantly different pathologically from IG1 (Table 21). 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. This virulence pattern is representative of race IB1.

Lines with different blast resistance genes from the M-206 backcross program were screened against the M-208 isolates (IB1 race type; data not shown). Again, lines with *Piz* and sometimes *Pik* genes were susceptible. However, lines with other genes were resistant to this new blast race.

The components of M-208 were also tested individually. They are still resistant to IG1, but not IB1. 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 5000 to 10,000 plants in 2010-14.

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. In California, it may be difficult to determine whether the blast fungus has epidemiologically overcome *Piz* resistance in subsequent years if environmental conditions are not always as favorable to disease as in 2010-11.

Molecular marker screening for blast resistance has been successful and is now a routine work at the DNA Lab. *Pi40, Pik^h*, and *Pita^2* genes from the program have been pyramided into 3 gene lines, and are being advanced for agronomic evaluation. These genes were chosen for their broad spectrum resistance to blast races. Presence of several genes in a variety should prevent rapid loss of resistance when exposed to natural blast fungus populations.

Over five hundred blast single spore IB1 isolates taken from M-208 as well as typical IG1 isolates have been screened first on the old international differential set of varieties and selected isolates were then screened on the new IRRI monogenic and NIL lines (which represent a wider variety of blast resistance genes).

Table 21. Comparison of IG1 and IB1 blast race for disease resistance or susceptibility in selected old differential set and California varieties.

				Old Internat. Diff. Set							
	M205	M206	M208	Newbonnet	NP125	Usen	Dular	Kanto 51	Cal-oro	Mars	Katy
Resistance genes											
Race			Piz	Pikh	Pik$^?$	Pia, ?	Pik, Pika?, ?	Pik, Pish	Piks	Piz, Piks	Pita2, Piks, ?
IG-1	S	S	R	R	R	S	R	R	S	R	R
IB-1	S	S	S	S	S	S	S	S	S	S	R

Monogenic lines have only one blast resistance gene, but may have different genetic backgrounds. NIL (near isogenic lines) have one gene per line and have nearly the same genetic background. NILs are preferable, since they differ from each other only for the blast resistance gene. Table 21 demonstrates how an IG1 and IB1 race differ from each other on the old differential set (R-resistant, S-susceptible).

Combining Disease Resistance

A first attempt at combining blast, SR and ASS resistance is in progress. It involved a cross of a 4-gene blast pyramid line with a SR resistant line. This attempt involves rapid generation advance with disease screening in the greenhouse.

Specifically, F_2 populations were screened against blast in March 2015. The F_3 was screened against SR in June, and the F_4 against blast in November. The F_5 will be screened against SR in the field in 2016.

A portion of the seed will be used in ASS screening in the greenhouse. Some lines evaluated in 2015 were found to be resistant to SS. Seeds were harvested and stored from resistant lines for further evaluation in 2016. Selecting for SR resistance in materials derived from wild species tends to enrich for SS resistance as well. It is hoped that agronomically acceptable lines with resistance to all three diseases can be identified in this way.

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.

A total of 200 URRN entry lines from the southern US were received for evaluation and use in the RES breeding program. The seeds of each line were properly treated and germinated in the laboratory. Generated seedlings were grown to full maturity inside the greenhouse in summer 2015. The germplasm materials were screened for seed contamination to ensure that each sample is free from insect pests and diseases before releasing the harvested seeds to the breeders.

All plant introductions were grown and released for breeder's use under the 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.

DNA MARKER LABORATORY

Cynthia B. Andaya

Overview

The DNA Marker Lab is now an integral component in the RES breeding program. The lab performs activities in support of the station's breeding projects and spearheads the implementation of special projects. The lab is involved in: marker-aided selection (MAS) for the different projects; fingerprinting and purity testing of advanced lines and RES-released rice varieties; gene introgression and pyramiding of blast resistance genes; genetic mapping of stem rot resistance gene(s); and generation of mutant populations using chemical mutagenesis.

The primary goal of the DNA marker laboratory is to assist the breeders in their selection work by using DNA marker technologies. The use of molecular markers reduces the number of breeding lines that the breeders will advance and grow in the field through initial MAS, thereby reducing costs and increasing breeding efficiency.

In 2015, the work in the DNA Lab came from MAS for the different grain types, fingerprinting materials, confirmation of stem rot resistance mapping, and generating mutant populations for the breeders. Materials generated from blast resistance gene pyramiding and mutagenesis work were transferred to our plant breeders and are in different stages of evaluation.

Marker-Aided Selection

MAS for both blast resistance and grain quality is now a routine work at the RES DNA Lab. The laboratory is capable of screening multiple blast resistance genes in a single PCR reaction through multiplexing. The lab is using five microsatellite or simple sequence repeat (SSR) markers namely: RM208, AP5930A, RM224, RM331 and RM7102, to screen for the presence of absence of specific blast resistance genes (Table 22). In 2015, a total of 6230 breeding lines were screened from the medium and short grain projects for blast resistance using different blast resistance markers (Table 23). In the medium grain project, a total of 5041 plants were screened for blast resistance using MAS, generating 20,164 data points. Likewise, a total of 1,189 plants were evaluated in the SG project, generating 4,756 data points.

Around 2252 long grain breeding lines were evaluated using five DNA markers for grain quality. Using the grain quality markers: gt-alk, RM190, and Waxy SNPs Intron1, Exon6, and Exon10, about 11,260 data points were generated. The genotype scores for these markers give the long grain rice breeder a predicted quality scores for amylose type, gel temperature, and viscosity. Though the marker data is not the breeders' ultimate selection criteria, it can assist them in discarding material that does not conform to their set standard.

Table 22. List of DNA markers used in MAS for blast resistance.

DNA Marker	Blast Resistance Genes
RM7102	*Pi-ta, Pi-ta2*
RM331	*Pi-33*
RM224	*Pi-1, Pi-kh, Pi-km*
AP5930A	*Pi-z2, Pi-z5, Pi-9, Pi-40*
RM208	*Pi-b*

Table 23. Number of lines evaluated using MAS for blast resistance in the breeding projects.

Project	Number of Lines	Number of Data Points
Medium Grain	5,041	20,164
Short Grain	1,189	4,756
TOTAL	6,230	24,920

DNA Fingerprinting

An important component of the DNA lab is to provide assistance in variety identity and purity assessment. In 2010, the lab started building a database of marker size information for SSR markers and performed DNA fingerprinting of all rice varieties released at RES as well as other rice variety introductions. As of 2015, marker information for more than 200 markers is available. The lab fingerprints advanced lines before they are recommended as varieties. These varieties are also surveyed for identity against commercially grown varieties. The DNA lab will continue to add DNA markers to the database since the success of DNA fingerprinting activities depends largely on markers that can distinguish one variety from another.

The lab has developed a panel composed of 11 DNA markers that can distinguish a medium grain variety from another (data not shown). These markers were labeled using fluorescent dyes to facilitate multiplexing and faster data analysis. A similar panel to fingerprint long grain and short grain varieties is also being developed.

Fingerprinting requests vary from year to year depending on the need of the breeding program. In 2015, the medium grain project put in a request to fingerprint various breeding materials (Table 24). About 1559 lines (consisting of M-206 head rows, blast resistance lines and advanced medium-grain lines) were assessed using different markers, generating 18,965 data points.

The Short- and Long-Grains Project requested a combined total of 1945 lines for fingerprinting in 2015, generating around 21,265 data points (Table 25). The SG project submitted 1100 lines for fingerprinting, consisting of advanced line 12Y2183, some elite components and some putative mutants, generating around 12,570 data points.

Table 24. Materials fingerprinted for the Medium-Grain Project.

Material	No. of Lines	No. of Markers	No. of Data Points
M-206 HR	384	12	4608
12Y113	501	13	6513
12Y3097	80	13	1040
15Y39,15Y40	270	12	3240
15P3104	324	11	3564
Total	1559		18965

Table 25. Materials fingerprinted for the Premium and Short and Long Grain Projects.

Material	No. of Lines	No. of Markers	No. of Data Points
12Y2183	900	11	9900
Elite Line Components	170	12	2220
Putative Mutants	30	15	450
Non-aromatic LG	600	10	6000
Aromatic LG	245	11	2695
Total	1945		21265

In the Long-Grains Project, around 845 entries were fingerprinted (Table 25), generating 8695 data points. The materials consisted of aromatic and non-aromatic lines.

Fingerprint data assures the breeders of the identity and purity of their materials.

Mapping Stem Rot Resistance

The ultimate goal of mapping stem rot resistance is to find a tightly- linked marker that can be used for marker-aided selection by the different breeding programs.

An advanced backcross recombinant inbred line mapping population from the cross 87Y550/M-206*2 was used to map the stem rot resistance from a wild rice relative, *O. rufipogon*. In the first replicated stem rot screening trial performed in Biggs in 2010, and in a follow-up study in Biggs and Glenn in 2011, genetic mapping analysis had identified putative quantitative trait loci (QTL) that are associated with stem rot resistance. This year, this original mapping population was again planted at Biggs in 2 locations to further confirm if the QTL identified to control stem rot resistance in previous tests are also detected using a different rating scale that is being developed by our new RES pathologist, Dr. P. L. Sanchez.

From 2011 to 2013, the medium grain breeder (Dr. V.C. Andaya) and the retired plant pathologist (Mr. J. Oster) generated a fine mapping population to further delineate the region close to the QTL region controlling stem rot resistance. The population was generated from a cross between the most resistant line SRM1-4 which was derived from the initial mapping population, and M-206. This fine mapping population (BC_3F_6 lines) was again evaluated this year to confirm the observed phenotypes from previous years. The fine mapping population was evaluated three times, in2013, 2014, and this year 2015.

Tissue samples and DNA samples of the 340 lines from the fine mapping population are kept in the lab for further genotyping work. We have a genotype scores from 29 selected markers. As phenotype scores are highly affected by the environment, across year and across location, another replicated stem rot evaluation is being planned in the greenhouse this coming year using a sub-population from both the original mapping population and fine mapping population. This subpopulation will consists of lines that are highly resistant and highly susceptible across several trials we have conducted throughout several years. The aim is to find consistent phenotype scores associated with marker genotype scores.

Based on the accumulated data that we have analyzed individually, stem rot resistance QTLs in Chromosomes 1 and 6 appear in a number of trials we have analyzed. The SR QTLs in Chromosome 2 and 3 reported by another group in 2001 appear to be linked to flowering days or maturity. Using a subpopulation to further study stem rot resistance, will we observe the same results as before? Could we find a consistent DNA marker for stem rot resistance that we could use for marker aided selection work?

Mutagenesis

Mutagenesis is an important tool to generate materials that can be used by breeders in their breeding program. Seeds from several varieties were treated with a chemical mutagen, ethyl methane sulfonate [EMS] (Sigma, M0880) in the DNA lab and treated seeds were planted in the greenhouse by the respective projects to generate populations for advancement and screening for traits of interest.

Approximately 10 kg of seed were treated with EMS for different projects in 2015. When requested, the DNA lab can perform DNA marker work on mutants identified by the breeders to confirm their parentage.

BREEDING NURSERIES

Seeding of the 2015 breeding nursery began April 24th, and was completed May 22nd. In 2015, 1285 crosses were made at RES for rice improvement, bringing the total number of crosses made since 1969 to 46,496. 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 2015, thereby accelerating the breeding process.

The 2015 RES breeding nursery occupied approximately 75 acres. Water-seeded yield tests included 5745 small plots and 3130 large plots. The nursery included about 60,600 water-seeded and 18,700 drill-seeded rows and plots. F_2 populations from 2013 and 2014 crosses were grown in drill-seeded plots on 21 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 2016.

Headrows (1600) of M-209, Calmochi-203, M-206, S-102, and experimentals 12Y20 and 11Y106 were grown for breeder seed production in 2015. 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 2014-15 winter nursery was completed and seed returned to RES and planted in May. The 2015-16 winter nursery of 8800 rows was planted October 27-28, 2015, and 600 F_1 populations were transplanted to the nursery November 14, 2015. Selection and harvest will occur in April, and seed returned for processing and planting in the 2016 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 5040 rows, and 5 acres of F_2 populations. Stand establishment and weed control was good. Very little blanking was observed in the rows and the F_2 populations for selection.

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.

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 2015 Statewide Yield Tests were conducted at seven locations in commercial fields by Mr. Raymond L. Wennig, Dr. Bruce A. Linquist, Dr. Luis Espino, Dr. Randall G. Mutters, and Mr. John Ray Stogsdill. 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 11, 2015. 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 SuperWham® and were applied for weed control and one application of Lambda Cy was applied for rice water weevil control. Cerano® was used in the nursery as well.

Tables 26 through 31 contain a summary of performance information from the 2015 Statewide Yield Tests. Yields are reported as paddy rice in pounds per acre at 14% moisture. 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 2016. Complete results of the UCCE Statewide Yield Tests can found on the web at http://rice.ucanr.edu/ Reports-Publications/Agronomy_Papers/.

Table 26. 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 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC) RES	Grain Yield (lb/A, 14% MC) State
5	10Y2043	S	4.8	79	86	18	3.0	10790	10070
9	CM-203	SWX	4.9	77	94	38	3.5	10610	9960
4	11Y2022	MPQ	4.8	78	97	1	3.0	9960	9320
2	12Y20	L	4.9	81	99	1	3.0	9740	9390
16	12Y113	MB	4.9	76	91	8	4.0	9590	9150
6	S-102	S	4.9	75	91	48	4.0	9520	8720
17	12Y3097	MB	4.8	76	94	8	4.0	9470	9000
14	M-209	M	4.9	78	91	3	3.0	9460	9220
12	M-205	M	4.9	81	89	1	3.5	9400	8820
13	M-206	M	4.9	76	97	13	4.0	9350	9180
15	M-208	MB	4.9	79	97	21	3.5	9090	8780
1	L-206	L	4.9	76	81	1	3.0	8910	8720
3	11Y1005	L	5.0	81	94	1	3.0	8870	8420
11	M-104	M	4.9	71	84	13	5.0	8580	8970
8	CH-201	SPQ	5.0	79	86	23	3.0	8560	8190
7	CH-202	SPQ	4.9	77	91	80	3.5	8180	7900
10	CM-101	SWX	4.9	75	97	35	3.5	7940	7560
MEAN			4.9	77	91	18	3.5	9290	8900
LSD (.05)			0.1	2	8	21	2.1	760	320
CV			1.4	1.5	5.3	81.4	27.3	5.8	5.1

† L = long grain; M = medium grain; MB = blast resistant medium grain; MPQ = premium quality medium grain; S = short grain; SPQ = premium quality short grain; and SWX = short grain waxy.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Number of days to 50% heading.
¶ SR = stem rot resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

Table 27. 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 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC)	
								RES	State
35	14Y2039	SWX	4.7	83	94	1	4.5	10440	9350
18	14Y1006	L	4.9	79	89	1	3.5	10290	9620
25	12Y2165	MPQ	4.8	86	99	1	3.0	10150	8810
30	13Y2031	SPQ	4.9	79	94	55	3.5	10030	9400
48	14Y3126	M	4.9	76	94	1	6.0	9880	9140
33	14Y2110	SLA	4.8	89	86	1	3.0	9460	8640
28	14Y2018	SPQ	4.6	76	84	1	3.5	9330	9060
29	13Y2130	SPQ	4.9	76	79	1	4.0	9290	8150
20	14Y1104	S	4.9	83	97	1	3.0	9120	9170
26	14Y2007	S	4.8	79	89	1	4.5	9000	9550
22	14Y1066	L	4.9	81	91	1	4.0	8990	9210
32	14Y2008	S	4.8	80	86	1	3.0	8990	9090
38	11Y3326	M	4.9	76	89	1	4.5	8970	9000
47	14Y3094	M	4.8	78	89	1	3.0	8910	9140
23	14Y1078	L	4.8	81	89	1	3.0	8900	8690
27	14Y2138	SWX	4.8	82	91	16	3.5	8870	9000
46	14Y3055	MB	4.9	73	91	1	3.5	8730	9120
31	14Y2096	S	4.8	81	94	1	4.0	8670	8750
21	14Y1061	LSR	4.9	80	97	1	4.0	8610	8730
41	13Y3046	M	4.8	73	89	6	4.5	8580	8860
45	14Y3052	MB	4.9	74	99	1	4.5	8570	8910
43	13Y3150	M	4.8	80	89	1	4.5	8560	8510
39	13Y3131	M	4.9	80	94	1	4.5	8480	8970
42	13Y3052	M	4.8	76	84	1	5.0	8450	8740
19	15Y19	L	4.9	74	86	1	5.0	8450	8590
50	13Y3123	M	4.9	78	89	16	6.0	8370	8830
51	14Y3137	MB	5.0	77	97	1	4.0	8370	8600
37	M-105	M	4.8	76	89	6	4.5	8150	8740
44	13Y3181	M	4.8	81	89	1	6.0	8130	8610
24	A-202	LA	5.0	79	89	1	3.0	8110	8400
49	14Y3047	M	4.8	75	86	1	4.5	7940	8660
36	M-202	M	4.9	80	91	11	4.5	7830	8230
40	13Y3146	M	4.8	78	86	1	3.0	7810	8460
34	CA-201	SLA	4.8	79	81	15	4.0	6160	5950
MEAN			4.8	79	91	4	4.1	8780	8780
LSD (.05)			0.1	2	10	12	2.1	950	460
CV			1.4	1.4	5.3	131.9	27.3	5.3	5.3

† L = long grain; LA = aromatic long grain; LSR = stem rot resistant long grain; M = medium grain; MB = blast resistant medium grain; MPQ = premium quality medium grain; S = short grain; SLA = short grain low amylose; SPQ = premium quality short grain; and SWX = short waxy grain

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

¶ SR = stem rot resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

Table 28. 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 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC)	
								RES	State
62	14Y1006	L	4.7	77	84	19	3.5	11090	11170
67	10Y2043	S	4.6	78	84	81	3.0	11020	11330
71	CM-203	SWX	4.9	75	89	86	3.5	10650	10380
63	12Y20	L	4.9	81	97	9	4.5	10550	10330
65	12Y2175	MPQ	4.5	82	97	26	4.0	10390	9880
68	S-102	S	4.8	75	89	90	5.0	10050	9200
78	12Y3097	MB	4.2	78	94	46	3.5	9960	9890
66	11Y2183	MPQ	4.4	85	89	30	4.0	9800	9360
77	12Y113	MB	4.7	77	94	83	4.5	9800	10230
74	M-206	M	4.7	77	91	70	4.5	9620	9700
75	M-209	M	4.7	81	94	5	3.0	9490	9700
64	11Y1005	L	4.9	80	94	14	3.0	9470	9430
61	L-206	L	4.7	77	81	5	5.5	9360	9740
76	M-208	MB	4.8	79	94	66	4.0	8850	9330
73	M-205	M	4.6	82	89	9	4.5	8720	9050
70	CH-201	SPQ	5.0	79	86	68	4.5	8580	8300
69	CH-202	SPQ	4.6	77	84	96	4.0	8510	8520
72	CM-101	SWX	4.8	74	84	84	3.0	8000	7610
MEAN			4.7	79	89	49	4.0	9660	9620
LSD (.05)			0.2	1	5	25	2.0	730	310
CV			2.5	1.3	4.7	35.8	27.7	5.3	4.6

† L = long grain, M = medium grain, MB = blast resistant medium grain; MPQ = medium premium quality; S = short grain; SPQ = premium quality short grain; and SWX = short waxy grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

Table 29. 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 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC)	
								RES	State
87	14Y1143	LSR	4.6	81	84	0	3.5	10430	9690
93	14Y2147	MPQ	4.6	83	91	13	3.0	10290	9970
112	14Y3124	M	4.8	83	102	73	4.0	9900	9480
79	14Y1054	L	4.9	80	94	1	3.0	9820	10720
92	14Y2160	MPQ	4.6	85	91	5	3.0	9770	9670
114	13Y3191	M	4.6	81	94	58	4.0	9720	9880
108	13Y3177	M	4.7	81	94	8	3.0	9660	9840
90	15Y90	LJ	4.9	81	94	3	3.0	9620	9320
107	13Y3176	M	4.7	81	89	8	3.5	9590	9640
88	14Y1104	L	4.8	81	89	0	4.5	9560	10070
84	15Y84	LJ	4.9	81	84	0	5.0	9560	10320
110	14Y3087	M	4.4	79	97	30	3.0	9410	9740
98	12Y2167	SPQ	4.6	82	91	25	3.5	9210	6770
111	14Y3088	M	4.6	82	91	73	3.5	9210	9720
103	13Y3146	M	4.3	81	94	20	4.5	9190	9570
96	11Y2182	MPQ	4.4	84	91	13	4.0	9140	9260
104	10Y3737	M	4.4	82	91	58	4.5	9050	9540
109	13Y3172	M	4.6	81	94	23	3.0	8870	9640
86	11Y106	LJ	3.9	89	91	23	3.5	8860	7700
105	11Y3655	M	4.6	82	94	0	3.0	8820	9550
94	12Y2174	MPQ	4.6	82	97	8	4.5	8820	9320
102	13Y3131	M	4.7	81	104	45	3.0	8790	9300
95	12Y2163	MPQ	4.7	83	91	5	3.5	8720	9180
101	11Y3326	M	4.4	77	89	53	3.0	8690	9750
99	M-105	M	4.4	76	91	73	4.0	8610	9610
113	13Y3180	M	4.7	82	91	20	4.0	8600	8690
100	M-202	M	4.8	81	97	70	3.5	8570	8950
83	12Y1022	LA	4.8	81	94	0	3.0	8410	9130
106	13Y3156	M	4.5	83	89	0	3.0	8360	9330
80	A-202	LA	4.9	80	89	4	3.0	8340	9100
82	A-301	LA	4.1	96	84	0	3.0	8090	8350
97	M-402	MPQ	4.8	105	99	0	3.0	7930	7380
89	15Y89	LJ	4.7	81	99	38	4.5	7850	7570
81	CT-202	LB	4.8	79	84	5	3.0	6790	6690
91	14Y1142	LB	4.6	82	86	0	3.5	6120	6670
85	15Y85	LB	4.7	87	74	0	3.0	5710	6450
MEAN			4.6	82	91	21	3.5	8840	9040
LSD (.05)			0.3	2	8	29	2.0	1160	460
CV			3.7	1.1	3.6	67.8	27.7	6.5	5.1

† L = long grain; LA = aromatic long grain; LB = basmati long grain; LJ = jasmine long grain; LSR = stem rot resistant long grain; M = medium grain; MPQ = premium quality medium grain; and SPQ = premium quality short grain.
V = seedling vigor score, where 1 = poor and 5 = excellent.
¶ SR = stem rot resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

Table 30. Agronomic performance means of intermediate to late advanced entries in Statewide Yield Tests at RES and over-location mean yields at Glenn and RES (4 reps) locations in 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC) RES	State
124	11Y2183	MPQ	4.8	86	97	0	3.0	10120	9900
130	M-209	M	4.9	79	97	0	3.0	9880	9790
129	M-206	MB	4.9	74	94	8	5.0	9710	9660
132	12Y113	MB	4.9	75	99	0	3.0	9680	9910
133	12Y3097	MB	4.9	75	97	13	3.0	9650	9500
121	L-206	L	4.9	76	84	1	4.0	9520	9710
123	11Y1005	L	4.9	79	99	0	3.5	9460	9370
122	12Y20	L	5.0	78	99	0	3.0	9450	10140
128	M-205	M	4.9	81	94	0	3.0	9120	9270
131	M-208	M	5.0	77	97	33	3.0	8990	9200
126	CH-202	SPQ	4.9	75	86	86	3.0	8550	9070
125	M-402	MPQ	4.9	101	94	0	3.0	8450	8580
127	CH-201	SPQ	5.0	78	86	15	3.5	7770	7980
MEAN			4.9	80	94	12	3.3	9260	9390
LSD (.05)			0.1	1	3	19	1.8	610	420
CV			0.8	1.3	2.7	109.1	26.7	4.6	4.5

† L = long grain; M = medium grain; MB = blast resistant 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 resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

Table 31. Agronomic performance means of intermediate to late preliminary entries in Statewide Yield Tests at RES and over-location mean yields at Glenn and RES (2 reps) locations in 2015.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Grain Yield (lb/A, 14% MC) RES	State
145	12Y2175	MPQ	4.9	79	104	0	3.0	10670	10590
155	14Y3092	M	4.9	86	99	0	3.0	10460	10190
153	13Y3129	M	4.9	79	89	0	3.5	10080	9780
149	CM-203	SWX	4.9	73	99	15	3.0	9900	9600
146	11Y2182	MPQ	4.8	82	94	23	4.0	9720	9940
151	M-105	M	4.8	73	94	0	4.0	9630	9590
147	M-401	MPQ	4.8	105	102	0	4.5	9380	9740
136	15Y136	LJ	4.9	80	97	0	3.5	9290	9310
154	13Y3182	M	4.8	81	91	0	3.0	9230	9070
134	A-202	LA	4.9	77	94	0	3.5	8840	9350
144	14Y156	LB	4.8	87	102	0	4.5	8410	7700
143	14Y1183	LJ	4.9	90	89	0	3.0	8370	8650
141	12Y133	LJ	4.9	94	89	0	3.5	8320	8400
152	M-202	M	4.9	77	97	0	3.5	8150	8350
150	CM-101	SWX	4.9	73	89	75	3.0	7970	7960
139	11Y106	LJ	4.8	86	94	46	3.0	7760	8280
135	15Y135	LJ	4.9	88	91	20	4.0	7230	7800
137	13Y1055	LB	4.7	84	84	18	3.0	6650	6550
140	14Y1172	LB	4.9	90	102	13	3.0	6580	6560
142	14Y1090	LB	4.7	93	91	0	3.0	6470	6060
148	KOSH	SPQ	4.8	97	112	93	3.0	5460	5770
138	14Y149	LB	4.8	95	109	0	5.0	5160	4780
MEAN			4.8	85	97	14	3.5	8350	8370
LSD (.05)			0.1	3	5	26	1.8	1040	620
CV			0.8	1.9	2.7	91.9	26.7	6.0	5.2

† LA = aromatic long grain; LB = basmati long grain basmati; LJ = jasmine long grain; M = medium grain; MPQ = premium quality medium grain; SPQ = short grain premium; and SWX = short waxy grain.
‡ SV = seedling vigor score, where 1=poor and 5=excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance score, based on 2 reps, where 0 = no damage and 10 = plant killed.

PRELIMINARY YIELD TESTS

Preliminary Yield Tests are the initial step of replicated large plot testing for experimental lines. The experimental design, plot size, and production practices are identical to the Statewide Yield Tests grown at RES. Two replications are planted at the early and late seeding date. A summary of the yields of 2015 Preliminary Yield Tests is presented in Table 32. These tests included 538 entries and check varieties.

Results in Table 32 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 2016 Statewide Yield Tests. ◆

Table 32. Summary of Preliminary Yield Tests at RES in 2015

Test	Type	Number of Entries	All	Highest	Top 5	Check	Standard Check
			----------Average Yield (lbs./acre)†----------				
Very Early							
Short grains	Conventional	5	11050	11370	11050	10590	S-102
	Specialty rice ‡	27	10430	11540	11320	9320	CH-202
Medium grains	Calrose, advanced	34	9860	10840	10590	9810	M-105
	Calrose, prelim	69	9420	10690	10450	9420	M-105
	Premium	2	9860	10090	9860	8640	M-402
	Specialty rice §	2	9670	9910	9670	9530	89Y235
Long grains	Conventional	58	10530	11520	11420	10800	L-206
	Specialty rice	23	8030	10030	9800	9780	A-202
Early							
Short grains	Conventional	6	9040	9680	9200	9720	S-102
	Specialty rice ‡	39	9400	10960	10680	8210	CH-202
Medium grains	Calrose, advanced	31	9830	10370	10330	10540	M-206
	Calrose, prelim	69	10000	11460	11060	9980	M-206
	Premium	21	10100	11060	10720	9100	M-402
Long grains	Conventional	55	10140	11840	11310	10340	L-206
	Specialty rice	26	7910	10820	10020	9840	A-202
Intermediate-Late							
Short grains	Conventional	5	10310	10640	10310	10760	S-102
	Specialty rice¶	1	10000	10000	10000	6990	CA-201
Medium grains	Premium	25	10530	11360	11260	9540	M-402
Long grains	Conventional	4	9560	10300	9560	9470	L-206
	Specialty rice	36	7520	10650	10110	10140	A-202

† Paddy rice yield at 14% moisture
‡ Rice grain types are short premium quality, short way, and short low amylose.
§ Rice grain type is bold grain or Arborio-type.
¶ Rice grain types are short premium quality and short low amylose.