2018 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
Teresa B. De Leon, Ph.D. .... Plant Breeder
Shyamal Talukder, Ph.D. .... Plant Breeder
Cynthia B. Andaya, Ph.D. .... Research Scientist

Plant Breeding Support

Matthew A. Calloway (resigned) .... Breeding Nursery Manager
Baldish K. Deol .... Senior Plant Breeder Assistant
Ravinder Gakhal .... Senior Plant Breeder Assistant
Christopher A. Putz .... Plant Breeder Assistant
Davinder Singh .... Plant Breeder Assistant
Benjamin Vander Sluis .... 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
Deven Benson .... Maintenance and Operator

Clerical and Accounting

Lacey R. Stogsdill .... Executive Assistant

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OVERVIEW

The California Cooperative Rice Research Foundation (CCRRF) is a private nonprofit research foundation [501(c)(5)] and membership is 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 in 2018 included a director, director of plant breeding, two plant breeders, and a research scientist. Eleven career positions consisting of a breeding nursery manager (resigned), five plant breeding assistants, one DNA Lab technician, a field supervisor, one mechanic and field operator, two maintenance and field operators, and one executive assistant make up the support staff. Approximately 30 seasonal laborers are employed during crucial planting and harvest times.

ORGANIZATION AND POLICY

Policy and administration of RES is the responsibility of an 11-member Board of Directors elected by the CCRRF membership. Directors serve a three-year term and represent geographical rice growing areas of California. They are rice growers and serve without compensation. CCRRF works to serve all California rice growers, and its policies generally reflect those of public institutions. 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 to develop 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, semi-dwarf 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 which 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 [501c(3)] established in 1962 to receive tax deductible contributions and gifts to support of rice research and the breeding program. RRT has been the primary funding source for capital improvements at RES.

The RES Breeding Program is reviewed annually by the Board of Directors, representatives of the UC, and the CRRB. All research is conducted under permits, 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. John Ray Stogsdill, (UCD Staff Research Associate III), under the direction of Specialist in Cooperative Extension, Dr. Bruce A. Linquist, (UCD) with University of California Cooperative Extension (UCCE) Farm Advisors Dr. Whitney Brim-DeForest (Butte, Placer, Sacramento, Sutter, Yuba), Dr. Luis Espino (Glenn, Colusa, Yolo), and Dr. Michelle Leinfelder-Miles (San Joaquin). The information collected 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, is working to develop improved breeding and genetics methods for rice variety improvement.

The CCRRF staff, facilities, and equipment also supported agronomic, weed, disease, and insect research of UCD scientists in 2018. Dr. Kassim Al-Khatib, (Professor, Department of Plant Sciences, UCD), Dr. Amar Godar, (UCD Project Scientist), and Mr. Michael Lee (UCD Junior Specialist) conducted research on 16 acres at Hamilton Road. Drs. Linquist and Espino are doing rice agronomic and entomology research on 18 acres at RES. They are being supported at RES by Mr. John Ray Stogsdill and Mr. Kevin Goding, (Staff Research Associate II, Department of Entomology). RES also provides technical input and support to the California Rice Commission (CRC).

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, high quality seed for the benefit of the California Rice Industry. Fifty-one improved rice varieties have been released since an accelerated research program began in 1969. Foundation seed of 19 rice varieties and one experimental line were produced on 130 acres at RES in 2018. 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. All seed growers of CCRRF rice varieties are required to be licensed by CCRRF. 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 all RES annual foundation and basic seed tests from 2007 through 2018 by CRC have been non-detect.

RICE BREEDING PROGRAM

The CCRRF continues its commitment to the California rice growers in the development and release of excellent high-yielding and high-quality rice varieties. The RES Breeding Program implements rice variety development on three major rice grain types namely: medium grains, short grains, and long grains that covers a total of eleven market classes broadly classified into conventional and specialty types. The medium grain breeding effort aims to develop and release superior conventional Calrose and premium M-401-type rice varieties with high and stable grain yield, superior quality, improved seedling vigor, wide adaptability, cold tolerance and disease resistance.

Breeding for short grains includes efforts to develop conventional short grains as well as specialty types such as premium Koshihikari-type, sweet or waxy rice, low amylose types, and bold or Arborio-type grain rice varieties. In the long grains breeding, the aim is to develop rice varieties that are high-yielding and have superior quality in both the conventional long grains and specialty types such as regular aromatics, Basmati-type, and Jasmine-type long grains.

Breeding for each of the 3 grain types is traditionally assigned to a rice breeder overseen by a Director of Plant Breeding. In 2018, all breeding projects were overseen by Dr. Virgilio Andaya while the two newly hired rice breeders gradually transition to their specific breeding assignments.

The DNA Lab continues to support all grain-types breeding projects for marker-assisted selection, genotyping, and DNA fingerprinting. Additionally, tremendous amount of work was contributed by the DNA Lab in genetic studies and mutation breeding, specifically in the generation of mutant populations for oxyfluorfen tolerance screening and the genetics of oxyfluorfen tolerance in rice. The rice pathology lab supports the programs in breeding rice for disease tolerance but is right now in transition due to departure of a full-time pathologist. Pathology work is being executed by Dr. Teresa de Leon, a plant breeder with extensive technical background in microbiology and plant pathology.

BREEDING OBJECTIVES

The primary research objective of RES is the development of high-yielding and superior quality rice varieties of all grain types and market classes that are commercially competitive in the world market. Rice breeding research priorities at RES can be divided into two main categories: (a) breeding for rice varieties for California and its markets, which is the main emphasis, and (b) breeding for specialty rice which require a more grain specific and quality-specific endeavor. The major breeding objectives of the RES Rice Breeding Program are discussed below.

High and stable yield potential across the state

Grain yield is a complex trait, controlled by several genes as well as highly affected by environment. It is likewise dependent on several agronomic traits of rice. To meet the demand for high yielding rice varieties without compromising the high quality of rice, special emphasis is given to select breeding lines in the pipeline with ideal plant type such as semi-dwarf height, upright long flag leaf, long panicle length with uniform grain maturity, and strong culm to support the heavy panicle heads. To ensure the stability and wide adaptability of materials to be released as varieties, preliminary and advanced lines are evaluated at RES and statewide in replicated yield trials. Advanced promising lines are repeatedly entered in the multi-year, multi-location yield trials for adaptability across the rice growing areas in California to evaluate their performance across locations and seasons. In addition to grain yield, materials at the statewide yield testing stage are also evaluated for cold-induced blanking and lodging (%) to give more detailed assessments of materials in specific growing areas.

Superior grain quality and milling yield

Grain quality is also a complex trait and is dependent on many factors. To ensure high grain quality of rice varieties developed and released by RES, lines are evaluated for desirable grain attributes as early as in the F_2 generation. Grain size, shape, length, width and chalkiness are assessed during winter and only lines that conform to the criteria set forth for specific grain types are advanced to the next generation. Strong emphasis is given to milling yield as this is directly translated to the profitability of growers. Consumer acceptability in terms of cooking and taste parameters are closely monitored. Advanced lines in the pipeline that passed the taste and cooking tests are advanced as promising lines. To assist the breeders in identification and selection for grain qualities, DNA markers are employed whenever possible. In the long grain project, markers are used to predict the amylose content, gelatinization temperature and RVA profiles of long grain (LG) materials. Wet chemistry evaluations are also performed to determine the percent apparent amylose content, and RVA profiles of the samples. For long grain aromatic rice, lines are evaluated for aroma following the protocol using potassium hydroxide solution.

Cold tolerance and seedling vigor

Cold tolerance and seedling vigor are both complex traits that can affect rice yield in California and just like other yield component, are controlled by several genes and highly affected by environment. As such, progress in incorporating these traits in CA rice is a very difficult process. Cold stress affects the spikelet fertility and ultimately grain filling. Rice seedling vigor, on the other hand, affects seedling establishment and its competitive growth against some weeds that may sometimes be left uncontrolled in the field. Lines in the preliminary and advanced yield trials, as well as segregating lines, are evaluated for cold tolerance and seedling vigor to assess their adaptability and yield stability across the state. As early as two weeks after planting, seedling stand and density of each lines are evaluated through a numerical scale. Breeding materials are planted in refrigerated greenhouses and in San Joaquin and Hawaii winter nurseries to examine their cold tolerance profiles. Improved varieties that show normal vegetative growth, minimum delay in maturity and resistance to panicle blanking are considered cold tolerant.

Early maturity and strong culm

Rice production in California starts early in May as temperature becomes favorable to rice cultivation. Short duration rice or early maturing rice variety allows rice growers to harvest their crop early, thus escaping from occasional rainfall in the fall. Short duration varieties likewise reduce water usage associated with growing rice. For all grain types of rice, efforts are continued to select for synchronous flowering for the different maturity groups, with emphasis on uniform flowering in the very early to early-maturing improved varieties. Moreover, breeding lines with strong culm or stem are being selected for lodging resistance as lodging affects the grain quality of the harvest.

Disease resistance

Despite the absence of major disease outbreak in California, the breeding program continues its effort to incorporate disease resistance to improve CA varieties for blast, stem rot, and aggregate sheath spot. Blast disease is observed occasionally in CA in some fields when the environmental conditions are permissive. The breeding program is continuing to stack blast resistance genes against several blast pathogen races into CA varieties to prepare for possible future disease infestation. The program actively uses DNA markers to select breeding materials with multiple blast resistant genes, thereby minimizing the laborious greenhouse and growth chamber evaluation.

Stem rot has been the most prominent disease in CA, but breeding for stem rot resistance is painstakingly slow, especially in the medium grains. We are attempting to transfer the stem rot resistance from the long grain germplasm into medium grain (MG) varieties and also evaluating other sources of resistance. Greenhouse and field evaluations for stem rot are conducted in advanced breeding lines and segregating populations in an effort to determine their resistance profiles.

BREEDING NURSERIES

The RES breeding nurseries are established in three locations: (a) RES facility in Biggs, CA, (b) Hawaii winter nursery in Lihue, HI for shuttle breeding, and (c) San Joaquin cold location nursery. RES breeding nurseries comprised of early breeding materials like F_1 transplanted rows, dry-seeded F_2 populations, water-seeded F_3 to more advanced progeny rows. Water-seeded preliminary yield (PY) test [10’ x 10’ plots] and advanced yield (AY) tests are also established at RES to evaluate yield at a larger scale [10’ x 20’plots]. Milling plots and cooking strips (variable plot size), are also planted at RES for specific milling and cooking evaluation tests. RES is a location for all maturity groups of the UCCE Statewide Yield Tests (SW) [10’ x 20’plots]. Headrows for preliminary and foundation seed production are also handled by the RES Rice Breeding Program.

Table 1 summarizes the breeding nursery composition of RES for 2018. Based on grain type, the breeding efforts are partitioned to 50% medium grains, 25% short grains, and 25% long grains. Based on market class, the program is broken down evenly to 50% conventional and 50% specialty type. A total of 1165 crosses were made in 2018, bringing an overall total of 50,208 crosses made since 1969. To accelerate the breeding process, controlled crosses are made in the greenhouse in early spring and summer of every year. The F_1 seeds made from early spring were grown in RES F_1 nursery while the F_1 seeds made during summer were planted in the Hawaii Winter Nursery. The combined F_2 populations generated from 2018 F_1 nurseries in RES and Hawaii will be planted for evaluation and advancement in RES and San Joaquin nurseries in 2019.

In 2018, the weather in Sacramento Valley permitted planting rice early in the season. The average precipitation of 3.97 inches in January tapered down to 0.76 inches in May. The winter cold spell was immediately replaced by near-summer temperatures of 98-107ºF between the month of April and May. Drill-seeding of the F_2 populations and seed maintenance materials and disease nursery were planted May 5^{th} to May 12^{th}. Water seeding of progeny rows, PYs, AYs and other breeding lines started on May 14th and were all completed by May 25th.

A total of 383 entries were evaluated in the AY tests, which included four replications, while 873 entries were tested in the PY. The breeding nursery also included about 38,976 water-seeded pedigree rows (excluding check rows), 832 drilled-seeded F_2 plots, and 13,200 drill-seeded seed maintenance (SM) rows.

Table 1. Composition of 2018 breeding nurseries by grain type in 2018.

Experiment/Nursery	Medium Grains	Short Grains	Long Grains	Total
F_1 transplant	275	204	205	684
F_2 populations	375	223	234	832
F_3-F_7 progeny rows	23,653	8,503	6,820	38,976
Preliminary yield test (PY)	562	138	173	873
Advanced yield test (AY)	262	65	56	383
Statewide test (SW)	45	21	14	80

Foundation seed headrows were grown for A-202, Calaroma-201 (CJ201), M-210, M-104, and Calamylow-201 (CA201). Head rows of experimental 10Y2043 proposed for released in 2019 were also grown, as well as head rows of 12Y2175 and 14Y1006 which were recommended for Foundation seed increase this year. The headrow seeds are stored under low temperature and humidity conditions for production of the breeder seeds in the future.

The San Joaquin Cold Tolerance Nursery and Hawaii Winter Nursery remain an essential part of selection environment for blanking resistance and are used in conjunction with two refrigerated greenhouses at RES. The Hawaii Winter Nursery allows the advancement of breeding material and screening for cold tolerance during the winter to hasten variety development. The Hawaii Winter Nursery is a very valuable breeding tool and has been a successful and integral part of the RES Rice Breeding Program since 1970. The 2018-19 winter nursery was comprised of 7860 regular rows including checks, 600 F_1 transplanted rows, and seed multiplication plots for ROXY™ lines of 17Y3000, 18P4069, 18P4091, 18P4082, 18P4116 and 18P4117. The rows were dry-seeded from October 30th to November 1st 2018, while the F_1 seeds were seeded on October 30, 2018 and seedlings were transplanted on December 10, 2018. Selection and harvest will be done in the Hawaii nursery in April, and seed returned for processing and planting in the 2019 RES breeding nursery. The San Joaquin Cold Tolerance Nursery was planted in cooperation with a local rice grower. The 3-acre drill-seeded nursery included 3600 rows and 405 F_2 plots. Weed control was good, but there was a little damage from geese during stand establishment. Minor cold-induced blanking was observed in the rows and in the F_2 populations.

BREEDING PERSONNEL

The RES Breeding Program is under the leadership of the Director of Plant Breeding, Dr. Virgilio C. Andaya. He is responsible for building an effective breeding and research team and for providing guidance to achieve the collective goal of developing improved CA rice varieties for all grain types and market classes. Dr. Cynthia Andaya has been the Research Scientist in charge of the DNA Lab since 2010. Her primary responsibility is to assist breeders in marker-assisted selection work, purity and uniformity testing through DNA fingerprinting, and development of mutant populations, and performing genetic studies for traits important to CA. She also provides technical DNA marker expertise to the California rice industry and other rice research cooperators. Dr. Kent McKenzie, Director of RES, is currently involved in the discovery and evaluation of novel sources of herbicide resistance using mutation breeding and passing any new traits to the breeding team so the trait can move through the breeding pipeline. He provides logistical support and guidance on variety releases, market evaluation, funding and recommendations to the Board of Directors, as well as facilitating patents, plant variety protection, licensing, naming of varieties, and germplasm exchange. Dr. Teresa De Leon was hired in January 2018 to join the breeding team. She also temporarily took charge of rice disease screening and quarantine of rice introductions. Dr. Shyamal Talukder joined the breeding program in March 2018 as a rice breeder and was appointed as the liaison to the public rice breeding programs in the southern US.

NEW VARIETY RELEASES IN 2018

M-210 – Blast-Resistant Medium Grain

M-210 is a blast resistant, high-yielding, early-maturing, Calrose-type medium grain derived via DNA marker-assisted backcrossing, using M-206 as the recurrent parent. The variety contains the *Pi-b* gene that confers resistance against the blast pathogens present in California. It heads earlier than M-208 and similar to M-206, and has longer, wider and heavier grains than M-206. It has superior milling yields. Internal and external quality evaluations were favorable and thus can be comingled to other Calrose medium grains.

Pedigree Information

M-210 is a blast-resistant, high-yielding, early-maturing, glabrous, Calrose-type medium grain formerly designated as 12Y3097. It has a cross designation of RP333 with pedigree designation M-206*8/97Y315vE. M-206 is a high-yielding, glabrous, early-maturing Calrose-type medium grain variety released by RES in 2003. The rice line, 97Y315vE, is a very early, blast-resistant, short grain advanced line developed at RES. Its pedigree is 18347/78Y043//86Y013/3/Daegwanbyeo. Daegwanbyeo is a cold-tolerant, blast-resistant Korean variety that has the *Pi-b* gene. After several backcrosses, M-210 is approximately 99% genetically similar to M-206. M-210 is a replacement for the medium grain variety M-208. It is acceptable to the rice market as evaluated internally and externally for grain quality.

Agronomic Performance

M-210, formerly designated as 12Y3097, was first entered in the preliminary UCCE Statewide Test (SW) tests in 2013. Starting in 2015, 12Y3097 was tested in all locations of the SW Tests that included sites in the counties of Yolo, Sutter and San Joaquin, Butte, Colusa, Yuba, Glenn, plus experiments at RES. 12Y3097 was tested in comparison to M-206 and M-208 in a total of 43 SW experiments over a span of 5 years. The overall grain yield of 12Y3097 across 43 SW experiments averaged 9300 lbs./acre compared to 9370 and 8910 lbs./acre for M-206 and M-208, respectively. The yield advantage of 12Y3097 over M-206 and M-208 were -0.74% and 4.4%, respectively. It reached 50% heading in 83 days, had slightly shorter plant height at 97 cm, and similar in terms of seedling vigor and lodging percentage. Performance of M-210 compared to other Calrose varieties in 2018 is presented in Table 2.

Cold-induced blanking experiment in San Joaquin (SJ) and GH cold tolerance screening at RES were performed from 2015 to 2017. In San Joaquin, 12Y3097 blanking ranged from 1-3% in 2015 to 2017 tests while the GH tests showed a wider spread of 16% to 48%. Overall, combined tests in San Joaquin showed that 12Y3097 average blanking was 1.8% compared to 1.7% and 3.5% for M-206 and M-208, respectively. GH blanking was 25%, 18% and 28% for 12Y3097, M-206 and M-208, respectively. Results further indicate that 12Y3097 had better cold tolerance than M-208 and is close to the level of M-206.

M-210 has a wider blast resistance spectrum and has comparable reaction to aggregate sheath spot as the check varieties. Reaction to stem rot of M-210 is slightly better than M-206 and M-208.

Grain Quality

The milled kernels of M-210 are heavier (1000-grain weight =21.65 grams) and slightly wider (width=2.78 mm) compared to M-208 (21.19g, 2.75mm) and M-206 (20.73g, 2.73mm). The grain length (5.96mm) and length/width ratio (2.14) were in between that of M-206 and M-208. Even with slightly heavier grains and wider grain width, M-210 meets the criteria for the Calrose rice market and therefore can be co-mingled with other Calrose rice varieties currently in production in California.

Milling data showed that the head rice yield of M-210 when harvested at 19-22% grain moisture, averaged 65/70 (head/total) compared to 64/69 and 63/68 for M-206 and M-208, respectively. When cut at moistures above 22%, milling yield improved to 66/70. Head rice decreased on all entries cut below 19% harvest moisture.

The average apparent amylose content and protein content of M-210 is 15.7% and 6.6%, respectively, which are values very close to M-206 and M-208. All three varieties had low gelatinization temperature, typical of a Calrose-type medium grain. The cooking characteristics of M-210 are also similar to other Calrose-type rice as revealed by internal and external evaluations. Feedback from selected marketing organizations was favorable and indicated high market acceptability.

Table 2. Performance of M-210, M-105, M-206 and M-209 in SW Tests at RES in 2018.

Variety	Grain Yield (lbs/A,14%MC)		Harvest MC (%)	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	SJ Blanking (%)
	RES	SW							
Very Early Group									
M-210	8570	9130	18.6	4.9	75	99	14	4.3	3.3
M-105	8600	9090	17.7	4.9	73	99	11	5.0	3.8
M-206	9090	9020	18.4	4.9	75	104	24	4.0	5.8
M-209	9710	9040	18.8	4.9	79	103	0	4.0	4.3
LSD (.05)	923		1.43	0.07	1.3	5.4	15		2.4
Early Group									
M-210	9230	8910	18.5	4.8	75	101	45	4.3	2.3
M-105	9360	8900	17.9	4.9	72	102	48	5.0	2.5
M-206	9050	8910	18.7	4.8	75	104	38	4.3	2.5
M-209	10640	9040	19.9	4.8	80	99	0	3.3	3.8
LSD (.05)	704		0.87	0.09	1.0	4.2	20		3.8
Intermediate-Late Group									
M-210	9480	9540	18.2	4.9	75	96	15	5.0	2.8
M-105	9350	9620	17.5	4.9	73	96	3	4.7	1.5
M-206	9730	9770	18.5	4.9	76	100	30	4.3	1.5
M-209	9760	9780	19.7	4.8	80	97	0	3.7	3.8
LSD (.05)	1123		1.10	0.07	1.4	5.9	20		2.9

‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = Resistant and 5 = Susceptible

Calaroma-201 – Jasmine-type Long Grain

Calaroma-201 (CJ201) is a Jasmine-type long grain and the first of its kind to be released by RES. The level of aroma is similar to a typical aromatic long grain but the taste characteristics are closer to the Thai Jasmine quality. It has the potential to become an excellent alternative to imported Jasmine. Area of adaptation is similar to L-206 but is not recommended in colder locations. It earned a favorable taste quality rating based on internal and external evaluations from Thai Jasmine rice consumers. CJ201 was planted in 2018 as check variety for long grain project and was compared to L-206 as both varieties performed well in similar adaptive zones (Table 3).

Pedigree Information

CJ201, formerly designated as 15Y84, was derived from a cross made in 2009 at RES. It has a pedigree R40709=07Y603/JES. The official pedigree is "00KDMX3-3/4/90Y563/3/L202/QUIZHAW/L202/5/JES". L-202 is an early maturing California long grain variety released by RES in 1984. 90Y563 is an advanced long grain line. Quizhaw is a high yielding rice introduction from China. 00KDMX3-3 is photoperiod-insensitive mutant line derived from a Thai Jasmine variety (KDM). JES is a mutant of KDM released by the USDA-ARS and University of Arkansas. Calaroma-201 is a high-yielding, semi-dwarf, early-maturing, glabrous, Jasmine-type aromatic long grain rice developed as an excellent alternative to imported Thai Jasmine.

Agronomic Performance

CJ201, formerly designated as 15Y84, was first entered in the preliminary SW Tests in 2015, and entered SW Tests in all locations in 2017. It was tested in a total of 22 SW experiments in three years and was compared closely with L-206 and A-202. The overall grain yield of 15Y84 across 22 experiments in the SW Tests averaged 9450 lbs./acre compared to 9,310 and 8890 lbs./acre for L-206 and A-202, respectively. It has an overall 3-year yield advantage of 6.3% and 1.5% over A-202 and L-206, respectively. CJ201 is comparable to L-206 and A-202 in terms of overall seedling vigor score and lodging scores. It reaches 50% heading about 5 days later than L-206 and one day later than A-202, and is slightly taller than L-206 but shorter than A-202 by about 8 cm. Calaroma-201's area of adaptation is similar to L-206, but as with other RES-bred long grain is not recommended in colder rice areas. Performance of CJ201 compared to other LG varieties is presented in Table 3.

In San Joaquin, CJ201 had an observed blanking percentage of 3.17% in 2017 compared to 2.42% and 2.17% for L-206 and A-202 respectively. CJ-201 like other LG are more sensitive to cold stress than MG and short grain (SG), and recommended only in warmer areas where L-206 or A-202 perform well.

CJ201 reaction to stem rot disease is in between L-206 and A-202's reaction, L-206 being more susceptible. It is, however, more susceptible to aggregate sheath spot. CJ201 is as susceptible to blast as L-206 and A-202 checks.

Grain Quality

The milled rice kernels of CJ201 has a 1000-kernel weight of 19.72 grams compared to 19.94 and 22.27 grams for L-206 and A-202, respectively. Though its grains are lighter, CJ201 has longer and narrower grains compared to L-206 or A-202, putting the length to width ratio of milled rice at 3.58. Three-year data showed that the head rice yield of CJ201 when harvested at 19-21% moisture is 60/67 (head/total), compared to 61/70 and 61/68 for L-206 and A-202, respectively. The percentage of total rice appeared to be lower compared to the checks.

The mean apparent amylose content of CJ201 is 15.76% compared to 22.41% and 22.38% for L-206 and A-202, respectively. Having a low amylose content and low gel type, it cooks softer and stickier compared to other conventional long grain types like L-206 or A-202.

Based on the results of the RVA evaluation, CJ201 has a higher peak viscosity and breakdown values, lower final viscosity value, and a negative setback, indicative of softer and stickier cooking characteristics different from that of L-206 and A-202. Internal and external cooking and tasting evaluation confirms the differences in cooking quality of CJ201 from the regular or aromatic long grains. Feedback on eating quality by Asian consumers of imported Jasmine rice is also favorable, indicating that it is acceptable to the market and can be an excellent alternative to imported Thai Jasmine.

Table 3. Performance of Calaroma-201(CJ201), L-206 and L-207 in SW at RES in 2018.

Variety	Grain Yield (lbs/A,14%MC)		Harvest MC (%)	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	SJ Blanking (%)
	RES	SW							
Very Early Group									
CJ201	10080	9630	14.0	4.9	79	90	0	4.7	7.0
L-207	9900	9940	14.1	4.9	75	111	0	4.3	4.8
L-206	9770	9060	14.5	5.0	75	94	1	4.3	6.0
LSD (.05)	923		1.43	0.07	1.3	5.4	15		2.4
Early Group									
CJ201	10860	9480	14.4	4.9	79	96	0	5.0	8.0
L-207	10120	9720	14.2	4.9	78	112	0	4.3	6.0
L-206	9750	8900	13.9	4.8	75	95	0	4.3	5.0
LSD (.05)	704		0.87	0.09	1.0	4.2	20		3.8
Intermediate-Late Group									
CJ201	10900	10070	14.5	4.8	80	96	1	5.0	5.8
L-207	10590	10440	14.2	4.8	77	110	0	4.3	5.5
L-206	9540	9440	14.2	4.8	73	92	1	5.0	2.5
LSD (.05)	1123		1.10	0.07	1.4	5.9	20		2.9

‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = Resistant and 5 = Susceptible

RECOMMENDATION FOR VARIETY RELEASE IN 2019

10Y2043 - Conventional Short Grain

Breeding and Selection History

The 10Y2043 line is a very high-yielding, early-maturing, semi-dwarf, temperate Japonica, conventional short grain type developed using the pedigree breeding method. It is a complex cross made in the spring of 2004 with the cross designation R29273 at the Rice Experiment Station in Biggs, CA. The pedigree of 10Y2043 is as follows: R29273 = "03Y324/02Y194", where 03Y324 = "84Y254//M-102/85Y13/3/DENGYU1/88Y013" and 02Y194 = "84Y254/ 85Y013//CP/CM-101/3/S-102". The expanded and official pedigree of 10Y2043 is therefore written as 84Y254//M-102/85Y13/3/DENGYU1/ 88Y013/4/84Y25/85Y013//Calpearl/CM-101/3/S-102. Some of the notable rice varieties in the pedigree of 10Y2043 included S-102, a very early maturing, pubescent, semi-dwarf, conventional short grain released in 1996. Calpearl is a high-yielding, pubescent medium grain, released by N.F. Davis. Calmochi-101 is a very early-maturing, pubescent, semi-dwarf, cold-tolerant, waxy rice developed and released in 1985. M-102 is a very early medium grain, glabrous, semi-dwarf rice developed and released in 1987. The rice line 10Y2043 is an excellent alternative to S-102 in terms of grain yield and quality, and is acceptable to the SG market as indicated in the internal and external for quality evaluations. **10Y2043 was approved for release by the Board of Directors on January 10, 2019 as "S-202".**

Yield and Agronomic Performance

The 10Y2043 was entered in the UCCE Statewide SW Tests, 2-replicate preliminary, from 2011 to 2014. In 2015 and 2016, 10Y2043 was entered in 4-replicate advanced yield tests, in both very early and early group. From 2017 to 2018, it was entered in all locations of the SW Tests. The entry was evaluated in 38 four-rep experiments. Headrow purification was performed in 2016 to 2018 under isolation in a water-seeded field. In 2018, head rows were grown in the Foundation Seed field for final purification, and uniformity and stability tests.

Table 4 summarizes the average performance of 10Y2043 and S-102 in RES and all UCCE Statewide Tests from 2015 to 2018. Compared to S-102, 10Y2043 consistently outperformed S-102 across the state, with an average yield of 10,185 lbs./acre, and an average yield advantage of 16% over S-102 for three years. Seedling vigor of 10Y2043 is similar to S-102, but the plant height is shorter by 4 cm on average. Lodging resistance is nearly the same in both varieties, except in Butte, Glenn and Sutter trials. In all locations, 10Y2043 requires an average of 83 days to flower, which is 2 days later than S-102 on average.

Grain and Milling Characteristics

Table 5 summarizes the grain dimensions of paddy, brown and milled rice samples of 10Y2043 and S-102. The appearance of the paddy, brown and milled rice samples of the two entries is shown in Figure 1. The grains of 10Y2043 are smaller and lighter compared to S-102. The 1000-grain weight of 10Y2043 milled rice was 21.1 grams compared to 25.3 grams for S-102. It is shorter (length=5.11 vs. 5.4 mm) and narrower (width=3.04 vs. 3.20

mm) but with a similar length/width ratio of 1.68. With slightly smaller grains compared to S-102, caution should be observed when comingling with S-102, especially if grain uniformity of milled rice product is desired.

Table 4. Overall average performance of 10Y2043 and S-102 in all SW locations from 2015 to 2018.

Location and Year	Entry	Grain Yield (lbs/A, 14%MC)	%Yield Adv. of 12Y2043	Harvest Moisture (%)	Seedling Vigor (1-5)	Days to Heading	Lodging (%)	Plant Height (cm)
RES, Biggs (E)	10Y2043	11370		14.8	4.8	76	66	90
2015-18	S-102	9440	21	11.1	4.8	74	65	94
RES, Biggs (VE)	10Y2043	10790		16.1	4.9	75	38	91
2015-18	S-102	8910	22	11.3	4.9	74	27	95
RES, Biggs (IL)	10Y2043	10690		13.9	4.9	74	40	93
2017-18	S-102	9480	13	10.7	4.9	73	25	97
Butte	10Y2043	10290		20.4	4.9	82	88	95
2015-18	S-102	8610	19	17.1	4.9	79	73	101
South Butte	10Y2043	10330		14.3	4.8	84	96	96
2017-18	S-102	8950	15	14.3	4.7	82	94	99
SUTTER	10Y2043	10960		19.9	4.9	83	77	89
2015-18	S-102	9480	16	17.7	4.9	82	43	94
Glenn	10Y2043	9060		16.8	4.2	89	94	104
2017-18	S-102	7420	22	15.8	4.3	83	63	109
Colusa	10Y2043	10080		16.4	4.8	87	50	96
2015-18	S-102	8300	22	15.8	4.9	82	28	99
Yuba	10Y2043	10390		16.2	4.8	84	95	101
2015-18	S-102	8350	24	13.7	4.9	79	94	102
Yolo	10Y2043	10270		17.1	4.9	81	19	93
2015-18	S-102	8580	20	15.5	4.9	79	6	97
South Yolo	10Y2043	8880		16.8	4.8	91	7	80
2017-18	S-102	8460	5	15.7	4.7	86	7	85
San Joaquin	10Y2043	9100		15	4.6	101	1	81
2017	S-102	9240	-2	13.5	5	99	3	84

Table 5. Grain dimensions of 10Y2043 and S-102.

		Paddy Rice			Brown Rice			Milled Rice			
Year	ID	Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	LW Ratio	1000-seed wt.
2017	S-102	8	3.77	31.4	8	3.77	31.4	5.41	3.18	1.7	24.2
	10Y2043	7.19	3.49	26.7	7.19	3.49	26.7	5.15	3.03	1.7	20.7
2018	S-102	8.74	3.85	35.5	5.74	3.33	29	5.39	3.22	1.67	26.4
	10Y2043	7.37	3.55	29.6	5.4	3.15	23.7	5.07	3.04	1.67	21.5
Mean	S-102	8.37	3.81	33.5	6.87	3.55	30.2	5.4	3.2	1.69	25.3
	10Y2043	7.28	3.52	28.2	6.3	3.32	25.2	5.11	3.04	1.68	21.1

Figure 1. Grain comparison of paddy, brown and milled S-102 and 10Y2043.

The total milled and head rice percentage of 10Y2043 and S-102 were taken at varying harvest moistures from 2017 and 2018 milling plots. Samples were collected when the moisture content of the grains averaged between 22-23% until moistures dropped to approximately 16.6%. The harvested samples were cleaned and dried, then milled to calculate the total rice and whole/head rice percentages. In 2017, milling data showed that the head rice yield of 10Y2043 harvested at 19-22% grain moisture averaged 61/67 (head/total) percent compared to 57/67 for S-102. When cut at moistures below 19%, the milling yield of 10Y2043 and S-102 were 61/70 and 57/68, respectively. In 2018, milling yield at 16-19% moisture content of 10Y2043 was 52/70 while S-102 was 52/68.

RVA and Quality Evaluations

Grain qualities such as apparent amylose content, protein content, and gel type of 10Y2043 were taken and compared to S-102 (Table 6). 10Y2043 has a lower AAC than S-102 with values of 14.4% and 16%, respectively. The protein contents of both brown and white rice of 10Y2043 are higher by 1.3% than S-102, but the gel type of both varieties is low.

Table 6. Apparent amylose, protein content and gel type of S-102 and 10Y2043.

Entry	Apparent Amylose content (%)	Protein, Brown (%)	Protein, White (%)	Gel Type
S-102	16.0	6.9	6.2	Low
10Y2043	14.4	8.2	7.5	Low

Comparison of RVA profiles for two varieties were collected in 2017 and 2018, and summarized in Table 7. S-102 has an average RVA peak, trough, and breakdown of 253, 141 and 112, respectively, with a final viscosity of 250, a setback of -3 and pasting temperature of 93. In contrast, the 10Y2043 has RVA peak, trough, and breakdown of 260, 121, and 139, respectively. The final viscosity of 10Y2043 is 219, which is 30 points lower than S-102. The setback is much lower (-41), but its pasting temperature is only 2ºF lower than S-102. Cooking and sensory evaluations by panelists of marketing organizations indicated an overall market acceptability of 10Y2043 similar to conventional S-102.

Table 7. RVA profile of 10Y2043 and S-102 at RES in 2017 and 2018.

Year	ID	Peak	Trough	Break down	Final Viscosity	Setback	Pasting Temp
2017	S-102	244	142	102	245	1	94
	10Y2043	229	119	110	209	-20	94
2018	S-102	262	140	122	254	-8	91
	10Y2043	292	123	168	229	-63	88
Mean	S-102	253	141	112	250	-3	93
	10Y2043	260	121	139	219	-41	91

Blanking and Disease Reaction

The cold-stress-induced blanking of 10Y2043 and S-102 are summarized in Table 8. Over the two-year experiments in San Joaquin cold nursery, 10Y2043 consistently showed a higher cold tolerance than S-102, as reflected in its lower percent blanking (1.46 %) when compared to S-102 (1.96%). Greenhouse experiments suggest that both S-102 and 10Y2043 have comparable levels of blanking.

Disease reactions of 10Y2043 and S-102 to stem rot (SR), aggregate sheath spots (ASS), and blast (BL) were documented for several years. On average, both S-102 and 10Y2043 are susceptible to stem rot, and moderately tolerant to ASS and blast diseases.

Table 8. Cold stress tolerance and disease reactions of 10Y2043 and S-102.

ID	% SJ Blanking	% GH Blanking	SR	ASS	BL
S-102	1.96	55.48	4.83	2.25	2.48
10Y2043	1.46	61.63	5.22	2.39	2.87

RECOMMENDATION FOR 2019 FOUNDATION SEED INCREASE

12Y2175 – Calrose Medium Grain

Agronomic Performance and Attributes

A Calrose-type medium grain, 12Y2175, is a line derived from a cross between M-206 and 06Y026 in 2007. Some notable parents in its pedigree are M-203 and M-205, which are early-flowering, high-yielding medium grain varieties, and M-401, a premium medium grain rice. The 12Y2175 has been in the statewide yield tests since 2013 and has consistently showed yield advantage over M-206, M-205, and M-209.

Table 9 summarizes the agronomic and yield data comparison of 12Y2175 against M-105, M-206, and M-209 at three maturity group experiments of the SW Tests at RES in 2018. In the very early SW group, 12Y2175 reached 50% heading at 80 days which is 7 days later than M-105, but nearly the same as M-209. It is 3 cm taller than M-105 but 1-2 cm shorter than M-206 and M-209. It has better lodging resistance than M-105 in the early SW Tests. 12Y2175 has an average yield of 10,740 lbs./acre at RES and a pooled mean of 9680 lbs./acre in the SW Tests. In the late-intermediate group, 12Y2175 yielded 11,420 lbs./acre at RES and 10,960 lbs./acre at SW Tests.

Overall, 12Y2175 had an excellent performance in 2018 with yield advantage of 10-21% over M-105, 9-19% over M-206 and 9% over M-209. The seedling vigor of 12Y2175 is similar to all check varieties. On average, 12Y2175 heads in 81 days, stands 5 cm taller than M-105 and M-209, is lodging resistant (3.3%), but slightly more sensitive to cold stress compared to check varieties, and is susceptible to stem rot.

Grain and Quality Attributes

Table 10 shows the grain dimensions of paddy, brown and milled rice samples of 12Y2175, M-206, and M-209. The milled rice grains of 12Y2175 were heavier (1000-grain weight =23.1 g) and slightly wider (width=2.83 mm) compared to M-209 (22.6g, 2.69mm) and M-206 (21.2g, 2.70 mm), while the grain length (5.92mm) and length/width ratio (2.09) were in between M-206 and M-209. With slightly heavier grains and grain dimensions meeting the criteria of the Calrose rice market, 12Y2175 can be co-mingled with other Calrose rice varieties currently in production in California.

The total milled and head rice percentage of 12Y2175, M-206 and M-209 were taken from varying harvest moistures at RES in 2018 milling plots. Sampling started when grain moisture content averaged about 25% until moistures dropped to approximately 15%. This entailed collecting samples twice a week for about 4-8 sampling dates for each of the entries. Harvested samples were cleaned and dried, then milled to measure the percentages of total rice and whole/head rice. All the data gathered in 2018 was categorized into samples taken above 19% moisture, 17-19%, and below 17% harvest moisture for 12Y2175, M-206, and M-209 (Table 10). Milling data showed that the milling yield of 12Y2175 when harvested at above 19% grain moisture averaged 65/69 (head/total) compared to 65/70 and 64/69 for M-206 and M-209, respectively. When cut at moistures between 17-19%, average milling yield was found as 58/69, 55/69 and 63/70 (head/total) for 12Y2175, M-206 and M-209, respectively. Data on RVA profile of 12Y2175, M-206 and M-209 taken in 2018 is summarized in Table 10. Internal evaluation, as well as external cooking quality evaluations by selected marketing organizations, showed similar observations. Feedback was favorable, indicating acceptability of quality in the market.

Table 9. Grain yield and agronomic performance of 12Y2175 and medium grain variety checks at RES SW Tests in 2018.

Entry	Grain Yield (lbs/A, 14%MC)		Harvest MC (%)	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	SJ Blanking (%)
	RES	State							
Very Early Group									
12Y2175	10930	9680	18.5	4.9	80	102	5	4.7	5.5
M-105	8600	9090	17.7	4.9	73	99	11	5	3.8
M-206	9090	9020	18.4	4.9	75	104	24	4	5.8
M-209	9710	9040	18.8	4.9	79	103	0	4	4.3
LSD (.05)	923		1.43	0.07	1.3	5.4	15		2.4
Early Group									
12Y2175	10740	9680	18.3	4.9	81	106	4	3	7.3
M-105	9360	8900	17.9	4.9	72	102	48	5	2.5
M-206	9050	8910	18.7	4.8	75	104	38	4.3	2.5
M-209	10640	9040	19.9	4.8	80	99	0	3.3	3.8
LSD (.05)	704		0.87	0.09	1	4.2	20		3.8
Intermediate-Late Group									
12Y2175	11420	10960	19.2	4.8	82	105	1	5	4.3
M-105	9350	9620	17.5	4.9	73	96	3	4.7	1.5
M-206	9730	9770	18.5	4.9	76	100	30	4.3	1.5
M-209	9760	9780	19.7	4.8	80	97	0	3.7	3.8
LSD (.05)	1123		1.1	0.07	1.4	5.9	20		2.9
MEAN									
12Y2175	11030	10110	18.7	4.9	81.0	104.3	3.3	4.2	5.7
M-105	9103	9200	17.7	4.9	72.7	99.0	20.7	4.9	2.6
M-206	9290	9230	18.5	4.9	75.3	102.7	30.7	4.2	3.3
M-209	10037	9290	19.5	4.8	79.7	99.7	0.0	3.7	4.0

‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = Resistant and 5 = Susceptible

Table 10. Grain characteristics of 12Y2175, M-206 and M-209.

Trait	M-206	M-209	12Y2175
RVA profile			
Peak	244	261	237
Trough	116	125	122
Break down	129	136	116
Final Viscosity	218	230	228
Setback	-26	-30	-9
Pasting Temp	93	93	95
Grain Dimension			
Paddy Rice			
Length (mm)	8.48	8.68	8.51
Width (mm)	3.23	3.17	3.37
1000- seed wt.	29.19	30.65	31.26
Brown Rice			
Length (mm)	6.20	6.55	6.32
Width (mm)	2.82	2.78	2.91
1000- seed wt.	24.40	25.37	25.48
Milled Rice			
Length (mm)	5.73	6.01	5.92
Width (mm)	2.70	2.69	2.83
Length/Width Ratio	2.12	2.23	2.09
1000- seed wt.	21.23	22.55	23.07
Milling performance			
MC greater than 19%	65/70	64/69	65/69
MC=17-19%	63/70	55/69	58/69
MC less than 17%	.	.	53/69

14Y1006 –Conventional Long Grain

Agronomic Performance and Attributes

Another line recommended for foundation seed increase is a conventional long grain designated as 14Y1006, which is an early maturing sister line of L-207. To characterize the performance of 14Y1006, it was evaluated in three SW maturity groups and compared with L-206 and L-207 (Table 11). In the very early SW Tests at RES, 14Y1006 has an average yield of 10620 lbs./acre compared to 9770 lbs./acre and 9900 lbs./acre for L-206 and L-207, respectively. It heads in 73 days after planting, which is 2 days earlier than L-206, with plant height of 97 cm. In the early SW at RES, 14Y1006 yielded 10,990 lbs./acre, and consistently showed higher yield than L-206 with a mean yield of 9750 lbs./acre. Compared to L-207, it has a slightly higher yield with a mean yield of 10,120 lbs./acre. In the intermediate-late SW group tests, 14Y1006 showed better yield than L-206 and L-207.

Overall results in the SW Tests at RES indicate that 14Y1006 is an excellent high yielding conventional long grain with 10-12% yield advantage over L-206 in all locations and with 2-5% higher yield than L-207. This line has a mean heading date of 74 days like the L-206; it is 7 cm taller than L-206 but 11 cm shorter than L-207. 14Y1006 is considered lodging resistant with 4% lodging percentage and also cold resistant with 4.7% blanking.

Grain and Quality Attributes

Milling yield of 14Y1006 is similar to L-207, and grains are less chalky. Internal evaluation of cooked 14Y1006 indicates favorable and similar texture to L-207. Based on RES experiments in 2018 (Table 12), the milled rice kernels of 14Y1006 has a 1000-kernel weight of 20.67 grams compared to 20.79 and 22.13 grams for L-206 and L-207, respectively. Milled grains of 14Y1006 were shorter (7.20 mm) than L-206 (7.26 mm) and L-207 (7.49 mm) narrower than L-206 (2.16 mm) and similar to L-207 (2.09 mm wide). The length to width ratio of milled rice is 3.44. The overall milling performance of 14Y1006, L-206 and L-207 harvested under high moisture (>19%), optimum moisture (17-19%), and low moisture (<17%) were determined. In 2018, data showed that the milling yield of 14Y1006 when harvested at 17-19% moisture is 67/70 (head/total) compared to 63/70 and 64/71 for L-206 and L-207, respectively.

RVA and Quality Evaluations

Based on the results of the RVA, 14Y1006 is characterized by having higher peak viscosity, breakdown values, final viscosity value, and a negative setback than L-206 and L-207 (Table 12), indicating softer and less sticky cooking characteristics.

Table 11. Grain yield and agronomic characteristics of 14Y1006, L-206 and L-207 in SW Tests, RES location in 2018.

Variety	Grain Yield (lbs/A, 14%MC)		Harvest, MC (%)	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	SJ Blanking (%)
	RES	SW							
Very Early Group									
14Y1006	10620	10260	14.8	4.9	73	97	3	3	6.3
L-206	9770	9060	14.5	5	75	94	1	4.3	6
L-207	9900	9940	14.1	4.9	75	111	0	4.3	4.8
LSD (.05)	923		1.43	0.07	1.3	5.4	15		2.4
Early Group									
14Y1006	10990	9930	14.3	4.9	75	103	9	4.7	3.3
L-206	9750	8900	13.9	4.8	75	95	0	4.3	5
L-207	10120	9720	14.2	4.9	78	112	0	4.3	6
LSD (.05)	704		0.87	0.09	1	4.2	20		3.8
Intermediate-Late Group									
14Y1006	10630	10430	14.6	5	74	100	0	5	4.5
L-206	9540	9440	14.2	4.8	73	92	1	5	2.5
L-207	10590	10440	14.2	4.8	77	110	0	4.3	5.5
LSD (.05)	1123		1.1	0.07	1.4	5.9	20		2.9
MEAN									
14Y1006	10750	10210	14.6	4.9	74.0	100.0	4.0	4.2	4.7
L-206	9690	9130	14.2	4.9	74.3	93.7	0.7	4.5	4.5
L-207	10200	10030	14.2	4.9	76.7	111.0	0.0	4.3	5.4

‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = Resistant and 5 = Susceptible

Table 12. Grain, milling and cooking attributes of 14Y1006, L-206 and L-207.

Trait	**L-206**	**L-207**	**14Y1006**
RVA profile			
Peak	235	264	301
Trough	118	112	126
Break down	117	152	175
Final Viscosity	259	240	265
Setback	24	-24	-36
Pasting Temp	91	78	78
Grain Dimension			
Paddy Rice			
Length (mm)	10.30	10.61	10.14
Width (mm)	2.56	2.39	2.42
1000- seed wt.	28.20	29.58	28.70
Brown Rice			
Length (mm)	7.89	7.99	7.66
Width (mm)	2.23	2.14	2.14
1000- seed wt.	23.04	23.72	22.61
Milled Rice			
Length (mm)	7.26	7.49	7.20
Width (mm)	2.16	2.08	2.09
Length/Width Ratio	3.36	3.60	3.44
1000- seed wt.	20.79	22.13	20.67
Milling performance			
MC greater than 19%	60/68	.	66/70
MC=17-19%	63/70	64/71	67/70
MC less than 17%	64/71	64/70	.

MEDIUM GRAINS BREEDING

The main goal of the medium grain project is to develop rice varieties with high and stable grain and milling yields as well as possessing high grain quality typical of Calrose-type and premium MG varieties. To achieve the breeding objectives of the project, emphasis is given to selecting materials with high seedling vigor and tolerance to low temperature-induced sterility or blanking. The cold tolerance screening is conducted in refrigerated greenhouses at RES and at San Joaquin nursery. Grain or brown rice appearance is examined from the earliest generation until a new variety is released. Milling yield in terms of both total and head rice are given top priorities in grain evaluation of advanced lines. Disease resistance to stem rot, aggregate sheath spot and rice blast are being incorporated in the varieties being developed, despite difficulty in disease resistance screening.

Breeding materials such as F_1 transplants, early generation progeny rows, and advanced stable breeding lines are mostly planted by hand at the RES breeding nursery, starting the second Monday of May, while the F_2 nursery and seed maintenance plots are drill-seeded in the first week of May. Advanced selections and new F_1 lines are also planted in the Hawaii Winter Nursery in November for seed increase and generation advance.

The medium grain project employs both traditional and molecular breeding methods. DNA markers, mostly microsatellite markers, are routinely and effectively being used in marker-assisted selection (MAS) blast resistance and grain quality as well as for fingerprinting and purity testing of breeding materials at various stages of development. It will soon embark in research geared towards using new tools in plant breeding like the use of genomic selection in an effort to breeding more efficiently and faster.

Performance of Medium Grain Varieties

The check varieties such as M-105, M-205, M-206, M-209, M-210 and M-104 are still in commercial production in California. For all evaluations, these varieties are being used as checks in experiments for PY, advanced AY, and preliminary and advanced SW Tests by UCCE. Table 13 summarizes the yield performance of the check varieties from the pooled data of the three maturity groups of the UCCE SW Tests in 2018 at the RES location. The M-209, a released variety in 2015, continues to be the top yielding check variety with an average grain yield of 10,040 lbs./acre compared to M-206 and M-205 yields of 9290 and 9240 lbs./acre, respectively. For the last six years, the grain yield performance of M-209 at RES was better than M-206 and M-205. It is adapted in warmer areas where M-205 is successfully grown. However, it may not perform well in cooler areas like San Joaquin County. Additionally, M-209 is lodging resistant and 3cm shorter than M-206. Among the check varieties, the M-104 had the lowest yield (7960 lbs./acre).

Table 13. Average grain yield and agronomic characteristics of medium grain check varieties in the UCCE Statewide Tests at RES in 2018.

Variety	Grain Yield (lbs/A,14%MC)	Harvest MC (%)	Seedling Vigor	Days to Heading	Lodging (%)	Plant Height (cm)
M-104	7960	15.7	4.9	70	28	96
M-105	9100	17.7	4.9	73	20	99
M-205	9240	18.4	4.9	82	0	96
M-206	9290	18.5	4.9	75	30	103
M-209	10040	19.5	4.8	80	0	100
M-210	9090	18.4	4.9	75	25	99

Promising Medium Grains in SW Tests

The yield and agronomic attributes of promising medium grains advanced lines tested in the 2-replicate preliminary SW Tests for very early, early and intermediate-late groups planted at RES are summarized in Table 14. The medium grain varieties M-104 and M-205 were used as check varieties. Thirteen promising lines showed higher yield compared to the check varieties and potential selected to the 2019 SW Tests pending grain quality evaluation. Two advanced lines that performed well in 2017 SW Tests, 15Y3171 and 15Y2153, were entered in all three maturity groups of the preliminary SW Tests.

In the very early group, 15Y3171 has the highest yield of 10500 lbs./acre followed by 17Y3150 at 10,380 lbs./acre; while a premium quality entry, 15Y2153, had a mean yield of 9920 lbs./acre. 15Y3171 heads a day later than M-205, is lodging resistant (0%) but susceptible to stem rot. It has a comparable cold tolerance level with M-205 but slightly lower level than M-104. On the other hand, 15Y2153 has excellent seedling vigor, plant height of 100 cm, is lodging resistant, has cold-induced blanking of 20%, and is moderately resistant to stem rot.

In the early group, 15Y3171 consistently has the highest yield of 10930 lbs./acre followed by 15Y2153 with a mean yield of 10,570 lbs./acre. Other promising lines with yields higher than 10,000 lbs./acre are 16Y3112 (10,400 lbs./acre), 17Y3086 (10,320 lbs./acre), 16Y3108 (10,230 lbs./acre), 17Y3081 (10,230 lbs./acre), and 17P3389 (10,090 lbs./acre).

In the late-intermediate group, a new entry (17Y3158), had an excellent grain yield of 11,460 lbs./acre. It is also lodging resistant and moderately resistant to stem rot. This line also has excellent seedling vigor, but heads 4 days earlier than M-205. The entries 15Y3171 and 15Y2153 yielded 11,090 lbs./acre and 10,610 lbs/acre, respectively. These two lines showed better yields in this SW experiment as compared to the very early and early experiments. The 15Y3171 and 15Y2153 flowered at 83 and 84 days after planting, which is similar to M-205. 15Y3171 is 1 cm shorter than M-205 while the 15Y2153 is 3 cm taller to M-205. Both lines are lodging-resistant and cold-tolerant like the M-205. 15Y3171 is moderately tolerant to stem rot like the M-205 while the 15Y2153 is more susceptible to the disease. However, 17Y3158 showed higher yield than 15Y3171 and 15Y2153.

Table 14. Average grain yield and agronomic characteristics of promising medium grain lines in SW preliminary test at RES in 2018.

Entry	Grain Yield(lbs/A, 14%MC)	Type†	Harvest MC (%)	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	SJ Blanking (%)
Very Early Group									
15Y3171	10500	M	19.0	4.9	82	96	0	4.3	19.0
17Y3150	10380	M	19.4	4.9	77	100	0	4.3	19.4
15Y2153	9920	MPQ	20.7	4.9	85	100	0	3.0	20.7
M-205	8910	M	18.1	4.9	81	94	0	4.0	18.1
M-104	7670	M	15.6	4.9	71	93	15	4.7	15.6
Early Group									
15Y3171	10930	M	18.5	5.0	81	97	0	4.0	18.5
15Y2153	10570	MPQ	21.0	4.8	84	102	3	4.0	21.0
16Y3112	10400	M	20.1	4.8	81	109	0	5.0	20.1
17Y3086	10320	M	17.4	4.8	78	106	28	4.0	17.4
16Y3108	10230	M	20.7	4.9	85	100	0	3.3	20.7
17Y3081	10230	M	18.1	4.9	78	103	8	4.7	18.1
17P3389	10090	M	18.0	4.9	82	100	0	4.7	18.0
M-205	9280	M	18.0	4.9	81	96	0	2.3	18.0
M-104	8260	M	15.9	4.8	70	99	40	4.7	15.9
Intermediate-Late Group									
17Y3158	11460	M	19.3	4.9	80	103	0	3.3	19.3
15Y3171	11090	M	19.7	4.9	83	96	0	3.3	19.7
17P3355	11060	MB	20.4	4.9	82	102	0	4.7	20.4
15Y2153	10610	MPQ	21.6	4.8	84	100	0	4.0	21.6
17Y2039	10480	MPQ	19.8	4.9	85	95	0	4.0	19.8
16P3279	10420	M	20.5	5.0	82	101	2	2.7	20.5
M-205	9530	M	19.0	4.8	84	97	0	3.3	19.0

† M=Medium grain, MB=Blast resistant medium grain, MPQ=Premium quality medium grain

Breeding using Genomic Selection

Almost all the national and international rice breeding programs still use conventional breeding schemes. The pedigree method, which involves visual selection for several generations, takes so much effort and time. With the advancement of rice molecular genetics and genomics, MAS has been implemented in plant breeding programs. However, the overall efficiency of MAS to enhance breeding methods is still limited due to the small number of useable markers and the polygenic nature of most traits, which needs to be improved. A new approach called genomic selection (GS) showed enormous potential to enhance breeding efficiency by increasing the gain per selection per unit time. In this approach, instead of few tagged markers, genome-wide DNA markers are utilized to predict the most valuable lines in a breeding program to use as parents for next generation off spring, as well as in selection of off spring for quick advancement. By using genome-wide DNA markers, the GS model thus can avoid ascertainment bias and information loss compared to MAS. Integrating GS in the RES rice breeding program will not only enhance the breeding efficiency, but also enhance genetic knowledge of rice for continued varietal improvement.

In 2018 a training population was developed to analyze the variability of all the advanced lines in the last five years. The training population size is 360, which consists of 210 medium grain type, 64 long grain, 73 short grain and 13 compound grain types. All the released varieties from the RES are included in the population, thus the training population is expected to capture most of the diversity of the RES breeding program.

SHORT GRAINS BREEDING

The short grain breeding project aims to develop conventional short grain and specialty types such as waxy or sweet rice, low amylose, bold-grain, and premium short grain varieties. High emphasis is given to development of varieties with excellent overall grain characteristics while retaining the high and stable yield performance and environmental adaptation across the rice growing areas in California. All breeding materials, including the early and advanced lines, were evaluated for grain yield and agronomic traits, milling and cooking quality, cold and blanking resistance, lodging resistance and disease resistance.

Performance of Short Grain Varieties in Yield Tests

Experimental lines in nurseries and yield tests are compared against check varieties, which include: S-102, Calhikari-201 (CH201), Calhikari-202 (CH202), Calmochi-101 (CM101), Calmochi-203 (CM203), Calamylow-201 (CA201), and an Arborio-type germplasm line 89Y235. S-102 is a commercially grown short grain variety released in 1996 and is the standard short grain variety check. It is very early-maturing, has large seeds, is pubescent, and has good cold tolerance. CH202 is the latest premium quality variety released in 2012. It is early, short, and pubescent, yields higher than CH201, and has better eating quality, smaller grains, and higher milling yield. CM203 is the latest waxy or sweet rice released by CCRRF in 2015. It is a high yielding, glabrous, early-maturing variety released as an alternative to CM101. CA201 is a low amylose (~7%) RES variety and served as a check for low amylose lines. The 89Y235 is an Arborio-type (bold grain) germplasm released by RES in 1993.

The average grain yields and agronomic performance of the short grain checks in the SW Tests at RES location in 2018 are presented in Table 15. Data is based on pooled results of the three SW maturity groups, wherever the checks were entered. Grain yield of CM203 was the highest at 9430 lbs./acre followed by CH202 at 8390 lbs./acre, while the yield of CA201 was the lowest at 6443 lbs./acre. The grain yield of S-102 and CH201 are 8195 lbs./acre and 8203 lbs./acre, respectively. Seedling vigor of CH201 and CM203 were the best among the short grains. The Arborio check 89Y235, CH201, and CM203 showed high percentage of lodging that ranged from 50 to 85%. The short grain check varieties were observed to have 50% flowering from 71 to 78 days after planting, which were nearly the same as in 2017.

Table 15. Average grain yield and agronomic characteristics of short grain checks in the UCCE Statewide Tests at RES in 2018.

ID	Type†	Grain Yield (lbs/A, 14%MC)	Harvest MC (%)	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)
S-102	S	8200	10.8	4.9	71	96	26
89Y235	SBG	7240	14.8	4.9	75	104	85
CA-201	SLA	6440	14.8	4.9	76	96	32
CH-202	SPQ	8390	13.5	4.9	75	92	30
CH-201	SPQ	7990	12.1	5	78	96	53
CM-101	SWX	6600	11.3	4.9	73	95	33
CM-203	SWX	9430	15.6	5	74	99	62

† S = Short grain, SBG=Arborio-type short grain, SLA=Low amylose short grain, SPQ=premium quality short grain, SWX=Waxy short grain

Promising Conventional Short Grain

In addition to 10Y2043, three advanced lines and three preliminary lines in yield trials are promising, and show higher yield than conventional S-102. The six lines on average showed yield advantage that ranged from 500 lbs. to 2000 lbs. of rice per acre in the RES yield tests (Table 16). In statewide tests, the 6 promising lines showed an average of 12% yield advantage over S-102, or yield performance that ranged from 9160-9920 lbs./acre. The seedling vigor, plant height, and stem rot reactions of these 6 lines are nearly the same as S-102, but heads 2 to 8 days later. The lines 17Y2069, 17Y2046, and 17P2216 have percent lodging of 0, 3 and 5%, respectively compared to 26% lodging by S-102. 17Y2046 is very promising, with consistent grain yield of 9900 lbs./acre in both RES and statewide yield trials. Further evaluations of these lines will be conducted to observe if yield performance and grain quality characteristics are consistent across time and locations. Table 16 summarizes the yield and agronomic attributes of promising conventional short grains.

Table 16. Promising conventional short grains in SW Tests at RES in 2018.

Entry	Grain Yield (lbs/A, 14%MC)		Harvest MC (%)	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)	Stem Rot Score
	RES	State						
S-102	8200	8510	10.4	4.9	71	96	26	4
17P2215	10520	9160	17.9	4.9	77	100	55	5
17Y2048	9960	9730	15.0	4.8	72	94	20	5
17Y2046	9900	9920	12.7	5.0	75	97	3	4
17Y2069	9550	9640	14.4	5.0	73	98	0	5
17P2217	9110	9240	15.7	4.7	76	107	20	4
17P2216	8700	9390	16.5	4.9	75	97	5	4
Mean	9420	9370		4.9	74	98	18	4
F value	60.98	2.7		0.45	9.44	45.83	6.03	0.87
Pr>F	0.0983	0.4377		0.8183	0.2456	0.1133	0.3041	0.68

Promising Specialty Short Grains

Premium Quality Short Grains

Significant effort is exerted in evaluating advanced lines for grain and cooking quality for short grain premium quality. To improve the evaluation procedures, a Satake Taste Analyzer and S21 Grain Analyzer were included in the grain evaluations. Moreover, DNA markers are being explored to aid in the taste quality screening. For cooking and taste characteristics, all entries in the advanced yield trials of 2017 were evaluated while 2018 entries will be characterized in 2019. Based on yield and agronomic characteristics, at least six lines in the advanced yield trial are promising lines for short grain premium quality type (Table 17). The seedling vigor of all six lines are either similar or better than CH202 check. These promising lines, however, all flower later than CH202, with days to heading that range from 76-80 days after planting. Four of the 6 lines are taller than CH202 by 1-8 cm. Except for 15Y2112 and 16Y2117, all promising premium short grains are lodging resistant, despite being taller than CH202. Grain yield advantage of all lines ranged from 8580-9768 lbs./acre in RES, while in statewide tests, grain yield ranged from 8770 to 9370, compared to the CH202 yield of 8457 lbs./acre.

Table 17. Promising premium short grains in SW Tests at RES.

Entry	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)	Stem Rot Score	Harvest MC (%)	Grain Yield (lbs/A, 14%MC)	
							RES	State
15Y2024	4.9	78*	94	1.5	4.5	13.5	8580	9240
15Y2112	4.9	80*	98*	43	3.5	19.4	9770	9250
16Y2117	5.0	76	92	40	4	13.8	9930	8770
16Y2127	5.0	77	95	0	5	15.5	8580	9370
17Y2087	4.9	77	92	0	3	15.2	8800	8940
17Y2140	4.9	77	100*	0	4	15.6	8180	9020
Mean	4.9	77	93	14	4		8972	9098
F-value	0.45	14.61	10.17	2.2	2.14		5.99	0.67
Pr>F	0.8183	0.0108	0.0209	0.2331	0.2411		0.0525	0.6835

*Significantly different to CH202 ($P<0.05$)

Waxy Short Grains

CM203, a high-yielding, glabrous, early-maturing waxy variety, continues to outperform CM101 in terms of grain yield and seedling vigor in all RES and statewide tests. However, CM101 shows a better lodging resistance than CM203. This year, two promising lines showed better yield and agronomic characteristics when compared to CM203 or CM101. The 15Y2135 has an average yield of 9860 lbs./acre at RES and 9270 lbs./acre in the statewide tests. Likewise, the line 17Y2142 has an average yield of 10,090 lbs./acre at RES and 10,100 in the statewide tests. In contrast, CM101 has an average yield of 6600 lbs./acre and 7300 lbs./acre in RES and statewide test, while CM203 has an average of 9450 lbs./acre yield in both RES and statewide yield trials. Table 18 shows the agronomic and yield performances of promising waxy rice lines and check varieties for waxy type rice.

Table 18. Promising waxy short grains in SW Tests at RES.

Entry	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)	Stem Rot Score	Harvest MC (%)	Grain Yield (lbs/A, 14%MC)	
							RES	State
CM203	5	74	99	62	5	15.6	9430	9460
15Y2135	4.7	76	100	45	5	15.5	9860	9270
17Y2142	5	78	107	0	4	14.6	10090	10100
CM101	4.9	73	95	33	4	11.3	6600*	7300*
Mean	4.9	75	100	35	5		9793	9610
F-value	3.71	7.66	1.99	3.03	5.91		35.1	14.12
Pr>F	0.1549	0.0642	0.2934	0.1938	0.0893		0.0078	0.0283

*Significantly different to CM203 (P<0.05)

Arborio-type and Low amylose Short Grains

Breeding efforts to develop low amylose and Arborio-type short grains are being continued despite low demand for these types. The line 15Y2100 is a lodging-resistant, high-yielding low amylose line with an average yield ranging from 9500 to 9600 lbs./acre, a 33-48% yield advantage over CA201. Compared to CA201, 15Y2100 has slightly higher amylose content, and heads two days later.

The demand for Arborio-type in the market remains uncertain and breeding for the Arborio-type remains a challenge due to the inherit chalky grain trait of Arborio. The most promising material in the pipeline for short bold grain is line 16Y2058 with an additional yield of 300-400 lbs./acre over the yield of 89Y235 check. Field evaluation indicated that 16Y2058 has better seedling vigor and is more lodging resistant compared to 89Y235. Table 19 summarizes the agronomic and yield attributes of promising low amylose and Arborio-type short grains.

Table 19. Promising low amylose and Arborio-type short grains in advanced yield tests at RES and SW.

Entry	Type †	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodg (%)	Stem Rot Score	Amylose Content (%)	Harv. MC (%)	Grain Yield (lbs/A, 14%MC)	
									RES	State
CA201	SLA	4.9	76	96	32	4.6	6.3	14.8	6440	7170
15Y2100	SLA	4.9	80	98	0	5	8.0	14.1	9570	9600
89Y235	SBG	4.9	75	104	85	5	18.8	14.8	7240	8320
16Y2058	SBG	5	77	104	20	4.7	17.8	15.2	7600	8750

† Type, SLA = Low amylose short grain, SBG = Arborio-type short grain

LONG GRAINS BREEDING

The long grain breeding program continues its effort in developing superior long grain varieties for California that include: (1) Conventional long grain and, (2) Specialty types such as Jasmine-types, Basmati-types, and aromatic long grains. The conventional long grain rice attributes in the US is based on quality characteristics of Southern US varieties. Cooking quality of conventional long grains are characterized 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 soft texture types in breeding material. Under the specialty long grains, the Jasmine-types are characterized by low amylose, low gel type, fragrant rice that have been derived from a tall and highly photoperiod sensitive Thai Jasmine variety, Khao Dawk Mali (KDM). Through mutation breeding efforts, non-photoperiod KDM mutants have been identified and isolated and used in the breeding program. For the regular aromatic long grains, a considerable number of aromatic lines are being generated from populations geared towards breeding for Jasmine quality. These aromatic long grains cook like conventional long grains but with an added aroma. California Basmati-types, such as Calmati-202, have low yield potential and are susceptible to low temperature stress. Despite grain and cooking quality approaching those of imported Basmati, breeding for Basmati-type varieties with improved yield potential and better agronomic attributes remains a great challenge.

Milling and cooking quality improvements for conventional and specialty long grain types remain the major priority breeding objectives, while concurrently improving yield potential and agronomic performance and introducing important traits like resistance to cold induced blanking and disease resistance traits as well.

Performance of Long Grain Varieties and Promising Entry in Yield Tests

Test materials in the 2018 SW Tests were compared to the long grain check varieties: L-207, L-206, CJ201, and A-202 for grain yield and agronomic performance. Milling characteristics, grain quality, blanking and disease reaction of these checks were also analyzed. L-206, an early-maturing, high-yielding conventional long grain variety with very good grain quality, has been the standard check variety for many years since its release in 2006. L-207 is the newest conventional long grain variety released in 2016 with higher yields, intermediate height, is early-maturing, and possess the Southern US long grain cooking quality. L-207 is adapted to most rice-growing areas in the state except the cold area of San Joaquin. Head rice yields of L-207 ranged between 63 to 67% compared to L-206, which ranged from 62 to 63%. Physicochemical testing of L-207 by the USDA Rice Quality Lab confirms it is similar to Southern long grains, with intermediate amylose, intermediate gel type, and moderate RVA profile. It had significantly lower stem rot disease and aggregate sheath spot resistance compared to L-206.

A-202 is a conventional aromatic variety that was released in 2014 as a replacement for A-301. A-202 heads 9 days earlier, is taller, and has a significantly higher seedling vigor score than A-301, but still has the same flavor sensory profile as A-301. Milled kernels of A-202 are slightly bolder than A-301, with apparent amylose content, gelatinization temperature type and RVA profile that is typical of conventional long-grain types like L-206 and L-207. Areas of adaptation for A-202 include Butte, Colusa, Yuba, Glenn, and Sutter counties and but are not recommended to be grown in the colder rice areas.

The average grain yield and agronomic performance of L-206, L-207, CJ201 and A-202 in the SW Tests at RES location in 2018 are summarized in Table 20. Data is based on pooled results of the very early, early and intermediate-late group experiments. Grain yield of L-207 was 10,200 lbs./acre compared to 9,690, 10,610 and 9,310 lbs./acre for L-206, CJ201 and A-202, respectively. L-207 headed at 77 days after sowing, which is 3 days later than L-206 and two days earlier than CJ201, with plant height taller by 18 cm but without any lodging penalty.

Table 20. Average grain yield and agronomic characteristics of long grain varieties in the SW Tests at RES in 2018.

Variety	Type†	Grain Yield (lbs/A,14% MC)	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)	Stem Rot Score
A-202	LA	9310	5	76	101	0	4.3
CJ201	LJ	10610	4.9	79	94	0	4.9
L-206	L	9690	4.9	74	94	1	4.5
L-207	L	10200	4.9	77	111	0	4.3

† L=long grain, LA=Aromatic long grain, LJ=Jasmine-type long grain

Promising Lines

In addition to 14Y1006, which performed well in RES and statewide yield trials, four promising lines showed higher yield than CJ201 and L-207 at RES experiments (Table 21). The new entry 17Y1100 has excellent seedling vigor, heads at 78 days, is moderately resistant to stem rot, and has a mean yield of 10,200 lbs./acre in all locations. However, it is susceptible to lodging (50%). Another promising line with moderate stem rot resistance is 17Y1083. It also flowers at 78 days, about 11cm shorter than 17Y1100 and lodging resistant (0%). The mean yield performance of 17Y1083 in RES and in statewide trials is 10,190 lbs./acre and 9,110 lbs./acre, respectively. These yields are lower than CJ201 and L-207 but higher than L-206 and A-202. Among the entries that enter the statewide tests, one long grain Basmati type, 16Y1154, has higher yield than A-202, with an average yield of 9660 lbs./acre and 9340 lbs./acre in RES and statewide. The 16Y1154 performed best in Butte, Colusa and RES experiments but had lower yield in cooler places such as Yuba County. 17Y1027 and 16Y1029 are promising conventional long grain lines, adapted to warmer locations such as Butte and Colusa Counties. The overall yield and agronomic performance of promising long grain entries are summarized in Table 21.

The performance of promising lines are evaluated in three maturity groups of the SW Tests. Based on the very early group experiment, the 17Y1100 has a mean yield of 10880 lbs./acre at RES and 9520 lbs./acre at statewide. Compare to A-202, the 17Y1100 has yield advantage of 5-14% at RES and statewide tests. The 17Y1100 heads 1 day later than A-202, is 1 cm taller and slightly more resistant to stem rot than A-202. 17Y1100, however, is more susceptible to lodging, despite having nearly the same plant height as A-202. Additional promising lines in the very early group experiment with higher yield than A-202 are listed in Table 21.

Table 21. Average grain yield and agronomic characteristics of promising long grain entries at RES and statewide tests in 2018.

Entry	Type†	Seedling Vigor	Days to Heading	Plant Height (cm)	Lodging (%)	Stem Rot Score	Harv. MC (%)	Grain Yield (lbs/A, 14%MC)	
								RES	State
Very Early									
17Y1100	LSR	4.9	78	104	50	3.7	15.5	10880	9520
17Y1087	LSR	5	76	102	0	4	14.4	10390	9590
17Y1007	LSR	5	74	100	0	5	14.3	10190	9640
16Y127	L	5	77	107	0	4.3	15.2	10010	9610
17Y1063	LJ	5	78	106	8	4	18.9	9940	8230
17Y1002	LSR	5	74	110	3	5	15.7	9330	9590
A-202	LA	5	77	103	0	4	15.4	9540	8990
Early									
17Y1027	L	4.8	75	97	0	5	14.6	10480	9730
16Y1029	L	4.8	76	99	0	4	14.8	10250	9200
17Y1083	LSR	4.8	78	93	0	3.7	15	10150	9110
16Y127	L	5	78	104	0	3.7	15.3	9740	8960
16Y1154	LB	4.9	76	112	0	4.7	13.9	9660	9340
A-202	LA	4.9	76	99	0	4	15.2	9070	8620
Inter- Late									
16Y127	L	4.9	77	101	8	4	15.7	9950	9350
A-202	LA	5	75	101	0	5	15.1	9320	8980

† L=Long grain, LSR=Stem rot resistant long grain, LA=Aromatic long grain, LJ=Jasmine-type long grain, LB=Basmati-type long grain

RICE PATHOLOGY RESEARCH

Integral to all crop breeding programs is development of disease resistance, as plants are immobile and in constant interaction with pests and pathogens. The rice pathology is one of the support arms for the CCRRF breeding program. Despite the absence of major disease outbreak in California, research and breeding efforts to develop rice varieties with resistance to stem rot, aggregate sheath spot, and rice blast continue. The Sacramento Valley weather from June to September 2018 was nice and cool for rice production. The average high and low temperatures were 90ºF and 60ºF, respectively. During the four-month period, the average precipitation was only 0.14 inches, with an average humidity of 55%. However, in the month of October, the valley received four days of rain, which increased the humidity to 63% and likely resulted in favorable conditions for development of few kernel smut that sometimes was mistakenly identified as ashes from wild fires. Additionally, stem rot was noted in fields in 2018.

Stem Rot

The RES continues to work on stem rot resistance project with the cooperation of Drs. Teresa De Leon and Cynthia Andaya. Dr. De Leon leads the pathology work in stem rot inoculum preparation, greenhouse and field evaluations, while Dr. C. Andaya is responsible for gene discovery and marker identification for stem rot resistance. To validate the resistance response of RES breeding materials to stem rot, greenhouse and field experiments were conducted. The inoculum was propagated and prepared from 16K1d1 Butte isolate collected by Jeff Oster in 2011. Based on previous characterization among isolates, this isolate has a virulence of 10, which is highly infectious to rice.

For the stem rot greenhouse experiment, 185 recombinant inbred lines (RILs) and 52 F_2 lines, developed from a cross between M-206 and 87Y550 were evaluated in randomized block design. The whole experiment was replicated three times with five plants per line. M-206 is susceptible to stem rot infection while 87Y550 is a resistant line. The plants were grown in pots following the standard soil fertilization. During the tillering stage around 40 days after planting, additional nitrogen was applied to enhance stem rot infection. On the 55-58th day, each plant was inoculated with approximately 2 ml of stem rot dust sclerotia. Disease development such as black lesions on the stems were observed 4-6 weeks after inoculation. Some blanking and lodging were also observed in susceptible lines (Fig. 2). For this experiment, a 1 to 5 scoring system was implemented with 1 as high resistant, 2 as resistant, 3 is moderately resistant, 4 is susceptible, and 5 is highly susceptible. Disease scores were based on percentage of stem infection, degree of pathogen penetration to leaf sheaths and formation of sclerotia in the culm. Table 22 summarizes the stem rot rating scale and symptoms observed for each score.

Figure 2. Symptoms of stem rot disease in rice by *Sclerotium oryzae*.

Table 22. Stem rot scoring system and symptom descriptions.

Stem rot score	Stem rot infection
1.0	No infection, leaf sheaths and culm are clean, no black lesion or sclerotia observed.
2.0	Leaf sheaths showed black lesion but culm is clean and no sclerotia is observed.
3.0	Leaf sheaths showed black lesion, covering 50% the stems, sclerotia are present inside the culm.
4.0	Leaf sheaths showed black lesion, covering 75% of the stems, sclerotia are present inside the culm, and culm started to rot.
5.0	Leaf sheaths showed black lesion, covering 100% of the stems, sclerotia are present inside the culm, stems are rotting, and snapping from the node.

Screening for stem rot resistance was also conducted in the field using the same batch of stem rot inoculum in the greenhouse experiment. A total of 3,600 rows including RILs, F_2, entries in advanced and statewide yield trials, and Uniform Rice Nursery (URN) materials from the South were evaluated for stem rot resistance.

Greenhouse evaluations indicated that out of 185 RILs, and 52 F_2 lines, only 26 RILs and four F_2 showed resistance to stem rot (Fig. 3). While the greenhouse screening is supposed to be more uniform and harsher than field screening, results indicated that only 3 of the 185 RILs were resistant to stem rot in the field. There was a low positive correlation (correlations of only 0.37) between results of greenhouse and field screening, indicating the complexity of disease. The data suggest that although greenhouse experiment may be conducted for stem rot screening, field conditions are better for disease development and evaluation for resistance. All variety checks in field evaluation are susceptible to stem rot except for CM101, which showed moderate stem rot resistance (scored 3). Among the AY and SW entries, 7 lines in the advanced yield trail showed resistance and scored between 2 to 2.3. Additionally, two lines out of 200 URN materials, (17URN-85,17URN-182) showed high resistance in the field evaluation (Fig 4.)

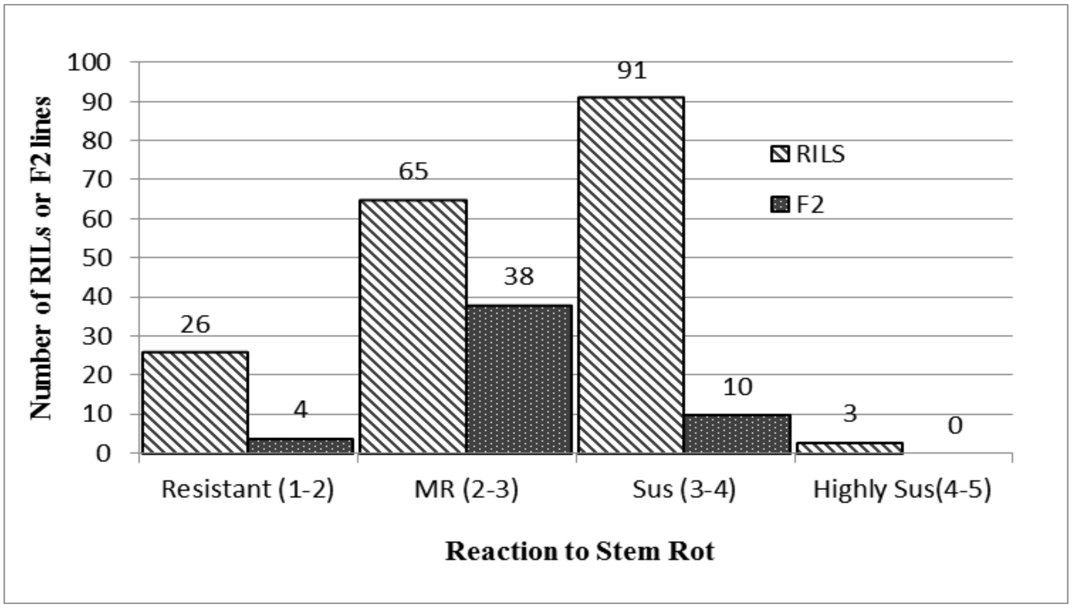

Figure 3. Summary of greenhouse stem rot screening in RILs and F_2 populations.

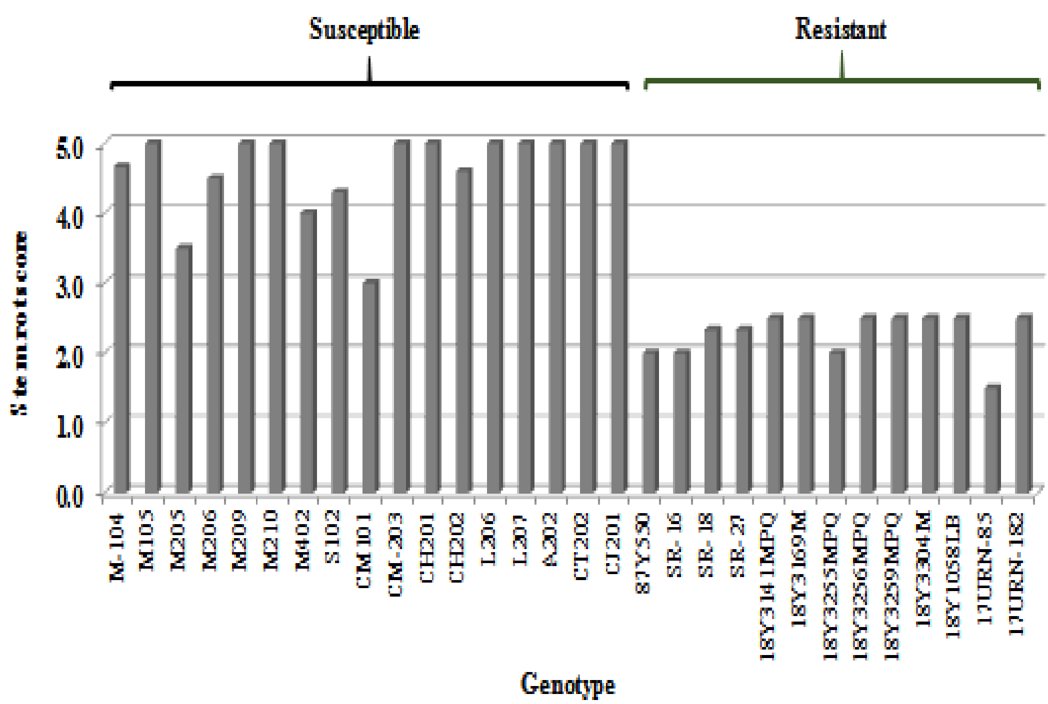

Figure 4. Reactions of variety checks and resistant lines identified in 2018 stem rot field screening.

Blast Disease

The presence of rice blast disease in California is not documented well in the past years. Nevertheless, effort on incorporation of blast resistance to California rice varieties was initiated. In 2005 and 2006, M-207 and M-208 were released as blast resistant varieties, containing *Piz* resistance gene. However, in 2009, M-208 succumbed to a new race of blast. This prompted the CCRRF to continue the effort in breeding rice for blast resistance. By backcrossing, several blast resistance genes (*Pib*, Pik^h, Pik^m, Piz^5, *Pi9*, *Pi40*, and $Pi\text{-}ta^2$) were introduced to M-206. In 2018, one of the near-isogenic lines of M-206 with a blast resistance gene, *Pi-b*, was released as a blast-resistant medium grain to replace M-208. To prevent the spread of disease during screening, the use of DNA markers for selecting blast resistant lines has been successful and routinely used in the breeding program. These markers are also being used to pyramid blast resistance genes (*Pi40*, Pik^h, and $Pi\text{-}ta^2$) mostly in the medium grains.

Aggregate Sheath Spot

Development of resistance to aggregate sheath spot was initiated in 2005 by backcrossing the resistance genes from Teqing, Jasmine 85, and MCR10277 to M-206 and L-206. Breeding lines developed in those crosses were advanced in the greenhouse and field. This year, greenhouse and field screening for aggregate sheath spot was not conducted due to the absence of a full time plant pathologist. Lines derived from the three donor parents are kept in the cold storage for future reference and use.

Quarantine Introductions

The CCRRF participates in the uniform regional rice nursery (URRN) of the Southern US rice breeding programs by providing field evaluation of Southern US rice materials. However, the seeds from outside California must undergo a brown rice quarantine protocol before field evaluation. Briefly, the seeds were de-hulled to check for unintended introduction of weedy red rice. After which, the seeds were treated with bleach and germinated in sterile condition in the laboratory. Seeds that showed fungal or bacterial infections were immediately autoclaved before discarding. To ensure that Southern germplasm seeds are clean of pest and diseases, only clean seedlings without infection are transplanted in the greenhouse and grown to full maturity. Once plants and seeds are confirmed clean of any diseases, the seeds are eligible for the next season’s field evaluation. Hence, normally, the result of California field evaluation is given to the South one year after receiving the seeds.

In 2017, a total of 200 URRN lines were received, but only 111 lines were evaluated in the disease nursery. Data gathered on heading date, plant height, stem rot score and yield data per row were then sent to the South after the experiment. This year, 237 lines were received and quarantined in the laboratory. Four to seven days after sterile seed germination, high infection rate ranging from 76-98 % were noted from Louisiana and Texas entries. Fungal infection from Mississippi entries were 35%, Arkansas entries had 28% infection, while Missouri had one infection out of 14 lines received. The low infection rate of seeds from Missouri is attributed to the chemical seed coating applied to the seeds prior to shipment to California. Clean seedlings were grown in the greenhouse. After two cycles of planting in the greenhouse, clean seeds were harvested and will be planted in 2019 disease nursey for field evaluation.

DNA MARKER LABORATORY

Since its establishment in 2008, the DNA Lab has been performing activities in support of breeding work as well as implementing special projects. It has become an integral component of the breeding program to do the following: marker-aided selection (MAS) work for blast resistance, grain quality, aroma and herbicide tolerance; fingerprinting and purity testing of advanced lines; genetic mapping studies for stem rot resistance and herbicide tolerance to oxyfluorfen; and generation of mutant populations using both irradiation and chemical mutagenesis. The DNA Lab has played an important role in the herbicide resistance project by generating rice mutant populations using chemical mutagenic agents, validating the identity of mutants using DNA markers, genetically mapping of oxyfluorfen tolerance as well as identifying the gene responsible for that specific herbicide tolerance.

The DNA Lab's activities vary in emphasis from year to year depending on the needs of the breeding program. The primary goal of the laboratory remains the same, which is to help the breeders in their selection work via DNA marker technology. The application 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. The fingerprint data generated for headrows ensure that materials advanced are uniform and homogenous.

Marker-Aided Selection

MAS for both blast resistance and grain quality is 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 repeats (SSR) markers, namely: RM208, AP5930A, RM224, RM331 and RM7102, to screen for the presence or absence of specific blast resistance genes (Table 23). The DNA Lab played a major role in the release of M-210 (12Y3097), a MG variety which has a wider blast resistance spectrum than M-208. Markers for blast resistance were used to monitor the introgression of the R genes.

Table 23. 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*

Four single nucleotide polymorphisms (SNP) markers and one SSR marker are being used to predict the grain quality parameters in the long grain program (Table 24). RM190, a SSR is being used in both the LG and MG programs for grain quality. A microsatellite primer B7-5 is also being used to detect the presence of fragrance gene in our breeding materials. As the whole breeding program transitioned with two new breeders this year, MAS for blast resistance and grain quality was temporarily suspended this season. Most of the MAS work was done on herbicide tolerance.

Table 24. List of DNA markers used in grain quality evaluation.

DNA Marker	Grain Quality parameter
Waxy exon 10	RVA curve
Waxy Exon 1	Amylose Type
Waxy Exon 6	Amylose Type
alk	Gel Temperature
RM 190	Amylose

As an upshot of the genetic mapping for oxyfluorfen tolerance, we have identified 2 microsatellite markers that can be used for MAS for oxyfluorfen tolerance. More importantly, we have also developed allele specific markers (SNP markers) that can be used to select for oxyfluorfen tolerance in rice. In 2018, about 1400 breeding materials and 400 headrows of 17Y3000 were analyzed in the DNA lab for herbicide tolerance using SNPs markers. Selected materials were advanced to the next generation by the breeders.

DNA Fingerprinting

Variety identity and purity assessments are principal components of the DNA Lab's role. The lab keeps a marker database of all rice varieties released at RES as well as other rice variety introductions. 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 continues 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 of DNA markers that distinguish one medium grain variety from another (data not shown). A panel of markers that can also distinguish long grain and short grain varieties have been identified. But from time to time, marker surveys for closely related materials are done to find discriminating markers that can be used for fingerprinting and purity assessments. This year, 129 markers were surveyed for fingerprinting of materials grown for headrow purification (data not shown).

About 2,200 headrows consisting of advanced lines and varieties were evaluated with at least 8 markers (Table 25). Around 21,200 data points were generated. Looking at the fingerprint profile of each individual headrows is important in deciding which materials are thrown out and which are maintained and advanced to the next generation. Varieties grown in large scales are sometimes sampled to examine homogeneity. For example, this year, A-202 foundation samples were also analyzed for purity.

Aside from doing purity assessment on breeder's seeds, markers can also be employed to verify identity of materials. Crosses made between medium-grain rice by long grain rice were examined using markers to determine if they are indeed "true crosses" or "selfs." Aside from cross verification, evaluation can help reduce the materials that can be grown in the limited greenhouse space. ROXY™ materials planted in the greenhouse and the field were also fingerprinted for identity. As the ROXY™ trait is being transferred to different varieties and fingerprint profiles can distinguish the genetic background of these resistant plants.

Table 25. Number of lines fingerprinted for the breeding program.

Identity	No. of Lines	No. of Markers	No. of Data Points
10Y2043	400	8	3200
12Y2175	400	9	3600
14Y1006	600	10	6000
CJ201	400	10	4000
A-202	400	11	4400
TOTAL	2200		21200

The DNA Lab also received requests from different entities for identity and purity issues this year. Growers submitted leaf samples for identification of the off-types in either heading days or appearance, or the identity of varieties planted in their field because of possible seed mix up. Off-types in grower's field were also submitted to the lab for analysis for red rice contamination. Our analysis showed that the samples are not red rice nor product of red rice hybridization.

A request from a private rice breeding company was accommodated because they hypothesized that adjoining farms planted next to RES varieties had contaminated their field. DNA marker analysis revealed that the off-types are, in fact, variants of the private varieties that flowered at different times. Earlier in the season, tall plants resembling Arborio variety were observed in several fields. These plants were compared to Arborio, 89Y235, red rice types, and representative MG varieties grown in the area. Results show that they are plants from crosses with Arborio.

Later this year a milled sample was submitted to the lab for analysis by a California marketing organization. The samples are being marketed as Calrose. DNA marker analysis shows that it is not one of our MG varieties, but rather Jupiter, a MG rice cultivar developed by the LSU Ag Center and grown in the Southern US.

Herbicide Resistance

The RES embarked on a project to find herbicide resistant/tolerant rice from materials generated either by gamma radiation or by EMS mutagenesis. An oxyfluorfen tolerant mutant was isolated from EMS-treated M-206 generated several years ago. The DNA Lab was tasked to determine the genetics of the herbicide tolerance trait and ultimately figure out what gene is responsible for such phenotype. Previous researchers in other crops, and also in rice, point to the possibility that a protoporphyrinogen oxidase (PPO) or protox gene encoding an enzyme responsible for chlorophyll cell membrane destruction, to be affected in oxyfluorfen tolerant plants. Sequencing of the PPO gene in both the mutants and M-206 reveal no sequence differences (data not shown), implying that the tolerance to oxyfluorfen herbicide is not due to the mutation in the PPO gene and therefore unique.

Genetic mapping studies revealed that herbicide tolerance to oxyfluorfen is located in Chromosome 5 between two SSR markers spanning around 950-kb (data not shown, patent published). To identify the specific herbicide tolerance gene, a multi-pronged approach was employed. Whole-genome sequencing (WGS) of the mutants G1-G9 and M-206 were done by Novogene. Concurrent with the external sequencing efforts, fine mapping efforts to further narrow down the region of interest were also made. Using fine mapping population between G6 mutant by L-206 of 1,116 individuals reduced the 950kb flanked by two SSR markers to 35 kb region containing 6 candidate genes (data not shown, patent filed). SNP reports in the specific regions we identified in our fine mapping did not identify significant changes in the candidate genes we had identified. Since our fine mapping and WGS are not in agreement, we sequenced the 35-kb region in house and by UCD DBS facility.

Analysis of the 35-kb region allowed us to identify a main candidate gene that could be responsible for oxyfluorfen tolerance. We found two independent mutations on the same gene in our mutants. Two mutants (G7and G8) have a mutation in site#1 characterized by Guanine to Adenine change (a nonsense mutation) resulting in early termination and shorter protein product. Six mutants (G1, G3-G6, and G9) have a deletion of Guanine in site#2 resulting in frameshift mutation and shorter protein product. The identification of two independent mutations suggests that we have probably identified the gene responsible for oxyfluorfen tolerance.

Efforts to confirm the candidate gene are continuing by evaluating mutations in other rice germplasm an in another plant system to see if they also confer tolerance to oxyfluorfen. Gene expression of our primary candidate gene in rice as well as in other plant systems will also be assessed. We are also trying to quantitatively measure the difference between the mutants and wild type variety. For example, we are measuring electrolyte leakage between our mutants and wild type.

These detailed investigations of the genetics of ROXY™ trait will be useful in understanding the tolerance mechanism, supporting the intellectual property protection, and the eventual commercialization of oxyfluorfen resistant rice as a weed control tool for rice growers.

Stem Rot Resistance

The ultimate goal of mapping the stem rot resistance is to find a tightly-linked markers that can be used for marker-aided selection by the different breeding programs. We are continuing our work on mapping the stem rot resistance focusing on the phenotyping of the disease symptoms. Although we have identified QTLs controlling stem rot resistance from our 2010-2012 work in cooperation with Mr. Jeff Oster, the bottle neck remains in getting consistent phenotyping. Dr. Teresa De Leon (See pathology section) together with the DNA Lab is continuing the genetics study of stem rot resistance. Since the mapping populations we used before are now considered as recombinant inbred lines (RILs), we can use them to conduct multi-location and multi-year trials to confirm the chromosome locations we have identified before. Multiple screenings will increase the confidence level in declaring the chromosomal region or regions contributing to the resistance trait.

Using the RILs from the cross between 87Y550 and M-206, the DNA Lab has started generating marker data. So far we have genotyped the RIL mapping population with 53 markers and we will continue to add more markers to saturate the 12 chromosomes of rice. Genetic analyses will again be done using the marker data and the stem rot scores of the mapping population. By consistent phenotyping and genotyping, markers associated with stem rot resistance will be more robust and useful in future MAS work.

SPECIAL RESEARCH PROJECT

Herbicide Tolerant Rice - ROXY™

ROXY™, a non-GM rice trait providing tolerance to oxyfluorfen has been recovered in our most widely grown Calrose variety M-206. Four years of research, involving multiple locations, show that oxyfluorfen applied preplant in a water-seeded system provides high levels of rice weed control with our ROXY™ trait. It is also effective in drill-seeded rice with a preplant and preflood application and may have potential in other rice-growing regions.

A provisional US patent for this trait was filed August 11, 2016, published March 15, 2018, and the ROXY™ trademark was granted September 4, 2018. In August of 2019 CCRRF joined in a "shared partnership" with Albaugh, LLC to pursue registration and commercialization of oxyfluorfen for rice weed control using the ROXY™ trait. A global leader in the production and sale of post-patent crop protection products, this privately owned US company currently markets this herbicide. They have also just launched the CoAXium™ Wheat Production System. This farmer-inspired non-GM herbicide-resistant wheat technology is a cooperative venture with the Colorado Wheat Research Foundation, Inc. The similarities to our grower owned/funded program and Albaugh's experience will contribute to the success of this joint venture.

In 2018, off-station testing was expanded with continued funding from the Rice Research Trust. Off-station rate and efficacy studies were again conducted with Colusa County Farm Supply in grower fields in Glenn (2 sites) and Colusa (2 sites) counties; with the Butte County Rice Growers Association (2 sites); and the Tremont Group in a growers field in Sutter County. The UC Weed Control Project and the RES Rice Breeding Program continued work on ROXY™ related research as well.

Genetic mapping, candidate gene identification–confirmation, and tolerance mechanism research is in progress at RES (see DNA Marker Lab). The breeding program is transferring this trait to other grain types with the first materials included in 2018 large plot yield tests at RES. 17Y3000, selected from a backcross to M-206, was tested in 2017-18 SW Tests (conventional herbicide programs). Yields of 17Y3000 compared with M-206 averaged 8870 and 9040 lbs./acre, respectively and were not significantly different. Headrows and a seed increase of 17Y3000 at RES with a 1.5 pt./acre 4L oxyfluorfen preplant application yielded 10,700 lbs./acre and will provide seed for 2019 research.

2018 weed control studies in the breeding program included replicated large plot oxyfluorfen rate and seeding rate experiments under water-seeding and drill-seeding using 17Y3000. In the water-seeded experiment, soaked seed was broadcast on treated soil and then flooded. This resulted in extensive seed burial and loss of stand and the field was briefly drained. Surprisingly, although the stands were very thin, the rice did recover and produce respectable yields with good weed control. There was significant delay in heading with increased rates of oxyfluorfen, but no significant effect on yield by herbicide or seeding rate in this experiment. The results for the water-seeded test are shown in Tables 26 and 27. In the drill-seeded experiment there were no emergence or stand differences over herbicide rates or in heading date. Yields were significantly different (Table 28), but this was thought to be due to the 1.0 pt./acre treatment's border location receiving a lower aerial fertilizer application and also glyphosate drift from roadside weed spraying. These experiments are scheduled to be repeated in 2019.

Table 26. Yields and heading of 17Y3000 in a water-seeded herbicide and seeding rate experiment.

Oxyfluorfen Pt./acre	Yield lbs./acre	50 % Heading Days	Seeding Rate lbs./acre	Yield lbs./acre	50 % Heading Days
1.0	9200	84	125	9010	85
1.5	9170	83	150	9260	85
2.0	9361	85	175	9450	85
3.0	9250	87	200	9260	85
Significance	NS	**		NS	NS

** Significant and the 0.01 level
NS Not significant at the 0.05 level

Table 27. Yields of 17Y3000 in a water-seeded herbicide and seeding rate experiment for control/check plots.

Entry[1]	Oxyfluorfen Pt./acre	Yield lbs./acre	Entry[2]	Plot	Yield lbs./acre
M-206	1pt	6009	17Y3000	1	6445
M-206	1.5pt	6378	17Y3000	2	6578
M-206	2pt	5680	17Y3000	3	6220
M-206	3pt	5406	17Y3000	4	8802

[1] Single plot in each treated basin.
[2] Series of 4 plots in an adjacent basin without oxyfluorfen, but Propanil applied.

Table 28. Yields and heading of 17Y3000 in a drill-seeded herbicide and seeding rate experiment.

Oxyfluorfen Pt./acre	Yield lbs./acre	50 % Heading Days	Seeding Rate lbs./acre	Yield lbs./acre	50 % Heading Days
1.5	8910	80	50	9610	80
2.0	9990	80	75	9740	80
3.0	9900	80	100	9530	80
			125	9770	80
Significance	**	NS		NS	NS

** Significant and the 0.01 level
NS Not significant at the 0.05 level

STATEWIDE YIELD TESTS RESULTS AT RES LOCATION

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 2018 Statewide Yield Tests were conducted at seven locations in commercial fields by Mr. John Ray Stogsdill, Dr. Bruce A. Linquist, Dr. Luis Espino, and Dr. Whitney Brim-DeForest, and Dr. Michelle Leinfelder-Miles. 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’ x 20’) and the experimental designs were randomized complete block design.

All of these advanced large plot entries were also tested at RES in a randomized complete block design. The large plot seeding date at RES was May 15-17, 2018. Water-seeding and conventional management practices were used in these experiments. Butte® and SuperWham® + Grandstand® were applied for weed control and one application of Lambda Cy® was applied for rice water weevil control. The experiments at RES had an effective harvest area of 140 ft^2 (7’ x 20’) and were harvested on September 20-21, 22-24, and 26-28 for very early, early and intermediate-late group, respectively. The nursery plots were harvested with the RES Almaco research combine.

Tables 29 through 34 contain a summary of performance information from the 2018 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, roads, 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 2019. Complete results of the UCCE SW Tests can found at http://rice.ucanr.edu.

Table 29. Agronomic performance means of very early advanced entries in Statewide Yield Tests at RES and over-location mean yields at Sutter, 2 Yolo sites, and RES (4 reps) locations in 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
11	12Y2175	M	4.9	80	102	5	4.7	18.5	10930	9680
9	14Y1006	L	4.9	73	97	3	3.0	14.8	10620	10260
12	10Y2043	S	4.9	72	95	49	4.0	14.4	10190	10260
1	CJ-201	L	4.9	79	90	0	4.7	14.0	10080	9630
3	L-207	L	4.9	75	111	0	4.3	14.1	9900	9940
2	L-206	L	5.0	75	94	1	4.3	14.5	9770	9060
6	M-209	M	4.9	79	103	0	4.0	18.8	9710	9040
5	M-206	M	4.9	75	104	24	4.0	18.4	9090	9020
10	17Y3000	M	4.9	75	103	15	5.0	18.0	9040	8930
4	M-105	M	4.9	73	99	11	5.0	17.7	8600	9090
7	M-210	M	4.9	75	99	14	4.3	18.6	8570	9130
8	S-102	S	4.9	71	98	18	4.3	10.7	7890	8740
MEAN			4.9	75	99	12		16.0	9530	
CV			1.0	1.2	3.8	88.5		6.2	6.7	
LSD (.05)			0.07	1.3	5.4	15		1.43	923	

† L = long grain, M = medium grain, and S = short grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = resistant and 5 = susceptible

Table 30. Agronomic performance means of very early preliminary entries in Statewide Yield Tests at RES and over-location mean yields at Sutter, 2 Yolo sites, and RES (2 reps) locations in 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
38	17Y1100	L	4.9	78	104	50	3.7	15.5	10880	9520
23	15Y3171	M	4.9	82	96	0	4.3	19.0	10500	8810
36	17Y1087	L	5.0	76	102	0	4.0	14.4	10390	9590
49	17Y3150	M	4.9	77	100	0	4.3	19.4	10380	8830
37	17Y1007	L	5.0	74	100	0	5.0	14.3	10190	9640
22	16Y127	L	5.0	77	107	0	4.3	15.2	10010	9610
39	17Y1063	L	5.0	78	106	8	4.0	18.9	9940	8230
24	15Y2153	M	4.9	85	100	0	3.0	20.7	9920	8750
42	17Y3082	M	4.9	75	103	25	4.3	18.9	9650	9390
15	A-202	L	5.0	77	103	0	4.0	15.4	9540	8990
40	17Y3043	M	4.9	76	99	0	3.7	18.9	9540	9100
43	17Y3047	M	4.9	77	94	0	5.0	16.5	9540	9200
26	15Y2112	S	5.0	79	99	13	4.3	19.8	9340	9450
35	17Y1002	L	5.0	74	110	3	5.0	15.7	9330	9590
41	17Y3119	M	4.9	75	95	5	4.0	17.7	9260	9100
47	17Y3014	M	4.9	75	108	35	4.0	18.0	9260	9650
28	16Y3019	M	4.9	76	102	5	4.3	18.7	9190	9320
46	17Y3131	M	4.9	78	102	0	3.3	18.3	9170	9010
33	13Y3152	M	5.0	76	102	0	3.3	17.6	9160	9030
25	15Y2100	S	4.9	79	102	0	4.7	13.7	9050	9700
14	CM-203	S	5.0	75	101	40	4.3	15.2	8980	9230
45	17Y3114	M	4.9	76	108	40	4.0	18.2	8970	9170
18	M-205	M	4.9	81	94	0	4.0	18.1	8910	8720
51	17Y3042	M	4.9	75	107	3	4.7	17.0	8810	9220
30	15Y3036	M	5.0	75	99	3	4.0	16.5	8800	9010
56	17Y2087	S	4.9	77	92	0	3.0	16.5	8790	9370
52	17P2216	S	4.9	75	97	5	4.3	16.2	8700	9390
48	17P3035	M	5.0	74	103	85	5.0	16.5	8650	9190
34	14Y3143	M	5.0	76	101	15	3.3	17.5	8630	9370
50	17P3450	M	4.9	75	94	5	4.3	16.8	8610	8960
32	16Y2127	S	5.0	77	95	0	4.7	15.5	8580	9370
29	16Y2028	S	5.0	76	95	60	4.0	13.8	8450	9550
44	17Y3023	M	4.9	75	105	10	4.3	17.5	8350	9300
13	CH-202	S	4.9	75	90	25	4.7	12.8	8340	8920
27	15Y2024	S	4.9	78	94	0	4.3	13.5	8280	9070
53	17Y2140	S	4.9	77	100	0	4.3	15.6	8180	9020
19	CH-201	S	4.9	78	94	40	4.7	11.9	7880	8830
17	M-104	M	4.9	71	93	15	4.7	15.6	7670	8920
31	16Y2058	S	5.0	77	104	20	4.7	15.2	7600	8750
21	89Y235	S	4.9	75	104	85	5.0	14.8	7240	8320
16	CM-101	S	5.0	72	91	20	4.0	10.7	6390	7510
20	CA-201	S	4.9	76	99	30	5.0	16.6	6190	7350
55	17Y2098	S	4.9	78	106	60	4.3	15.4	4960	5780
54	17Y2096	S	4.9	78	103	100	4.3	16.2	4700	6170
MEAN			4.9	76	100	18		16.4	8750	
CV			1.5	1.2	4.1	90.5		4.2	6.7	
LSD (.05)			0.15	1.8	8.2	33		1.38	1186	

† L = long grain, M = medium grain, and S = short grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = resistant and 5 = susceptible

Table 31. 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 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
69	14Y1006	L	4.9	75	103	9	4.7	14.3	10990	9930
61	CJ-201	L	4.9	79	96	0	5.0	14.4	10860	9480
71	12Y2175	M	4.9	81	106	4	3.0	18.3	10740	9680
66	M-209	M	4.8	80	99	0	3.3	19.9	10640	9040
72	10Y2043	S	4.9	72	92	55	3.0	13.8	10280	9880
63	L-207	L	4.9	78	112	0	4.3	14.2	10120	9720
62	L-206	L	4.8	75	95	0	4.3	13.9	9750	8900
64	M-105	M	4.9	72	102	48	5.0	17.9	9360	8900
67	M-210	M	4.8	75	101	45	4.3	18.5	9230	8910
65	M-206	M	4.8	75	104	38	4.3	18.7	9050	8910
70	17Y3000	M	4.9	75	101	45	4.0	18.0	8980	8700
68	S-102	S	4.8	71	97	55	4.0	10.4	8220	8100
MEAN			4.8	76	100	25		16.0	9850	
CV			1.4	0.9	2.9	57.2		3.8	5.0	
LSD (.05)			0.09	1.0	4.2	20		0.87	704	

† L = long grain, M = medium grain, and S = short grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = resistant and 5 = susceptible

Table 32. 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 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
82	15Y3171	M	5.0	81	97	0	4.0	18.5	10930	8840
83	15Y2153	M	4.8	84	102	3	4.0	21.0	10570	8900
117	17P2215	S	4.9	77	100	55	4.7	17.9	10520	9160
100	17Y1027	L	4.8	75	97	0	5.0	14.6	10480	9730
95	16Y3112	M	4.8	81	109	0	5.0	20.1	10400	9370
109	17Y3086	M	4.8	78	106	28	4.0	17.4	10320	9140
87	16Y1029	L	4.8	76	99	0	4.0	14.8	10250	9200
102	17Y3047	M	4.9	77	95	0	4.0	16.4	10240	9250
93	16Y3108	M	4.9	85	100	0	3.3	20.7	10230	8600
114	17Y3081	M	4.9	78	103	8	4.7	18.1	10230	9270
101	17Y1083	L	4.8	78	93	0	3.7	15.0	10150	9110
84	15Y2112	S	4.8	80	98	60	4.0	19.4	10090	8780
112	17P3389	M	4.9	82	100	0	4.7	18.0	10090	9000
116	17Y2048	S	4.8	72	94	20	4.7	15.9	9960	9730
94	16Y3111	M	4.8	81	109	0	3.3	19.5	9950	8960
90	16Y2117	S	5.0	76	92	40	4.3	13.8	9930	8770
98	15Y2135	S	4.7	76	100	45	4.7	15.5	9860	9270
106	17Y3045	M	4.9	78	106	3	4.3	18.8	9850	8760
113	16P3288	M	4.9	78	104	0	3.3	17.4	9760	9000
81	16Y127	L	5.0	78	104	0	3.7	15.3	9740	8960
96	16Y3121	M	4.9	80	98	0	3.7	18.3	9700	8670
74	CM-203	S	5.0	73	102	75	4.7	15.9	9690	9150
107	17Y3129	M	4.9	77	104	18	3.0	17.5	9690	8860
88	16Y1154	L	4.9	76	112	0	4.7	13.9	9660	9340
92	15Y3086	M	4.8	76	93	15	4.0	15.8	9590	9090
108	17P3020	M	4.8	74	96	65	3.3	16.7	9540	9390
111	17P3344	M	4.9	80	99	0	4.3	17.5	9530	8470
115	17Y3090	M	4.9	79	109	10	4.3	17.9	9490	8790
85	15Y2100	S	4.8	80	96	0	5.0	14.5	9390	9170
78	M-205	M	4.9	81	96	0	2.3	18.0	9280	8360
104	17Y3114	M	4.9	76	101	50	5.0	18.3	9280	8920
103	17Y3023	M	4.9	75	107	55	4.7	17.0	9240	8670
118	17P2217	S	4.7	76	107	20	4.3	15.7	9110	9240
110	17Y3087	M	4.9	78	98	3	3.7	18.0	9100	8790
75	A-202	L	4.9	76	99	0	4.0	15.2	9070	8620
99	14M206G4	M	4.8	75	104	60	4.3	18.3	8890	8510
120	17Y2138	S	4.8	77	96	0	4.0	12.4	8890	8650
105	17Y3131	M	4.9	77	102	5	3.7	17.6	8820	9110
119	17Y2087	S	5.0	76	93	0	3.0	15.2	8800	8520
89	16Y3054	M	4.9	76	98	25	4.7	18.2	8630	8500
79	CH-201	S	5.0	78	98	65	4.7	11.3	8510	7180
73	CH-202	S	4.7	75	93	35	3.3	13.3	8340	7670
77	M-104	M	4.8	70	99	40	4.7	15.9	8260	8340
86	15Y2024	S	4.8	79	92	0	5.0	13.1	7950	8190
76	CM-101	S	4.8	73	98	45	4.0	12.0	6800	7080
80	CA-201	S	4.9	77	99	45	3.7	13.7	6640	6720
91	16Y1064	L	4.7	79	98	0	5.0	13.1	6410	6710
97	15Y1195	L	4.9	81	87	0	3.7	14.2	5940	5840
MEAN			4.8	77	99	19		16.4	9330	
CV			1.5	1.0	3.9	85.2		4.2	5.7	
LSD (.05)			0.14	1.5	7.7	32		1.39	1068	

Table 33. Agronomic performance means of intermediate to late advanced entries in Statewide Yield Tests at RES and over-location mean yields at Butte, Glenn and RES (4 reps) locations in 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
131	12Y2175	M	4.8	82	105	1	5.0	19.2	11420	10960
121	CJ-201	L	4.8	80	96	1	5.0	14.5	10900	10070
129	14Y1006	L	5.0	74	100	0	5.0	14.6	10630	10430
123	L-207	L	4.8	77	110	0	4.3	14.2	10590	10440
132	10Y2043	S	4.9	73	91	35	4.7	13.6	10070	10460
126	M-209	M	4.8	80	97	0	3.7	19.7	9760	9780
125	M-206	M	4.9	76	100	30	4.3	18.5	9730	9770
130	17Y3000	M	4.9	75	100	31	4.3	18.7	9600	9750
122	L-206	L	4.8	73	92	1	5.0	14.2	9540	9440
127	M-210	M	4.9	75	96	15	5.0	18.2	9480	9540
124	M-105	M	4.9	73	96	3	4.7	17.5	9350	9620
128	S-102	S	5.0	71	94	5	4.3	11.3	8500	8690
MEAN			4.9	76	98	10		16.2	9970	
CV			1.0	1.3	4.2	134.6		4.7	7.8	
LSD (.05)			0.07	1.4	5.9	20		1.10	1123	

† L = long grain, M = medium grain, and S = short grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = resistant and 5 = susceptible

Table 34. Agronomic performance means of intermediate to late preliminary entries in Statewide Yield Tests at RES and over-location mean yields at Butte, Glenn and RES (2 reps) locations in 2018.

Entry Number	Identity	Type †	SV ‡	Heading (d) §	Height (cm)	Lodging (%)	SR ¶	Harvest MC (%)	Grain Yield (lbs/acre, 14%MC)	
									RES	State
149	17Y3158	M	4.9	80	103	0	3.3	19.3	11460	10830
140	15Y3171	M	4.9	83	96	0	3.3	19.7	11090	9920
150	17P3355	M	4.9	82	102	0	4.7	20.4	11060	9700
141	15Y2153	M	4.8	84	100	0	4.0	21.6	10610	9730
153	17Y2039	M	4.9	85	95	0	4.0	19.8	10480	9960
152	16P3279	M	5.0	82	101	2	2.7	20.5	10420	10120
142	15Y2100	S	5.0	80	96	0	4.3	14.2	10280	9940
156	17Y2142	S	5.0	78	107	0	4.0	15.6	10090	10100
139	16Y127	L	4.9	77	101	8	4.0	15.7	9950	9350
155	17Y2046	S	5.0	75	97	3	4.0	12.7	9900	9920
145	15Y2151	M	4.9	82	106	3	4.0	18.5	9830	9650
143	15Y2112	S	4.9	80	96	50	2.7	20.6	9820	9380
151	17P3398	M	5.0	85	96	0	3.7	19.8	9770	9910
148	17Y3085	M	4.9	82	104	0	4.7	21.1	9720	9800
134	CM-203	S	5.0	73	95	70	4.7	15.7	9620	10010
154	17Y2069	S	5.0	73	98	0	5.0	14.4	9550	9640
136	M-205	M	4.8	84	97	0	3.3	19.0	9530	9520
135	A-202	L	5.0	75	101	0	5.0	15.1	9320	8980
147	17Y3127	M	4.9	77	96	10	4.3	17.8	9160	9370
144	15Y2024	S	4.9	78	94	3	4.7	14.3	8880	9400
146	17Y1070	L	4.9	76	105	5	5.0	14.4	8730	9320
133	CH-202	S	5.0	75	92	30	4.3	14.4	8490	8780
137	CH-201	S	5.0	75	92	20	4.0	13.2	7580	8540
138	CA-201	S	5.0	77	90	20	5.0	14.0	6500	7440
MEAN			4.9	79	98	9		17.2	9660	
CV			1.2	0.8	4.9	58.8		5.8	4.6	
LSD (.05)			0.12	1.3	9.9	11		2.04	922	

† L = long grain, M = medium grain, and S = short grain.
‡ SV = seedling vigor score, where 1 = poor and 5 = excellent.
§ Days to 50% heading.
¶ SR = stem rot resistance, where 1 = susceptible and 5 = resistant