2022 RICE BREEDING PROGRESS REPORT

CALIFORNIA COOPERATIVE RICE RESEARCH FOUNDATION

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

RICE EXPERIMENT STATION STAFF

Administration

Dustin Harrell, Ph.D. .... Director
Emily Schaaf .... Executive Assistant

Plant Breeding

Teresa B. De Leon, Ph.D. .... Plant Breeder
Nirmal Sharma, Ph.D. .... Plant Breeder
Frank Maulana, Ph.D. .... Plant Breeder
Gretchen Zaunbrecher, Ph.D. .... Research Scientist

Plant Breeding Support

Baldish K. Deol.......... Senior Plant Breeder Assistant
Ravinder Singh Gakhal.......... Senior Plant Breeder Assistant
Davinder Singh .... Plant Breeder Assistant
Joseph Martin III .... Plant Breeder Assistant
Gabriel Cade Janish .... Plant Breeder Assistant
George B. Yeltatzie, M.S. .... DNA Lab Technician

Field Operations and Maintenance

Randall C. Jones .... Field Supervisor
Deven Benson (Resigned 11/01/22) .... Maintenance and Operator
Ashley Averitt.......... Maintenance and Operator
Kirk Troughton .... Maintenance and Operator

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TABLE OF CONTENTS

OVERVIEW

Dustin Harrell

The California Cooperative Rice Research Foundation (CCRRF) is a private nonprofit research foundation [501(c)(5)] made up of California rice grower members. The Rice Experiment Station (RES) is owned and operated by CCRRF and carries out the public breeding program for the California rice industry. 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.

In 2022 the RES scientific professional staff included a director, three plant breeders, and a research scientist. Eleven career positions consisting of four plant breeding assistants, one DNA Lab technician, a field supervisor, two maintenance and field operators, and one executive assistant made up the support staff. Approximately 20 seasonal laborers are employed during crucial planting and harvest times.

Organization and Policy

Policy and administration of RES is the responsibility of an eleven-member Board of Directors elected by the CCRRF membership, which is a free membership to all California rice growers. 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 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; the remaining 20% is derived from grants, investment revenue, and the sale of foundation rice seed to seed growers. RES does receive some donations from agribusiness and funds from the Rice Research Trust (RRT). The RRT is a tax-exempt trust [501(c)(3)] established in 1962 to receive tax deductible contributions and gifts to support 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 is 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 (Placer, Sacramento, Sutter, Yuba), Dr. Luis Espino (Butte, 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 by UCD scientists. Dr. Kassim Al-Khatib (Professor, Department of Plant Sciences, UCD), Michael Lynch (Staff Research Associate), and Mr. Aaron Becerra-Alverez (UCD Junior Specialist) conducted research on 16 acres at Hamilton Road. Drs. Linquist and Espino, and Extension Entomologist Ian Grettenberger, 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. 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. All seed growers of all classes of certified seed of CCRRF varieties must be annually licensed by CCRRF. This is being done to ensure that California growers are the beneficiary of their research investments as well as assuring that clean, red-rice-free seed is produced. Although the foundation seed program is self-sustaining and not supported with CRRB funds, foundation seed and certified seed production provides very significant benefits to the whole California rice industry.

CCRRF has followed an aggressive testing program of foundation seed for the presence of the Liberty Link Trait that was discovered at trace levels in Southern US long-grain rice. All results from the initial 2006 USDA tests on all RES annual foundation and basic seed by CRC have been non-detect.

RICE BREEDING PROGRAM

The CCRRF is committed to the development and release of excellent high-yielding and high-quality rice varieties. The RES Breeding Program implements rice variety development for all market classes of long, medium, and short grains. The program covers a total of eleven market classes broadly classified as conventional, premium, and specialty types. The breeding program is divided into medium, short, and long grain projects. Each project is led by a plant breeder and overseen by the station's Director. The Genetics laboratory is under the direction of a research scientist and supports the breeding projects for marker-assisted selection and purity testing. All project leaders are involved in cooperative studies with scientists from UC, USDA, and rice industry for off-station statewide field tests, nurseries, and herbicide resistance research. Project leaders also have areas of responsibility in the operation and management of the overall program.

Breeding Objectives

The focus of the RES rice breeding program to develop improved rice varieties with high-yielding and superior-quality of all grain types and market classes that are commercially competitive in the world market for the benefit of California rice growers now and in the future. Below are few of the goals of the breeding program.

High Grain Yield - The RES breeding program pays particular attention to selecting breeding lines with ideal yield components and plant architecture such as semi-dwarf height, upright long flag leaf, long panicle length with uniform grain maturity, and strong culm to support the heavy panicles to improve grain yield. Multi-year and multi-location yield trials in cooperation with UCCE scientists are conducted to ensure the stability and wide adaptation of advanced breeding lines for release. Advanced breeding lines are repeatedly evaluated and selected for high seedling vigor, tolerance to cold-induced blanking, and low lodging potential prior to release.

High Grain Quality – The RES breeding program has been working to improve rice grain quality and milling yield as these traits directly translate to the profitability of the growers. The maturity and milling yield of advanced breeding lines are extensively monitored until the end of the season to determine the optimum maturity and percent harvest moisture content (%MC) that will return the highest percent whole and total milling yield potential. Rice quality components are evaluated with physicochemical testing that utilize advanced instruments and DNA marker technology. Emphasis is given to grain size, shape, length, width, and chalkiness for the rice market class. Wet chemistry evaluations are also performed to determine the percent apparent amylose content, protein content, and cooking profiles of experimental lines. Aromatic rice market classes of Jasmine and Basmati rice lines are evaluated for aroma using potassium hydroxide solution or by using DNA markers developed for the *BADH2* gene in the early generation selection.

Cooking and Taste Qualities - Consumer acceptability is a top priority goal in the RES breeding program. All breeding projects keep improving lines by introgression of market class-grain quality, cooking, and taste attributes. Germplasm of desirable qualities and grain types are crossed and backcrossed several times to introduce the desired market-class trait to breeding lines of superior yield, quality, and adaptability to California. Advanced improved lines are sent to several rice marketing companies and intended consumers of rice for blind evaluations of grain appearance, cooking, and taste qualities to ensure market acceptance of the variety before release. Experimental lines that passed the taste and cooking tests are advanced as promising lines for further headrow purification, foundation seed increase, and variety release.

Early Maturity - Short-duration or very early to early maturing rice varieties allow rice growers to plant and harvest early, or plant late and still harvest the crop before the occasional rain in the fall. The breeding program actively incorporates early flowering and early maturing traits in all breeding lines for this reason. Breeding efforts continue to select for synchronous and uniform flowering of early maturing lines.

Disease Resistance **-** The breeding program continues its effort to incorporate disease resistance to improve varieties for blast and stem rot diseases. The program stacks blast resistance genes against several blast races to ensure the resistance of rice varieties to future disease outbreaks. The program utilizes DNA markers to track and incorporate blast resistance genes. For stem rot disease, mapping of chromosomal regions controlling resistance is underway. Field screening for stem rot resistance is conducted every year to evaluate the level of resistance present in the advanced breeding lines.

Herbicide Resistance **-** Breeding for herbicide tolerance is now an integral component of all breeding projects. Genetic studies for other herbicide resistance traits are being conducted to explore opportunities for California rice growers.

The oxyfluorfen resistance trait (ROXY) has led to the development of the advanced line 19Y4000, which is projected to be the first varietal release of the ROXY® Rice Production System. The ROXY RPS will include the variety 19Y400 released from the RES, the use of the herbicides ALB2023 and ALB2024 released by Albaugh LLC, and the stewardship agreement.

Breeding Personnel

Dr. Dustin Harrell served as the Rice Experiment Station Director. Dr. Teresa De Leon led the medium grain breeding program and served as the Station's Pathologist. Dr. Frank Maulana and Dr. Nirmal Sharma led the short and long grain breeding programs, respectively. Dr. Gretchen Zaunbrecher provided leadership for the Genetics laboratory.

The RES breeding team also includes five breeding assistants, one lab technician, and seasonal workers during planting and harvesting.

Nurseries

Three breeding nurseries are established to accelerate breeding activities. The breeding nursery locations include: (1) Rice Experiment Station facility in Biggs, CA, (2) the Hawaii Winter Nursery for generation advance and seed increase in Lihue, HI, and (3) the San Joaquin Cold-Tolerance Nursery for cold-induced blanking screening.

The RES breeding nurseries were composed of 1,660 drill-seeded F_{2-3} populations; 41,114 water-seeded F_3 to F_6 progeny rows; 873 preliminary yield test plots, and 629 advanced yield test plots (10′ × 20′). A total of 1,420 milling yield plots (6′ × 10′ plots) and cooking strip demo plots (10′ × 60′) are also planted at RES for maturity, grain quality, and cooking evaluations. The RES is also a location for very early, early, and late-intermediate maturity group experiments of the UCCE Statewide Yield Tests (10′ × 20′ plots). In 2022, 4,880 headrows (promising lines and foundation headrows), and an additional 19,069 rows of seed maintenance were managed by the RES Rice Breeding Program. Seeds of new F_1's were planted in pots and grown to maturity in the greenhouses, with 340 medium grain populations, 339 long grains F_1, and 293 short grains. 519 lines were evaluated for cold-induced panicle blanking in the refrigerated greenhouse and 4,165 lines in San Joaquin nursery. The genomic selection special project at the RES had 360 plots.

Table 1 summarizes the 2022 RES breeding nursery composition. Breeding efforts were approximately 47% medium grain, 29% short grain, and 24% long grain. A total of 684 crosses were made in the spring and 1,087 crosses during the summer of 2022, bringing the overall total of crosses made since 1969 to 55,337. Overall, the RES breeding program evaluated 77,552 entries in 2022. Crosses made during early spring were planted in the RES F_1 nursery (greenhouse) while the F_1 seeds made during summer were planted in the Hawaii Winter Nursery to accelerate the breeding process. The combined F_2 populations generated from the 2022 F_1 nurseries at the RES and Hawaii will be planted for selection at the RES and San Joaquin nurseries in 2023.

In 2022, all the F_1 populations were planted in the greenhouse on May 16 and 17. All F_1 populations were grown to seedling stage inside the greenhouse and the transplanted to the field. Water-seeding for progeny rows, preliminary yield tests (PYT), advanced yield tests (AYT), statewide yield tests (SW), ROXY, and other breeding lines began on May 7 and was completed by May 11. Drill-seeding of F_2 populations was done on April 27 and 28. Seed maintenance and milling yield plots were drill-seeded on May 18 to May 20, while drill-seeding of the training population of genomic selection (GS), disease nursery, URN was completed on May 23. All the ROXY experiment (F2, Rows, AYT, PYT, SM, Trail) were planted on May 16 to May 19.

Entries from the PYT, AYT, and SW trials were planted in the greenhouse 4 on April 18 to evaluate the lines for cold tolerance. The temperature of the greenhouse was maintained at 90-100°F during the day and 65-75°F during the night with natural radiation from the sun penetrating through the glass roof for normal growth. Once the entry line entered the microsporogenesis stage, or booting stage, the line was transferred to refrigerated greenhouse number 2 and 3 with a nighttime temperature setting of 50-55°F for 10-12 hours.

The San Joaquin Cold-Tolerance Nursery was planted in cooperation with a local rice grower on April 19. The 2.2 acre drill-seeded nursery included F2, preliminary, advanced and state wide breeding lines. The plants in San Joaquin nursery had a good stand establishment, but weed control was poor. Only minor cold-induced panicle blanking was observed in the rows. Conversely, the lines grown in the refrigerated greenhouse showed high panicle blanking due to cold stress.

Table 1. Composition of 2022 breeding nurseries by grain type

Popn = Population; PY = Preliminary yield test; AY = Advanced yield test; SW = Statewide test, MG= medium grain, SG = short grain, LG = long grain

2022 Breeding Materials	Number of Plots/Rows/Entries			Total
	MG	SG	LG	
Spring Crosses	249	196	239	684
Summer Crosses	539	283	265	1,087
F1	340	293	339	972
F2-3	826	408	426	1,660
F3-F6 progeny rows	14,610	14,694	11,810	41,114
Preliminary Yield Test	497 (entries, conv. and ROXY)	211 (entries)	165 (entries, conv and ROXY)	873
Advanced Yield Test	341 (entries)	175 (entries)	113 (entries)	629
Statewide Yield Test	30 (entries)	14 (entries)	15 (entries)	59
Milling Yield Plots	736 (plots)	384 (plots)	300 (plots)	1,420
Cooking Strip Demo	29 (plots)	13 (plots)	19 (plots)	61
Headrows, Seed increase (Line purification)	2,640 (rows)	880 (rows)	1,360 (rows)	4,880
Seed Maintenance	12,719 (rows)	3,600 (rows)	2,750 (rows)	19,069
San Joaquin (Cold Nursery)	2,635 (rows)	748 (rows)	782 (rows)	4,165
Cold GH (Cold tolerance study)	223 (entries)	178 (entries)	118 (entries)	519
Genomic Selection-Training Pop	208 (entries)	77 (entries)	75 (entries)	360
Total	36,622	22,154	18,776	77,552

In 2022, winter nursery planting in Hawaii began on October 24 and completed on October 29. Transplanting of F_1 seeds occurred on December 9, 2022. The Hawaii nursery consisted of 16 Roxy plots, 896 F_1's, and 7,800 rows of F_5-F_7 lines for generation advance and seed increase, for a total of 7,371 rows. Plant establishment and stands were very good except for the F_1's which germinated poorly in the potting mix**.** Selection and harvesting will be completed at the Hawaii winter nursery during the first week of April 2023. The harvested seeds will be returned for processing and planting in the 2023 RES breeding nurseries. Table 2 summarizes the breeding composition planted in 2022-2023 at the Hawaii Nursery.

Table 2. Composition of breeding lines in 2022-2023 Hawaii Nursery.

2022-23 HI Entries	Pond # (Field)	Plot/Row #	Composition			Total
			MG	SG	LG	
Roxy Plots	F_1 basin	Rx1-16	16	0	0	16
F_5-F_7 Rows	1, 2	10,001-16,372	4,338	1,838	1,115	7,291
2022 Summer Crosses (F_1)	5, 6	9001-9938	357	283	256	896
% Composition			57%	26%	17%	
Total			4,711	2,121	1,371	8,203

MG= medium grain, SG = short grain, LG = long grain

MEDIUM GRAIN BREEDING

Teresa B. De Leon

The Medium Grain Breeding Project develops outstanding regular and premium quality Calrose-type rice varieties adapted to the rice growing areas in California. The breeding effort is focused on development and improvement of grain yield, grain quality, cooking, and eating qualities preferred by the medium grain market. Furthermore, emphasis is given to selecting breeding lines with high seedling vigor, very early to early maturity, with strong straw, cold tolerance, disease and herbicide resistance, and wide adaptation to California-rice growing counties.

The project employs both traditional (pedigree method) and molecular (marker-assisted selection) breeding methods. DNA markers such as microsatellite and SNP markers are routinely used in marker-assisted selection (MAS) for blast resistance, grain quality, and herbicide resistance. These markers are also used for fingerprinting and purity testing of breeding materials at various stages of variety development.

Table 3 summarizes the 2022 breeding lines evaluated for the medium grain project. A total of 788 crosses were made for the medium grain project alone. The project evaluated 340 F_2 populations, more than 14,000 F_3 to F_6 progeny rows, 2,555 preliminary and advanced yield plots including ROXY lines, and more than 15,000 headrows and seed maintenance rows for a total of 45,088 breeding lines.

Table 3. Medium grain breeding lines evaluated in 2022.

Generation/ Experiment	Number of Plots/Rows/Entries	Total
Crosses	249 (SPR) + 539 (SUM)	788
F_1	340 fam	340
F_2	432 (RES) + 284 (SJ)	826
F_3-F_6 Progeny rows	14,610 rows	14,610
Preliminary Yield Trial	742 (CONV) + 378 (ROXY) (497 ENTRIES)	1,120
Advanced Yield Trial	891 (CONV) + 132 (ROXY) (341 ENTRIES)	1,023
Statewide Yield Trial	30 ENT x 4 or 2 reps x 3 exp (137LA)	432
Cooking Strip Demo	29 adv lines	29
Milling Yield Plots	736 plots (PY, AY, SW)	736
Headrows	1200 (FND-HR) + 1440 (adv-HR)	2,640
Seed maintenance	12,719 rows	12,719
San Joaquin Cold Nursery	2,635 rows	2,635
Stem rot Disease Nursery	756 rows	756
Genomic Selection- Training Pop	720 plots	720
Hawaii Nursery	5,333 ROWS + 365 F_1's + 16 Roxy	5,714
Total Breeding Lines Evaluated		45,088

Figure 1 summarizes the mean yield of medium grains at RES (orange bars) and at Statewide Test (blue bars). Overall, medium grains had an average yield of 8,555 lb/A at the RES and 8,556 statewide. M-211 had the highest yield averaging 9,071 lb/A in the SW and 9,851 lb/A at RES. M-209 also showed high yields at 88 and 93 sacks per acre at SW and RES, respectively. Among the Calrose varieties, M-210 has a 2% SW yield advantage over M-206 and a 6% SW yield advantage over M-105. At RES, M-210 had 8% and 7% yield advantage over M-206 and M-105.

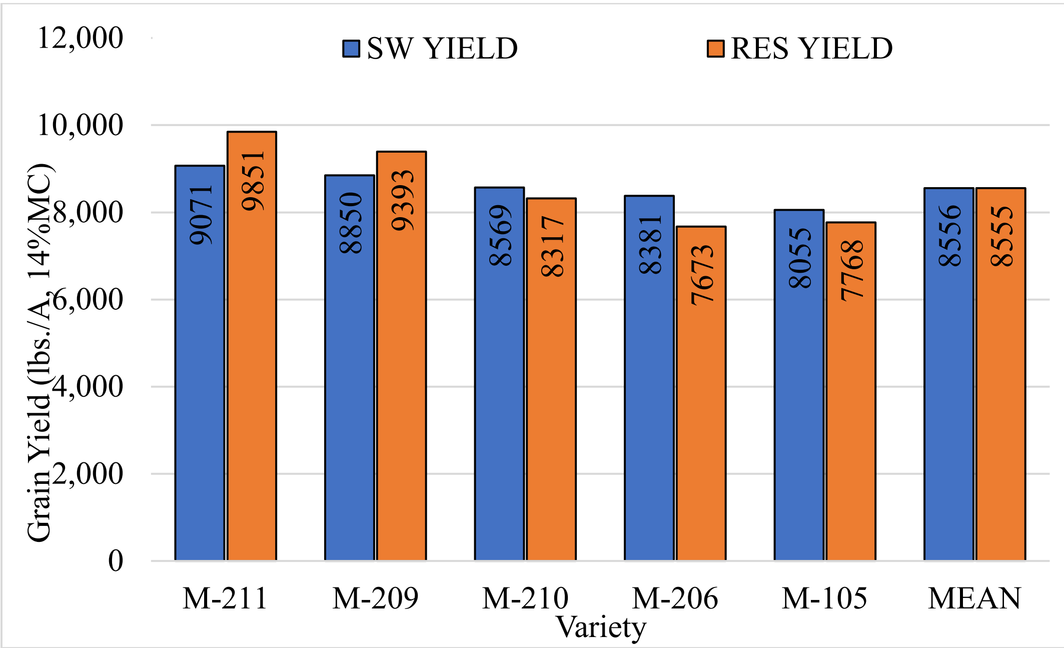

Figure 1. Statewide and RES performance of medium grain check varieties in 2022.

While lower yields were observed among medium grains in 2022 compared to 2021, agronomic characteristics of the check varieties were apparently not affected by the 2022 unusual weather issue. Table 4 summarizes the agronomic traits of medium grains at RES. For comparison, average days to 50% heading at SW Tests were included. On average, medium grains flowered at 85 days, had high seedling vigor, and plant height of about 100 cm. Percent lodging potential data were taken before the September rains. All medium grains were cold tolerant, with low cold-induced panicle blanking observed in San Joaquin cold nursery. In contrast, more than 20% cold-induced panicle blanking was observed among medium grains at RES refrigerated greenhouse. Field evaluations showed resistance of M-211 and M-210 to stem rot disease while M-209, M-206, and M-105 were all moderately susceptible.

Table 4. Agronomic characteristics of medium grain check varieties at RES 2022.

ID	50% to Heading (SW)	50% to Heading (RES)	Seedling Vigor	Plant Height (cm)	% Lodging	%Panicle Blanking (SJ)	%Panicle Blanking (GH)	Stem rot Score*
M-211	97	90	4.9	103	2	2	8	1 (HR)
M-209	97	90	4.9	97	0	1	37	3 (MS)
M-210	90	83	4.9	101	8	2	25	2 (R)
M-206	91	83	4.9	101	10	1	20	3 (MS)
M-105	88	81	4.8	99	10	2	22	3 (MS)
MEAN	92	85	4.9	100	6	1.6	44	3
CV	10	2	1.3	5	115	71.5	28	22
5%LSD	4	1	0.1	4	14	1.6	18	1

HR=highly resistant, R=resistant, MS=moderately susceptible

Grain Quality of Medium Grains

Advanced promising lines in the pipeline were grown in 10'x 60' plots for milling yield and grain quality evaluations. Each plot is sampled when the grain moisture content reached between 28-13%. Based on milling yield data, medium grain check varieties had the typical patterns of fissure resistance as observed in previous years. Figure 2 shows the milling yield trends of Calrose varieties at various harvest moisture content (MC) during harvest. At 20% MC, medium grain varieties averaged a milling yield of 68% head rice and 71% total (Table 5). Based on milling yield trends, M-105 had the most stable milling with head rice not going lower than 69% at harvest moistures ranging from 15-28%. M-206 and M-210 had overlapping lines indicating the similarity of their grain stability to milling (Fig. 2). Both varieties had more than 67% head rice at 18-26% MC. In contrast, M-209 had a slightly lower head rice yield than M-206 and M-210. M-211 had the lowest head rice yield among the five Calrose varieties. For better milling yield, it is ideal to harvest M-211 at grain moisture content not lower than 20%. Moreover, growers should be cautious of draining M-211 fields early. On average, M-211 flowered one week later than M-206, and thus, has later maturity compared to M-105, M-206, and M-210.

The August-September heatwave apparently had affected the grain quality of medium grains. For grain chalkiness and other grain attributes, 50 grams of milled rice sample were scanned using the S-21 machine. Rice sampled from milling yield plots showed significant amount of chalky kernels. The M-206 showed the highest whole chalky kernels at 3.2%. The M-211 had 2.6% chalk, M-209 had 2% while the M105 and M-210 had 1.9% whole chalky kernels. Furthermore, the taste values of medium grains were lower than usual based on Satake Taste Analyzer. Typically, Calrose varieties had taste values of about 75 and M-211 at about 80 value score. Whether it was due to heatwave or environmental factors, all medium grain checks had taste value not higher than 70 (Table 5).

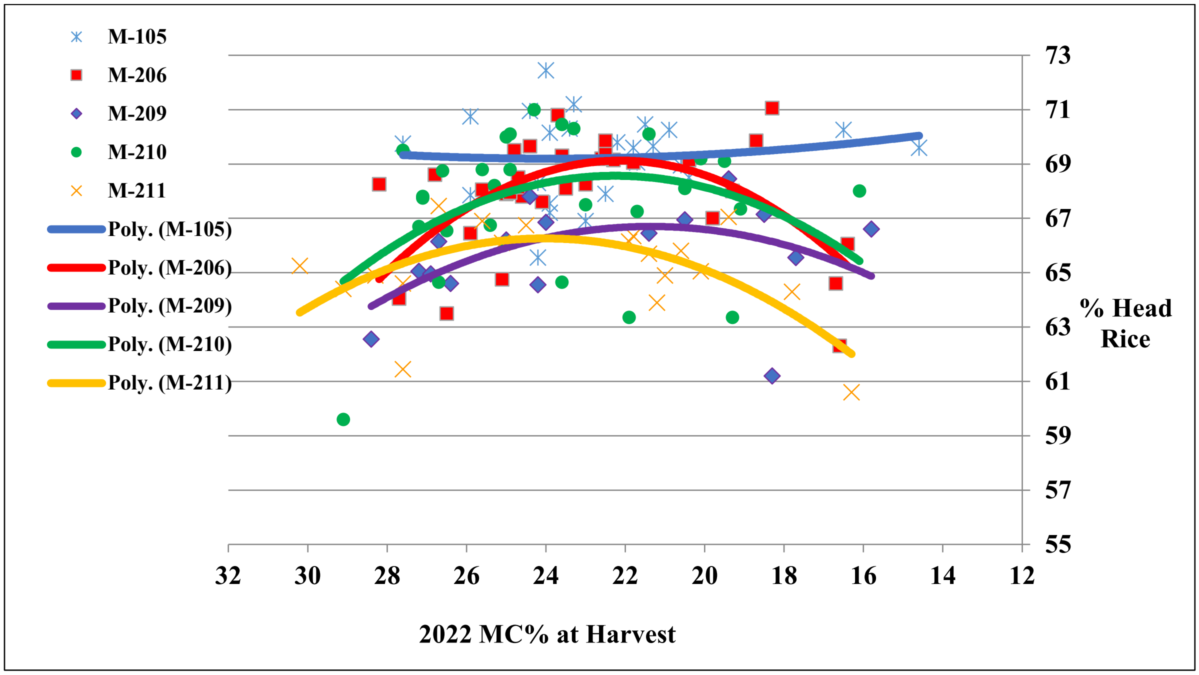

Figure 2. Milling yield of medium grain varieties across harvest moistures in 2022 at RES.

Table 5. Grain quality and taste value of medium grain varieties at RES, 2022.

22 ID	Harvest %MC	%Head	%Total	Whole Chalky Kernel (%)	Taste Value (Satake)	Protein Content (Satake)	Amylose Content (Satake)
M-105	21	69.5	71	1.9	62	7.7	20.3
M-206	20	69.3	72	3.2	58	8.2	20.9
M-209	19	65.9	71	2.0	70	6.8	19.6
M-210	20	68.5	71	1.9	58	8.4	20.8
M-211	21	65.8	70	2.6	68	7.3	19.7
MEAN	20	68	71	3	63	8	20
5%LSD	1.4	1.9	0.9	1.2	5.8	0.8	0.6
CV	6.0	2.4	1.1	38.7	7.8	9.1	2.7

Promising Advanced Lines in Medium Grain Yield Tests

The medium grain project evaluated 30 advanced lines in the Statewide yield tests and 341 conventional (non-herbicide) and ROXY medium grains in the advanced yield trial (AYT). The water shortage in the west resulted in reduction of UCCE Statewide yield test locations. In 2022, SW yield trials were only conducted in Glenn, North Butte, South Butte, RES, Sutter, Yuba, and San Joaquin. Among the lines the 30 lines in the SW yield tests, at least six lines were identified better than current check varieties. Table 6 summarizes all the characteristics of the six promising lines in the SW tests. For regular Calrose, 19Y3128 and 19Y3105 showed higher yield potential compared to all medium grains. 19Y3128 averaged 9,373 lb/A and 10,132 lb/A at SW and RES yield trials, respectively. 19Y3105 also outyielded M-211 in the SW yield testing, averaging 9,246 lb/A compared to 9,071 lb/A of M-211. Both promising lines had excellent seedling vigor, flowered similarly like M-211 at 90 days, had strong cold tolerance, high resistance to stem rot, and significantly higher taste values (78, 84 vs 68) than M-211. However, both lines showed lower head rice yields than M-211 at 20% MC.

In the premium quality medium grain class, 19Y3127 had an average yield of 8,891 lb/A (SW) and 9,883 lb/A (RES). This advanced line flowered at 95 days, had very good seedling vigor, a plant height of 104 cm, 55% head rice, 70% total milling, and very low % chalky kernel.

For blast-resistant Calrose type, 18Y3018 had a 3-5% yield advantage over M-210. 18Y3018 has *Pi-b* and *Pi-z5* blast resistance genes, and thus, may offer a broader blast resistance than M-210. In the SW yield tests, 18Y3018 averaged 8,836 lb/A compared to 8,569 lb/A of M-210. 18Y3018 had a similar seedling vigor to M-210, flowered at 88 days (5 days later), was more lodging resistant than M-210, was more cold tolerant in San Joaquin, had lower chalky kernel (1% vs 2%), and has higher taste value than M-210 (77 vs 65). However, 18Y3018 had a lower milling yield than M-210 at 20%MC.

Table 6. Characteristics of promising advanced lines in the medium grain project.

22 ID	TYPE	YIELD, (lb/A, 14%MC) SW	YIELD, (lb/A, 14%MC) RES	Harvest MC (%)	Seedling Vigor	Days to 50% to Heading (RES)	Plant Height (cm)	Lodging (%)
19Y3128	M	9373	10132	17	4.9	90	103	0
19Y3105	M	9246	10077	17	4.9	90	112	17
19Y3127	MPQ	8891	9883	18	4.9	95	104	0
18Y3018	MB, z5,b	8836	8793	17	4.9	88	99	0
19Y4048	MH	8458	8777	17	4.9	86	96	2
20Y4033	MF	8333	8115	20	4.9	82	100	17
M-211	MPQ	9071	9851	16	4.9	90	103	2
M-209	M	8850	9393	16	4.9	90	97	0
M-210	M	8569	8317	17	4.9	83	101	8
M-206	M	8381	7673	18	4.9	83	101	10
M-105	M	8055	7768	16	4.8	81	99	10

Table 6. continued.

22 ID	TYPE	%Panicle Blanking (SJ)	%Panicle Blanking (GH)	Stem rot Score	%Head Rice (20%MC)	%Total	%Chalky Kernel (S-21)	Taste Value
19Y3128	M	1	2	2.3	58	67	0.8	78
19Y3105	M	2.5	40	2	58	70	3.1	84
19Y3127	MPQ	3.0	20	3	55	70	0.5	80
18Y3018	MB, z5,b	0.8	60	3	62	69	1.0	77
19Y4048	MH	1.3	80	3	63	72	0.2	78
20Y4033	MF	2.3	40	3	64	71	2.0	77
M-211	MPQ	2	8	1 (HR)	65	70	2.7	68
M-209	M	1	37	3 (MS)	65	71	1.6	69
M-210	M	2	25	2 (R)	69	71	2.0	65
M-206	M	1	20	3 (MS)	68	71	2.5	64
M-105	M	2	22	3 (MS)	69	71	1.8	64

HR=highly resistant, R=resistant, MS=moderately susceptible

In addition to regular, premium, herbicide, and blast resistant Calrose types, the medium grain project started developing a fragrant Calrose. For this type, 20Y4033 was identified promising, with equal or better yield than M-206. 20Y4033, flowered one day earlier than M-206, had similar agronomic traits, cold tolerance, had lower chalky kernel, and a higher taste value than M-206. Overall, the six promising lines had higher yields and desirable taste values as compared to current medium grain varieties. However, all promising lines require a higher grain moisture content during harvest for higher milling yield.

M-521 (19Y4000), A Blast Resistant and Herbicide Tolerant Calrose Approved for Release in 2023

19Y4000 was approved for release by the CCRRF Board of Directors in 2023. This line will be the first herbicide resistant medium grain in California. The official variety name of 19Y4000 will be M-521. It is not only herbicide tolerant but is also a blast resistant Calrose. Table 7 summarizes the breeding history of M-521 (19Y4000). It was bred conventionally with the aid of marker-assisted selection (MAS) for *Pi-b* and the ROXY trait. 19Y4000 was derived from 2015 summer cross designated as RM3447 = M-210 x 14G9. M-210 was developed by backcrossing a blast donor isoline to M-206 seven times (BC7), making it genetically similar to M-206 by 99.6%. M-206 is a high yielding, glabrous, early maturing, Calrose-type medium grain variety released by RES in 2003. M-206 is the most widely grown Calrose variety in California with excellent milling yield and grain quality. 14G9 is an EMS-induced mutant of M-206 containing nucleotide deletion at *UGP3* gene and confers high tolerance to oxyfluorfen herbicide (US Patent 11,180,771 B2 and trademark ROXY®). Ten of the fifty-one F1 seeds of RM3447 were grown and transplanted in the 2015-16 Hawaii nursery to advance and increase the seeds of F_1 lines. The resulting F_2 seeds were bulked and grown in a 6-row plot (F_2 95457-95462) of the 2016 F_2 Nursery at RES. F_3 panicles were selected based on ideal plant type, early flowering, and brown rice grain appearance. From the 2017 MG F_3 progeny row nursery, row #91867 was selected and entered in the 2018 10'x10' preliminary yield trial (PYT) as 18P4082 (F_4 generation). The PYT field for the ROXY project was treated with oxyfluorfen at 2 pints per acre, applied preplant. 18P4082 was selected and entered in the 2018-19 Hawaii nursery for seed increase as 18-81245 (F_5) with plot# 8003. 18P4082 had an average yield potential of 10,818 lb/A and flowered at 80 days. The F_6 seed of 18-81245 was bulked harvested from Hawaii and was promptly entered into the 2019 two-rep UCCE Statewide (SW) Advanced Yield Test (A2). The line was designated as 19Y4000 (F_6). Mean yield for 19Y4000 was 8,983 lb/A in the 2019 SW Advanced Yield Test. 19Y4000 was entered in the four replication SW Advanced yield Tests (A4) at all locations in 2020 (F_7). The SW evaluation of 19Y4000 continued in 2021 (F_8) and 2022 (F_9). Overall, the 19Y4000 was evaluated in the UCCE SW Yield Tests for four years (2019-2022), for a total of 41 yield experiments (Table 8). The line purification seed increase of 19Y4000 was conducted from 2020 to 2022 with marker-assisted selection. The SSR marker RM208 was used to check for the presence of the *Pi-b* gene while the *Rox1.1* SNP marker for the Roxy trait was used. All seed maintenance and head rows of 19Y4000 were carefully checked for the presence of *Pi-b* and *Rox1.1* alleles to verify the traits. For purity, uniformity, stability, and fingerprinting, all head rows of 19Y4000 were genotyped using SSR markers.

Table 7. Breeding and selection history of 19Y4000.

Year and Location	R#, P#, Y# Designation	Experiment	Plot#
2015, Summer, RES	RM3447 = M-210/14G9	M206*8/97Y315vE(Pi-b)//14G9	
2015-16, Hawaii	RM3447	F_1 Transplants	2015-16, HA F_1 9166
2016 Summer, RES	RM3447-bu	F_2, Population	2016 F_2 95457-95462
2017 Summer, RES	RM3447-bu-re1	F_3, Progeny row	2017 MG Row 91867
2018 Summer, RES	18P4082	F_4, 10'x10' PYT plots	2018 SM 35117-35120
2018-19, Hawaii	18-81245	F_5, Seed increase	2018-19, 8003
2019 Summer, RES	19Y4000 (ID), 19Y24, 19Y84, 19Y144	F_6, 1LA, 3LA, 7LA	2019 HR 51521-51600
2020 Summer, RES	20Y12, 20Y68, 20Y124	F_7, 1LA, 3LA, 7LA, HR	2020 HR 67451-68050
2021 Summer, RES	21Y4, 21Y60, 21Y116	F_8, 1LA, 3LA, 7LA, HR	2021 HR 80001-80400, Breeder Seed
2022 Summer, RES	22Y5	F_9, 1LA, 3LA, 7LA, HR	2022 HR 8001-8400, Breeder Seed, FND
2023 Summer, RES	M-521	F_{10}, propose to release	

NOTES and ABBREVIATIONS: Summer nurseries were planted at the Rice Experiment Station (RES) in Biggs, CA. By convention, filial generations are designated as F and the generation number (e.g., F_1=first filial generation); PYT= Preliminary Yield Trial at RES; 1LA =SW-Very Early Group; 3LA=SW-Early Group; 7LA=SW-Intermediate-Late Group; HR=Head Row purification; SM=Drill-seeded Seed Maintenance Nursery; FND=Foundation Seed Production.

Table 8. Summary of tests and number of locations for 19Y4000 from 2019 to 2022.

Experimental Trial	Year	No. of Locations
Statewide Advanced Preliminary Test (A2)	2019	11
Statewide Advanced Test (A4)	2020	10
Statewide Advanced Test (A4)	2021	11
Statewide Advanced Test (A4)	2022	9
Total	2019-22 (4 years)	41

Yield and Agronomic Performance of 19Y4000 in SW Tests

Based on the pooled four-year SW Yield Tests, field performance of 19Y4000 was closely similar to M-206 and M-210 in all SW test locations starting in 2019 (Table 9). It has very good seedling vigor, flowered at 87 days, plant height of 96cm, and lodging potential like M-206 and M-210. Yield performance of 19Y4000 in different zones or UCCE test locations are summarized in Table 10 and Supplementary Tables 1,2,3. Location-specific performance of 19Y4000 indicated 2-4% yield advantage of 19Y4000 over M-206 and M-210 in San Joaquin and Biggs. However, in other locations, 19Y4000 had an average of 2% lower yield than the two Calrose varieties. Overall, 19Y4000 has similar adaptation like M-206 and M-210 across rice growing counties in California (Figure 3).

Table 9. Mean performance of 19Y4000, M-206 and M-210 in a total of 41 experiments of UCCE SW Tests from 2019 to 2022.

ID	Grain Yield (lb/A)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
19Y4000	8,839	4.8	87	96	31
M-206	8,907	4.8	88	97	38
M-210	8,949	4.8	88	96	30
MEAN	8,899	4.8	88	96	33
LSD (0.05)	345	0.0	3	3	15
CV	9	1.3	9	8	104

Table 10. Mean yield comparison of 19Y4000, M-206, and M-210 in UCCE SW Test locations from 1019-2022.

Location (County)	Grain Yield (lb/acre, 14%MC, 4 year data)			Yield advantage over M-206	Yield advantage over M-210
	M-206	M-210	19Y4000		
San Joaquin	9,618	9,502	9,848	2%	4%
South Butte	9,292	9,578	9,131	-2%	-5%
Glenn	9,152	9,487	8,885	-3%	-6%
Colusa	9,295	9,178	9,000	-3%	-2%
Sutter	9,200	9,246	8,748	-5%	-5%
Yolo	9,130	9,067	8,894	-3%	-2%
Biggs	8,752	8,733	9,018	3%	3%
North Butte	8,624	8,982	8,882	3%	-1%
Yuba	7,860	7,538	7,334	-7%	-3%
MEAN	8907	8949	8839	-2%	-2%

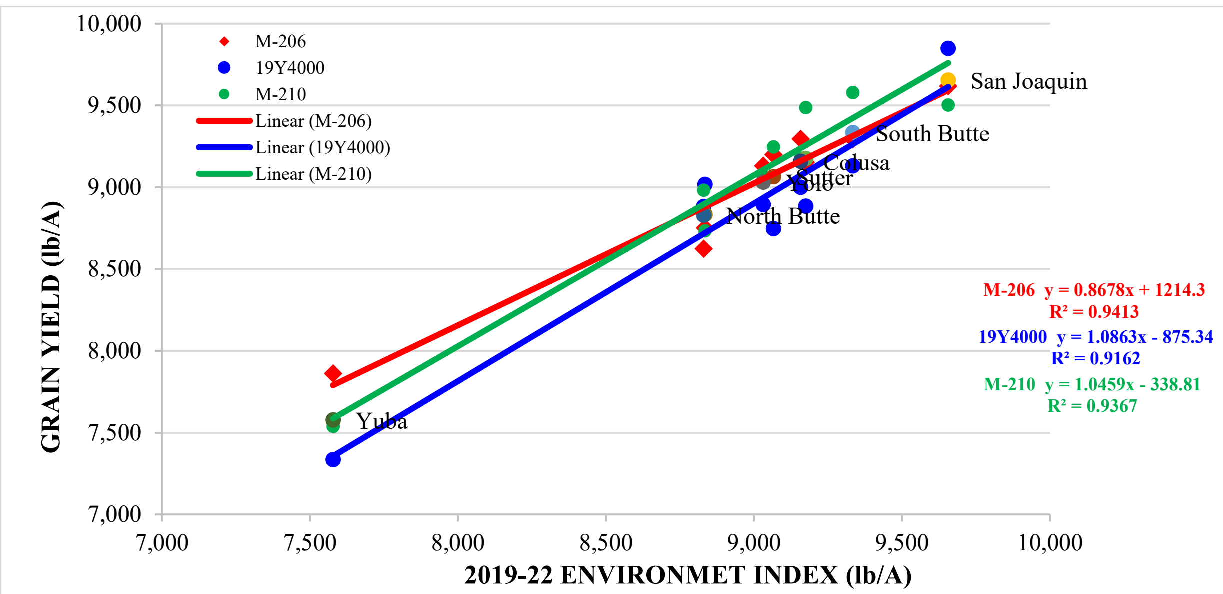

Figure 3. Four-year combined trend analysis of the SW average grain yield of 19Y4000, M-206, and M-210 plotted against grain yield environment index (2019-2022).

Grain Characteristics and Milling Quality of 19Y4000

A comparison of grain dimensions and appearance of 19Y4000, M-206, and M-210 are presented in Table 11 and Fig. 4. The milled grains of 19Y4000 were marginally lighter (1000-grain weight = 21.05 g) and slightly longer (length = 5.83 mm) as compared to M-206 (21.09 g, 5.78 mm) and M-210 (21.39 g, 5.80 mm). Grain width of 19Y4000 (2.69 mm) was narrower than M-206 and M-210. 19Y4000 meets the criteria of the Calrose rice market with a slightly longer grain and higher L/W ratio of 2.19 and therefore can be comingled with other Calrose rice varieties currently in production in California.

Table 11. Grain dimensions of 19Y4000, M-206 and M-210.

Year	ID	Paddy Rice			Brown Rice			Milled Rice			
		Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	LW Ratio	1000-seed wt.
2019	M-206	8.11	3.33	30.80	6.23	2.86	24.20	6.04	2.90	2.09	22.50
	M-210	8.18	3.37	31.60	6.25	2.88	24.90	5.92	2.84	2.09	22.20
	19Y4000	8.14	3.25	29.60	6.30	2.83	24.00	5.97	2.76	2.17	21.40
2020	M-206	7.77	3.30	29.96	6.02	2.79	23.74	5.75	2.73	2.11	21.91
	M-210	8.05	3.31	32.21	6.17	2.79	24.66	5.79	2.68	2.17	22.22
	19Y4000	7.93	3.29	30.69	6.14	2.77	24.08	5.73	2.65	2.17	21.78
2021	M-206	7.74	3.25	26.94	5.96	2.78	16.60	5.67	2.69	2.12	19.89
	M-210	7.81	3.21	27.41	6.03	2.79	23.28	5.86	2.71	2.18	21.31
	19Y4000	7.79	3.26	26.13	5.97	2.76	22.38	5.83	2.67	2.20	20.68
2022	M-206	7.71	3.25	26.74	6.14	2.88	24.51	5.66	2.70	2.10	20.05
	M-210	7.72	3.29	26.52	6.28	2.87	24.34	5.63	2.68	2.11	19.84
	19Y4000	7.82	3.23	27.32	6.28	2.83	23.77	5.79	2.66	2.24	20.33
Mean	**M-206**	**7.83**	**3.28**	**28.61**	**6.09**	**2.83**	**22.26**	**5.78**	**2.75**	**2.10**	**21.09**
	M-210	**7.94**	**3.30**	**29.43**	**6.18**	**2.83**	**24.30**	**5.80**	**2.73**	**2.14**	**21.39**
	19Y4000	**7.92**	**3.26**	**28.44**	**6.17**	**2.80**	**23.55**	**5.83**	**2.69**	**2.19**	**21.05**

M-206 19Y4000 M-210

Figure 4. Paddy, brown, and milled rice samples of M-206, 19Y4000, and M-210.

The averaged total and head rice milling percentage of 19Y4000, M-206, and M-210 taken from varying harvest moisture contents at RES from 2019 to 2022 milling plots are presented in Figure 5. The overlapping regression lines of 19Y4000, M-206 and M-210 at about 19-24% MC indicate the similarity of the three lines in terms of milling yield and grain fissure resistance. All three lines had excellent milling yields. Further classification of milling yields into samples taken above 22% moisture, 18-22%, and below 18% harvest moisture for 19Y4000, M-206, and M-210 are summarized in Table 12. When cut at 22% MC and above, M-206 had 68/71, while M-210 and 19Y4000 had 67/71. At 18-22% MC, the milling yield of 19Y4000 was slightly improved to 67/72 similar to M-210. However, when harvested at moistures below 18%, all three entries tended to have reduced head rice as grains became drier.

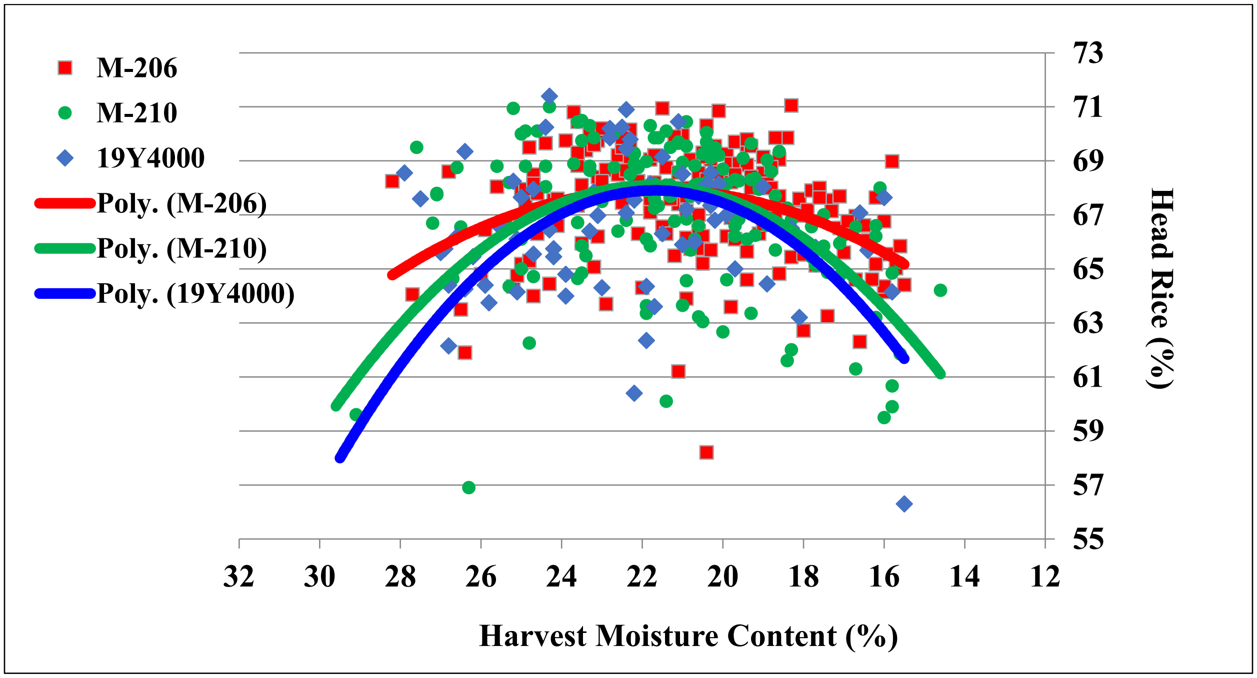

Figure 5. Regression analysis of the effect of harvest grain moisture on head rice of 19Y4000, M-206, and M-210 in milling plots at RES from 2019 to 2022.

Table 12. Average head and total milled rice of 19Y4000, M-206, and M-210 at harvest grain moisture content above 22%, 18-22%, and below 18% from 2019 – 2022.

Entry	% Moisture Content at Harvest		
	More than 22%	18-22%	Less than 18%
19Y4000	66/71	67/72	64/72
M-206	68/71	68/71	66/71
M-210	67/71	67/72	65/71

RVA and Quality Evaluation of 19Y4000

Apparent amylose, protein content and gel type of 19Y4000, M-206, and M-210 from 2019 to 2022 is presented in Table 13. The protein content was quantified by California Wheat Commission while the apparent amylose content was determined following the USDA's protocol on colorimetric and spectral measurement of amylose, conducted at the RES Genetics Lab. The average apparent amylose and protein content of 19Y4000 was similar to M-206 and M-210 at 20.66% and 5.96%, respectively. All three lines had low gel type typical of a Calrose-type medium grain.

The RVA profile of 19Y4000, M-206, and M-210 from 2019 to 2022 is presented in Table 14 while the amylograph profile based on the 2022 RVA data is illustrated in Figure 6. Based on the average of four-year RVA data, 19Y4000 does not deviate significantly from the profile of M-206 or M-210. These results indicate that 19Y4000 cooking characteristics are similar to M-206 and typical of a Calrose type rice.

Table 13. Amylose, protein content and gel type of 19Y4000, M-206, and M-210. Grain samples were taken from milling plots and seed fields at RES in 2019-22.

Year	Entry	Apparent Amylose (%)	Protein (%) (White rice)	Gel Type
2019	19Y4000	-	6.16	Low
	M-206	19.60	5.54	Low
	M-210	19.60	5.04	Low
2020	19Y4000	21.10	5.77	Low
	M-206	18.10	5.40	Low
	M-210	18.90	5.68	Low
2022	19Y4000	20.22	5.96	Low
	M-206	19.85	6.60	Low
	M-210	19.85	6.59	Low
Mean	**19Y4000**	**20.66**	**5.96**	**Low**
	M-206	**19.18**	**5.85**	**Low**
	M-210	**19.45**	**5.77**	**Low**

Table 16. RVA profile of 19Y4000, M-206, and M-210 measured at RES from 2019-2022.

YEAR	ID	Peak	Trough	Break down	Final Viscosity	Setback	Peak Time (min)	Pasting Temp
2019	19Y4000	249	129	119	230	-19	6	90
	M-206	297	146	151	253	-44	6	88
	M-210	301	146	156	253	-49	6	88
2020	19Y4000	276	141	134	254	-21	6	92
	M-206	261	140	121	249	-12	6	93
	M-210	286	133	152	241	-44	6	90
2021	19Y4000	245	123	121	235	-9	6	93
	M-206	250	123	127	232	-18	6	93
	M-210	261	129	133	241	-21	6	92
2022	19Y4000	273	144	129	239	-34	6	88
	M-206	278	151	127	248	-31	6	89
	M-210	253	139	114	225	-27	6	89
Mean	**19Y4000**	**260**	**134**	**126**	**240**	**-21**	**6**	**91**
	M-206	**272**	**140**	**132**	**245**	**-26**	**6**	**91**
	M-210	**275**	**137**	**139**	**240**	**-35**	**6**	**90**

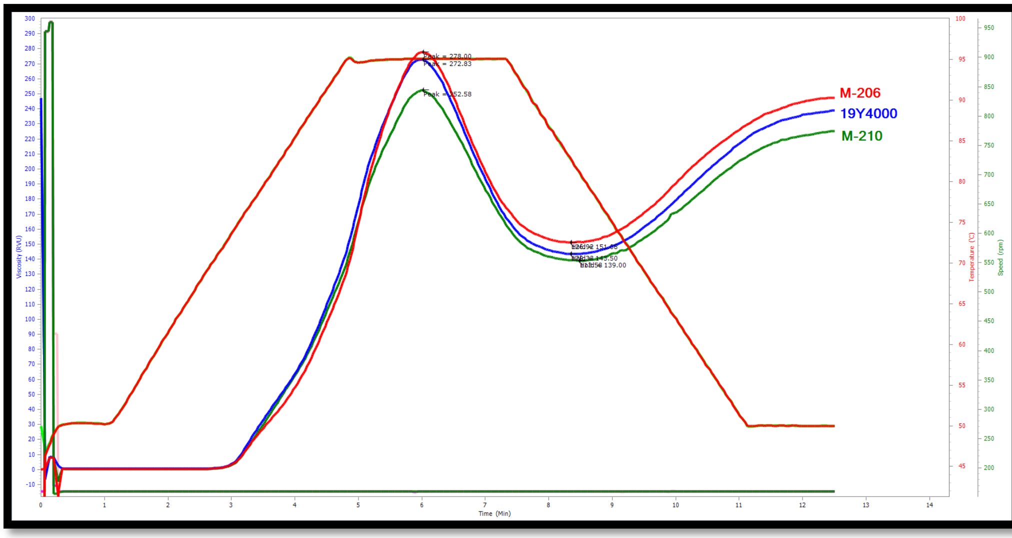

Figure 6. Amylographic profile of 19Y4000, M-206, and M-210 (2022 data).

Cold-induced Panicle Blanking and Disease Screening Tests

Table 17 summarizes the results of cold tolerance screening in San Joaquin (SJ) and the refrigerated greenhouse (GH) at RES from 2019 to 2022. Four-year combined results in San Joaquin showed that 19Y4000 had an average blanking of 1.3% compared to 1.5% and 1.2% for M-206 and M-210, respectively. In the greenhouse, 19Y4000 showed 34% panicle blanking while M-206 and M-210 had 31 and 35%, respectively. Overall, in both San Joaquin and greenhouse testing, 19Y4000 had cold tolerance level similar to M-206 and M-210.

Table 17. Refrigerated greenhouse and San Joaquin cold tolerance data for 19Y4000, M-206, and M-210 from 2019 – 2022.

Year	ID	SJ Blanking (%)	GH Blanking (%)
2019	19Y4000	1.0	15.0
	M-206	1.0	15.8
	M-210	1.0	20.8
2020	19Y4000	1.0	56.0
	M-206	1.0	70.0
	M-210	1.0	53.0
2021	19Y4000	2.0	47.0
	M-206	3.0	20.0
	M-210	1.0	41.0
2022	19Y4000	1.1	20.0
	M-206	1.0	20.0
	M-210	1.7	25.0
Mean	**19Y4000**	**1.3**	**34.5**
	M-206	**1.5**	**31.5**
	M-210	**1.2**	**35.0**

Field evaluations for stem rot disease resistance was conducted at RES by inoculation of sclerotia to advanced breeding lines rows. For blast, disease resistance screening is limited to detection of incorporated blast R gene using DNA marker such as RM208 for *Pi-b*. Based on the four-year stem rot resistance screening (Table 18), 19Y4000 had an average stem rot score of 3.38 which is moderately susceptible to stem rot disease. Similarly, M-206 and M-210 were both susceptible to stem rot (scored 3.77 and 3.45). Aggregate sheath spot was not observed in all three lines being compared from 2019 to 2022. 19Y4000 and M-210 were both positive for the presence of the *Pi-b* blast gene using RM208 marker (R+) while M-206 was negative for the desired *Pi-b* allele (R-). Therefore, in the event of blast disease outbreak, 19Y4000 and M-210 are both expected to show resistance to the blast pathogen.

Table 18. Disease reaction of 19Y4000, M-206, and M-210 to stem rot, blast marker, and aggregate sheath spot from 2019 – 2022.

YEAR	ID	Blast R Gene (RM208)	Stem rot Score	Aggregate Sheath Spot Score
2019	19Y4000	R+	3.80	nt
	M-206	R-	4.50	nt
	M-210	R+	4.00	nt
2020	19Y4000	R+	4.00	nt
	M-206	R-	3.30	nt
	M-210	R+	4.00	nt
2021	19Y4000	R+	3.00	nt
	M-206	R-	4.00	nt
	M-210	R+	3.80	nt
2022	19Y4000	R+	2.70	nt
	M-206	R-	3.27	nt
	M-210	R+	2.00	nt
Mean	**19Y4000**	R+	**3.38**	**nt**
	M-206	R-	**3.77**	**nt**
	M-210	R+	**3.45**	**nt**

Blast score for RM-208 where: R+ indicates *Pi-b* gene for blast resistance is present and R- indicates gene is absent.
Stem rot scores: 1-5 where 1 is highly resistant and 5 is highly susceptible; 1=all but 1 leaf sheath penetrated, 3=all leaf sheath penetrated but not the culm, 5=100% infection, culm filled with sclerotia.
Aggregate Sheath Spot score: nt = not tested or observed.

17Y2087, Premium Quality Short Grain Rice Approved for Release in 2023 as Calhikari-203

17Y2087 is a semidwarf, early maturing, high yielding premium quality short grain rice approved for release in 2023 by the CCRRF Board of Directors, and will be named as Calhikari-203 (CH-203). It has an 11-13% yield advantage over Calhikari-202 and Calhikari-201, averaging 9,050 lb/A yield based on five-year UCCE Statewide Yield Tests. The leaves and paddy rice of 17Y2087 are glabrous. 17Y2087 consistently showed higher lodging resistance (33% vs 65 and 61% of CH-202 and CH-201). It has high milling quality, heavier milled grains than CH-202 and CH-201 (1000 seed wt=18.05g vs 17.20g and 17.61g) and has slightly longer grain length. Internal and external blind test evaluations indicated the excellent grain appearance, cooking, and taste qualities of 17Y2087 for the premium quality short grain market. Taken all together, the 17Y2087 attributes make it suitable for comingling with existing premium quality short grains or a viable alternative to CH-202 or CH-201.

Selection History

The breeding and selection history of 17Y2087 is summarized in Table 19. It was bred conventionally using pedigree selection for the premium short grain market. 17Y2087 originated from a cross designated as RS2095. The cross was made in the spring of 2012 and generated 27 F_1 seeds. Ten F_1 seeds were grown and transplanted in the 2012 Summer RES F_1 Nursery. The F_2 seeds from the F_1 row were harvested, bulked, and grown to a spaced planted 6-row F_2 plot at RES F2 Nursery in 2013. Panicles were selected from F_2 plots based on plant type, early flowering, panicle blanking, and brown rice grain appearance. Selected panicles were planted into progeny rows (one panicle to a row) at RES F_3 Nursery in 2014. Row#16 was selected and entered in a three-row RES F_4 Nursery in 2015. From which Row#3 was selected and bulked to enter in 2015-16 Hawaii F_5 progeny row (Hi 5564) for generation advance. The resulting F_6 seeds harvested from Hawaii were bulked and entered in the 10'x10' 2016 RES preliminary yield trial (PYT) and was designated as 16P2355. In 2017, 16P2355 was entered into 10'x 20' RES advanced yield trial (AYT) as 17Y2087 (ID). Due to its promising yield potential, grain, and eating qualities of a premium short grain, the 17Y2087 was entered in the Very Early Group-Preliminary UCCE Statewide Tests (1LB-A2) in 2018 (F_8) to 2019 (F_9). The 17Y2087 showed higher yield potential over CH-201 and CH-202 in cooler areas of Sutter, Yolo, and Yuba. Thus, in 2020, the 17Y2087 (F_{10}) was entered in four-rep advanced SW tests (A4) in all locations. The SW all-location yield testing was continued in 2021 (F_{11}) and 2022 (F_{12}). 17Y2087 was evaluated for a total of 43 yield experiments in five years of statewide yield testing. In all SW yield testing, 17Y2087 showed a significant yield advantage over CH-201 and CH-202. Head row purification of 17Y2087 began in 2020 by growing seventy panicles to seventy rows (20HR 61151-61220). In 2021, 17Y2087 seeds were increased by growing four hundred head rows (21HR 63401-63800). Four hundred panicles were selected from head rows, then all head rows were bulked harvested to compose the breeders seed that was planted in 2022 foundation seed field production. To ensure the purity, uniformity, and stability of 17Y2087, 400 foundation head rows (22FND HR 66151-66550) were grown in the foundation seed field in 2022. All head rows were carefully checked for off types and each row was genotyped using 16 SSR markers in 2021-2022.

Yield and Agronomic Performance of 17Y2087 in SW Tests

Table 20 summarizes the records of 17Y2087 in the UCCE SW Tests from 2018 to 2022 while Table 21 summarizes the five-year SW field performance of 17Y2087 along with other premium quality short grain checks. In 2018, the 17Y2087 outyielded CH-202 by 6% and 10% over CH-201. 17Y2087 had an average yield of 8,944 lb/A compared to 8,427 and 8,154 lb/A yield of CH-202 and CH-201, respectively. In the following year (2019), 17Y2087 was again entered in the Very Early Group UCCE SW Test (1LB). Results indicated the strong yield potential of 17Y2087 over other Calhikari checks. Thus in 2020, 17Y2087 was entered in four-rep, all SW group yield tests (1LA4, 3LA4, 7LA4). The 17Y2087 had an average of 9,448 lb/A and yield advantage of 18% compared to 7,982 lb/A of CH-202. In 2021, SW yield testing of 17Y2087 was repeated in all locations, and 17Y2087 had an average yield of 9,161 lb/A, which was about 12% higher than CH-202

(8,144 lb/A). In 2022, the state experienced a drought and a September heatwave. SW yield trial was not conducted in Yolo, South Yolo, and Colusa. Nonetheless, the 17Y2087 had a SW average yield of 8,637lb/A compared to 8,158 and 8,002 lb/A of CH-202 and CH-201, respectively. Overall, 17Y2087 is a high yielding line with SW average yield of 9,050 lb/A. Over 43 SW replicated trials, 17Y2087 had 11% yield advantage over CH-202 and additional 13% yield over CH-201 (Table 21).

Table 19. Breeding and selection history of 17Y2087.

Year and Location	**R#, P#, Y# Designation**	**Experiment**	**Plot#**
2012 Spring, RES	Cross RS2095 = RS1955/CH-202	10Y2049/04Y177/4/Kosh*2/S-101//Kosh/S-101/3/Hitome	
2012, Summer, RES	RS2095	F_1 Transplants	
2013 summer, RES	RS2095(12RES)-(13RES)BU	F_2, Population	
2014 Summer, RES	RS2095(12RES)-(13RES)BU-(14RES)R16	F_3, Progeny row	
2015 Summer, RES	RS2095(12RES)-(13RES)BU-(14RES)R16-(15RES)R3	F_4, Progeny row	
2015-16, Hawaii	15-16 Hi 5564	F_5, Progeny row	
2016 Summer, RES	16P2355	F_6, 10'x10' small plot (3763)	16SM 115167- 115172
2017 Summer, RES	17Y2087 (ID)	F_7, 4LP	17SM 112476- 112490
2018 Summer, RES	18Y56	F_8, 1LB	18SM 101021- 101050
2019 Summer, RES	19Y48	F_9, 1LB	19SM 100421- 100450
2020 Summer, RES	20Y13, 20Y69, 20Y125	F_{10}, 1LA4, 3LA4, 7LA4, HR	20HR 61151-61220
2021 Summer, RES	21Y9, 21Y65, 21Y121	F_{11}, 1LA4, 3LA4, 7LA4, HR	21HR 63401-63800
2022 Summer, RES	22Y7	F_{12}, 1LA4, 3LA4, 7LA4, HR	22HR 66151-66550, FND
2023 January, RES	CALHIKARI-203	F_{13}, Proposed to release	

NOTES and ABBREVIATIONS: Summer nurseries were planted at the Rice Experiment Station (RES) in Biggs, CA. By convention, filial generations are designated as F and the generation number (e.g., F_1=first filial generation); PYT= Preliminary Yield Trial at RES; LP= Large Plot (10'x20' plot); 1LB = SW-Very Early Preliminary Group; 1LA4 =SW-Very Early Group, four-rep test; 3LA4=SW-Early Group, four-rep test; 7LA4=SW-Intermediate-Late Group, four-rep test; HR=Head Row purification; SM=Drill-seeded Seed Maintenance Nursery; FND=Foundation Seed Production.

Table 20. Summary of UCCE SW testing and number of locations for 17Y2087 from 2018 to 2022.

UCCE SW Experimental Trial	Year	No. of Locations
Statewide Preliminary Test, Very Early Group (1LB)	2018	8
Statewide Preliminary Test, Very Early Group (1LB)	2019	5
Statewide Advanced Test, (1LA4, 3LA4, 7LA4)	2020	10
Statewide Advanced Test, (1LA4, 3LA4, 7LA4)	2021	11
Statewide Advanced Test, (1LA4, 3LA4, 7LA4)	2022	9
Total	2018-2022 (5 Years)	43

ABBREVIATIONS: 1LB = SW-Very Early Preliminary Group; 1LA4 =SW-Very Early Group, four-rep test; 3LA4=SW-Early Group, four-rep test; 7LA4=SW-Intermediate-Late Group, four-rep test.

Table 21. Overall mean performance of 17Y2087, CH-202, and CH-201 in UCCE SW Tests from 2018 to 2022.

Year	ID	Grain Yield (lb/A)	%Yield Advantage over	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
2018	17Y2087	8,944		4.9	84	93	22
	CH-202	8,427	6	4.8	83	92	72
	CH-201	8,154	10	4.8	86	94	64
2019	17Y2087	8,920		4.8	89	93	34
	CH-202	8,353	7	4.8	87	94	69
	CH-201	7,777	15	4.8	91	96	70
2020	17Y2087	9,448		4.8	87	92	39
	CH-202	7,982	18	4.8	86	91	82
	CH-201	nt	-	-	-	-	-
2021	17Y2087	9,161		4.8	92	89	38
	CH-202	8,144	12	4.8	89	87	55
	CH-201	nt	-	-	-	-	-
2022	17Y2087	8,637		4.8	91	90	31
	CH-202	7,808	11	4.8	89	86	52
	CH-201	8,090	7	4.9	93	90	45
MEAN 2018-22	17Y2087	9,050		4.8	89	91	33
	CH-202	8,158	11	4.8	87	90	65
	CH-201	8,002	13	4.8	90	93	61
	MEAN	8,418		4.8	88	91	54
	LSD (0.05)	454		0.03	3	3	16
	CV	13		1.6	9	8	71

CV=Coefficient of Variation (%), LSD=5% Least Significant Difference, nt=genotype not evaluated in SW test.

Compared to CH-202 and CH-201, 17Y2087 had similar seedling vigor, it flowered at 89 days which is two days later than CH-202 but, one day earlier than CH-201 in SW Tests. The 17Y2087 is considered semidwarf like CH-202 and CH-201 at 90 cm plant height. Despite the similarity in plant height among the three entries, 17Y2087 had excellent straw strength as shown by low lodging potential at 33% compared to 65 and 61% lodging potentials of CH-202 and CH-201, respectively (Table 21).

Statewide yield performance of 17Y2087 by location is summarized in Table 22 and Figure 7. Supplemental Tables 4, 5, and 6 list the details of yield and agronomic characteristics of 17Y2087 in all UCCE SW Tests. In the cooler areas of Sutter, Yuba, Yolo, and San Joaquin, 17Y2087 showed to be cold tolerant as indicated by higher yields especially in Yolo and San Joaquin, averaging more than 10,000 lb/A. In Sutter, and South Yolo, 17Y2087 had 5-8% yield advantage over checks. In the low yielding environment of Yuba, 17Y2087 significantly had a 16% yield advantage over CH-202 or CH-201. In North and South Butte including Biggs, 17Y2087 had grain yield that ranged from 8,691 to 9,595 lb/A, for an average of 9,107 lb/A. In contrast, CH-202 yields ranged from 7,232 to 8,659 lb/A, with an average of 8,002 lb/A. CH-201 yields ranged from 7,235 to 8,555 lb/A, with an average of 8,000 lb/A. Similarly, 17Y2087 showed a strong field performance in Glenn and Colusa. 17Y2087 had 2-10% yield advantage in Glenn while in Colusa, 13-15% yield advantage were observed when compared to CH-202 or CH-201.

In summary, 17Y2087 had superior grain yield advantage over CH-202 or CH-201 in all SW test locations. It is adapted in all rice growing counties of California that makes it a viable alternative rice variety for commercial rice production.

Table 22. Mean yield comparisons of 17Y2087, CH-202, and CH-201 in all UCCE SW Test locations from 2018-2022.

Location	**Grain Yield (lb/Acre, 14%MC, 5-year data)**			**17Y2087 Yield Advantage over**	
	17Y2087	**CH-202**	**CH-201**	**CH-202**	**CH-201**
YUBA	**7,960**	6,890	6,844	16	16
GLENN	**8,303**	7,539	8,144	10	2
SOUTH YOLO	**8,370**	7,865	7,725	6	8
NORTH BUTTE	**8,691**	7,232	7,235	20	20
COLUSA	**9,059**	7,982	7,910	13	15
RES (BIGGS)	**9,122**	8,529	7,882	7	16
SUTTER	**9,165**	8,609	8,761	6	5
SOUTH BUTTE	**9,595**	8,167	8,555	17	12
YOLO	**10,243**	9,309	9,500	10	8
SAN JOAQUIN	**10,348**	9,818	8,218	5	26
MEAN	**9,086**	**8,194**	**8,077**	**11**	**13**

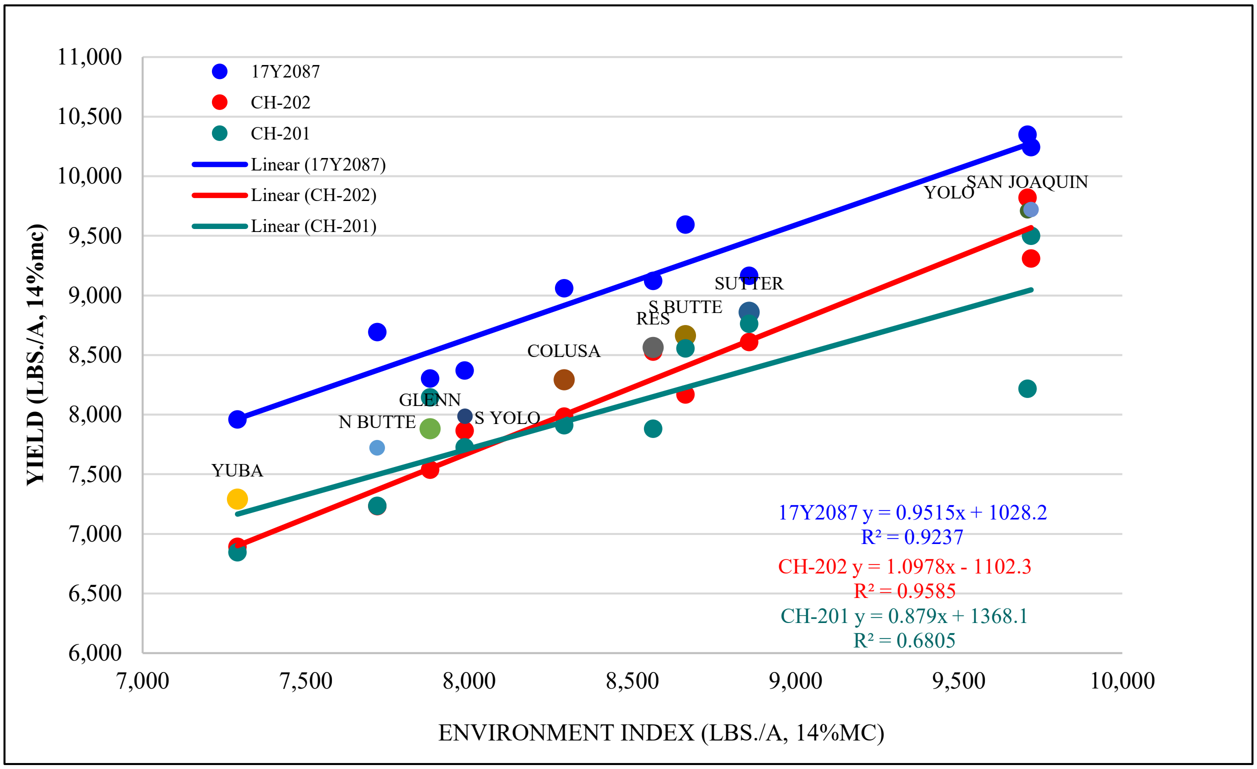

Figure 7. Five-year combined trend analysis of SW average grain yield of 17Y2087, CH-202, and CH-201 plotted against grain yield environment index (2018-2022).

Grain Characteristics and Milling Quality of 17Y2087

Table 23 summarized the grain dimensions of paddy, brown and milled rice samples of 17Y2087, CH-202, and CH-201. Figure 8 showed the comparative appearance of the grains of the three short grains. The dimensions of rough, brown, and milled rice kernels of 17Y2087 are remarkably similar to CH-202 and CH-201 in four years of grain measurement comparisons. On average, the milled rice grains of 17Y2087 were 0.45 to 0.85g heavier than CH-201 and CH-202 (100 seed weight). The grain widths of the three lines are all the same at 2.68-2.69mm. However, grain length of 17Y2087 milled rice grains are slightly longer (length=4.68mm) compared to CH-202 (4.58mm) and CH-201 (4.56mm). This slight increase in grain length of 17Y2087 resulted in marginally higher L/W ratio than the two checks (1.75 vs 1.72, 1.70). Despite that, the 17Y2087 has grain dimensions very closely similar to premium short grains and thus can be co-mingled with commercially grown CH-202 or CH-201.

Total milled rice and head rice of 17Y2087, CH-202, and CH-201 taken from varying harvest moisture content at RES from 2018 to 2022 milling plots are presented in Supplemental Table 7. Milling yields were further categorized into samples taken above 22% MC, 18-22% MC, and below 18% MC (Table 24). Based on these categories, 17Y2087 and CH-202 had similar milling quality of 67 / 71 (% Head/%Total) at 22%MC and above. At 18-22%, 17Y2087 had 1% to 2% higher head rice than CH-202 and CH-201. At less than 18% MC, all three lines tend to have lower % head rice, but 17Y2087 and CH-202 still had milling quality of 60 / 72.

Table 23. Grain dimensions of 17Y2087, CH-202 and CH-201.

Year	ID	Paddy Rice			Brown Rice			Milled Rice			
		Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	1000-seed wt.	Length (mm)	Width (mm)	LW Ratio	1000-seed wt.
2019	17Y2087	6.58	3.28	24.78	4.90	2.84	19.66	4.76	2.63	1.81	18.05
	CH-202	6.47	3.34	23.73	4.75	2.86	18.69	4.63	2.63	1.76	17.30
	CH-201	6.61	3.45	24.07	4.85	2.92	19.30	4.56	2.69	1.70	17.61
2020	17Y2087	6.50	3.25	23.95	4.83	2.80	18.94	4.60	2.67	1.73	17.90
	CH-202	6.54	3.33	23.42	4.75	2.88	18.77	4.55	2.69	1.70	17.30
	CH-201	6.61	3.46	24.15	4.78	2.89	19.67	4.56	2.69	1.70	17.61
2021	17Y2087	6.39	3.34	24.37	4.78	2.86	19.73	4.65	2.71	1.73	18.00
	CH-202	6.37	3.32	23.69	4.68	2.82	19.06	4.60	2.69	1.72	17.10
	CH-201	6.57	3.46	25.08	4.73	2.89	19.72	4.56	2.70	1.70	18.19
2022	17Y2087	6.36	3.34	23.86	4.94	2.92	19.20	4.72	2.74	1.73	18.26
	CH-202	6.37	3.31	21.89	4.63	2.81	19.23	4.55	2.72	1.69	17.11
	CH-201	6.64	3.46	23.28	4.75	2.87	19.98	4.56	2.67	1.71	17.03
Mean	**17Y2087**	**6.46**	**3.30**	**24.24**	**4.86**	**2.85**	**19.38**	**4.68**	**2.69**	**1.75**	**18.05**
	CH-202	**6.44**	**3.32**	**23.18**	**4.70**	**2.84**	**18.94**	**4.58**	**2.68**	**1.72**	**17.20**
	CH-201	**6.61**	**3.46**	**24.15**	**4.78**	**2.89**	**19.67**	**4.56**	**2.69**	**1.70**	**17.61**

Figure 8. Paddy, brown, and milled rice samples of CH-202, 17Y2087 and CH-201.

Table 24. Average percent head rice and total milled rice (2018 to 2022) of 17Y2087, CH-202, and CH-201 at harvest grain moisture content above 22%, 18-22%, and below 18%.

Entry	% Moisture Content at Harvest		
	More than 22%	18-22%	Less than 18%
17Y2087	67 / 71	66 / 72	60 / 72
CH-202	67 / 71	65 / 72	61 / 72
CH-201	55 / 65	64 / 71	56 / 71

Regression of all head rice and harvest MC data taken from 2018 to 2022 for 17Y2087, CH-202, and CH-201 are illustrated in Figure 9. At 12-18%MC, 17Y2087 and CH-202 had overlapping trendlines indicating the similarity in their grain quality and fissure resistance.

Based on the milling yield curves of the three rice lines, despite fewer data points taken at higher moisture content for the CH-202 comparison, CH-201 had the lowest head rice (64%) and 17Y2087 had the highest (68%) among the three lines when harvested at about 20-23%MC.

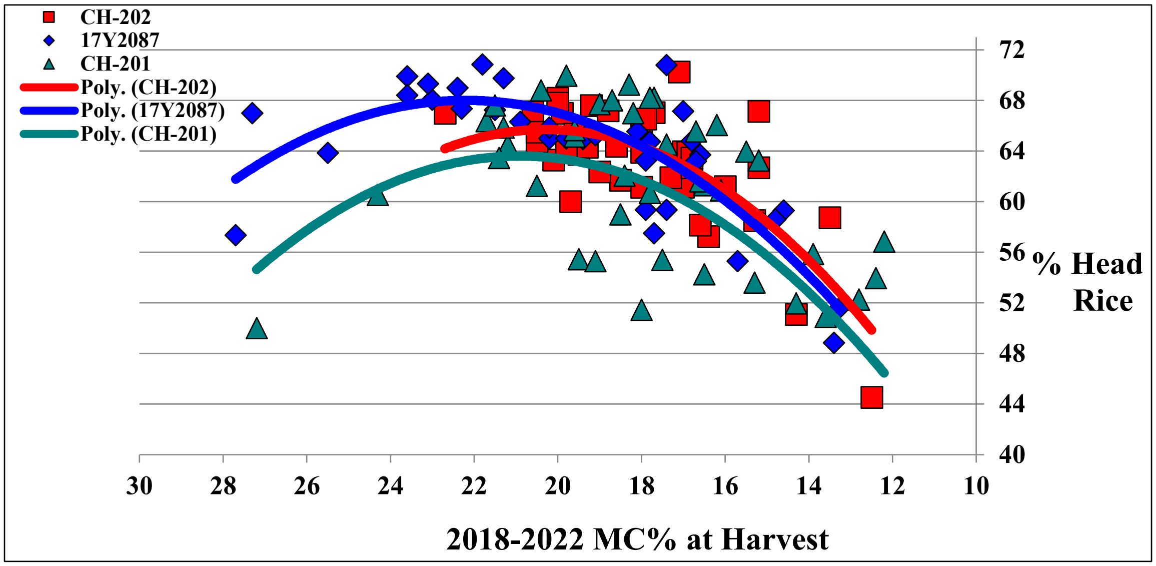

Figure 9. Scatter plot of the average head rice percentage of CH-202 and 17Y2087 plotted against moisture content at sampling. Data taken from milling plots at RES in 2018 to 2022.

To substantiate the milling quality comparison of 17Y2087 and CH-202, 2000g rough rice of each line were submitted to USDA Cal Agri Inspection Co., LTD (FGIS) for external milling yield and US rice grading in 2021 and 2022. Based on FGIS two-year evaluation (Table 25), 17Y2087 had 68% head rice and 71% total at 21%MC during harvest while CH-202 had similar milling quality at 67% head rice, 71 total at 19%MC. Both lines had similar degree of grain whiteness at 42, and both lines received a US Grade of 1, indicating the superior grain quality of CH-202 and 17Y2087. However, at RES internal grain quality analysis using S-21 grain scanning instrument, two-year data showed that 17Y2087 had lower %whole chalky kernel (1.58%) compared to CH-202 (2.78%). In terms of whiteness and vitreousness, both lines are similar, thus supporting the suitability of co-mingling the two lines.

Table 27. Two-year grain quality evaluation of 17Y2087, and CH-202 by California Agri Inspection Co., LTD (USDA FGIS) and RES.

Year	Field	ID	Harvest MC	Milling MC	CA Agri Report (FGIS)				S-21 Analysis (RES)		
					% Head	% Total	White*	US Grade	Chalky Kernel (%)	White-ness	Vitreous-ness
2022	27 (FND)	17Y2087	23	12	69	70	42.7	1	1.97	126	119
	96 (FND)	CH-202	20	11.2	68	70	42.9	1	2.70	128	120
2021	4B	17Y2087	19	12.1	67	72	-	1	1.19	125	119
	4B	CH-202	18	11.7	65	71	-	1	2.86	124	116
Mean		**17Y2087**	**21**	**12.05**	**68**	**71**	**42.7**	**1**	**1.58**	**126**	**119**
		CH-202	**19**	**11.45**	**67**	**71**	**42.9**	**1**	**2.78**	**126**	**118**

*Whiteness based on KETT-300, MC = grain moisture content

RVA and Quality Evaluation of 17Y2087

The grain attributes and cooking profile of 17Y2087 were characterized from 2019 to 2022. The protein content was quantified by California Wheat Commission while the % apparent amylose content was determined following the USDA's protocol on colorimetric and spectral measurement of amylose, conducted at the RES-Genetics Lab. Table 26 summarizes the data on apparent amylose, protein content and gel type of 17Y2087, CH-202, and CH-201. All three lines had apparent amylose content of 20% and low gel type grain, indicating similar softness when cooked. Low protein content is desirable because low protein content is correlated to high taste value. Two-year protein analysis indicated that 17Y2087 had lower protein content than CH-202 and CH-201. On average, 17Y2087 had 5.84% protein compared to 6.12% of CH-202 and 5.89% of CH-201. Therefore, 17Y2087 has taste value that would be similar or better than CH-202 and CH-201.

Table 26. Amylose, protein content and gel type of 17Y2087, CH-202, and CH-201 measured by RES Genetics Lab and CA Wheat Commission. Grain samples were taken from milling plots at RES in 2019-22.

Year	Entry	Apparent Amylose[a] (%)	Protein[b] (%) (White rice)	Gel Type
2019	17Y2087	-	-	-
	CH-202	18.9	5.97	Low
	CH-201	20.3	6.08	Low
2020	17Y2087	20.3	5.75	Low
	CH-202	21.1	**5.9**	Low
	CH-201	-	-	Low
2022	17Y2087	20.3	5.93	Low
	CH-202	20.3	6.50	Low
	CH-201	20.3	5.69	Low
Mean	**17Y2087**	**20.3**	**5.84**	**Low**
	CH-202	**20.2**	**6.12**	**Low**
	CH-201	**20.3**	**5.89**	**Low**

[a]Quantified based on pure potato amylose standard curve following the USDA's colorimetric-spectrophotometry protocol for apparent amylose content.
[b]Estimated by the California Wheat Lab Commission.

Table 27 summarized the four-year RVA profile of 17Y2087, CH-202, and CH-201 while Figure 10 showed the amylograph profiles based on the 2022 RVA data of premium short grains including Koshihikari. Based on four-year RVA data, 17Y2087 cooked at 90ºC in 6 minutes, similar to CH-202 and CH-201 at 89ºC and 91ºC, respectively. During cooking analysis while hot, 17Y2087 was less viscous than CH-202 or CH-201 (peak at 251 vs 261 and 258), but at cool temperature, 17Y2087 had final viscosity like CH-202 (final viscosity of 226). Overall, the 17Y2087 cooking profile was not vastly different from CH-202 and CH-201, instead, 17Y2087 cooking curve overlapped with the Koshihikari profile, as shown in Figure 10. Overall, these results indicated that 17Y2087 has cooking characteristics typical of premium short grain rice. Furthermore, internal, and external blind evaluations for grain appearance, cooking and taste qualities by mills, rice handlers, marketing organizations, and some Japanese evaluators indicated the very close similarity of 17Y2087 to Koshihikari and CH-202, and thus acceptable to the premium short grain market. Table 28 summarized the rice handlers and marketing companies who evaluated the suitability of 17Y2087 to premium short grain market. Details of the evaluations are shown in supplemental documents.

Table 27. RVA profile of 17Y2087, CH-202 and CH-201 measured at RES from 2019-2022.

YEAR	ID	Peak (cP)	Trough (cP)	Break down (cP)	Final Viscosity (cP)	Setback (cP)	Peak Time (min)	Pasting Temp (°C)
2019	17Y2087	234	124	110	226	-8	6	93
	CH-202	277	132	145	230	-47	6	87
	CH-201	236	124	112	219	-17	6	94
2020	17Y2087	283	134	148	247	-36	6	88
	CH-202	253	124	130	222	-31	6	90
	CH-201	-	-	-	-	-	-	-
2021	17Y2087	258	118	141	224	-35	6	90
	CH-202	255	121	134	222	-33	6	89
	CH-201	-	-	-	-	-	-	-
2022	17Y2087	231	116	115	206	-25	6	91
	CH-202	259	133	126	229	-30	6	89
	CH-201	280	126	154	223	-57	6	87
Mean	**17Y2087**	**251**	**123**	**129**	**226**	**-26**	**6**	**90**
	CH-202	**261**	**127**	**134**	**226**	**-35**	**6**	**89**
	CH-201	**258**	**125**	**133**	**221**	**-37**	**6**	**91**

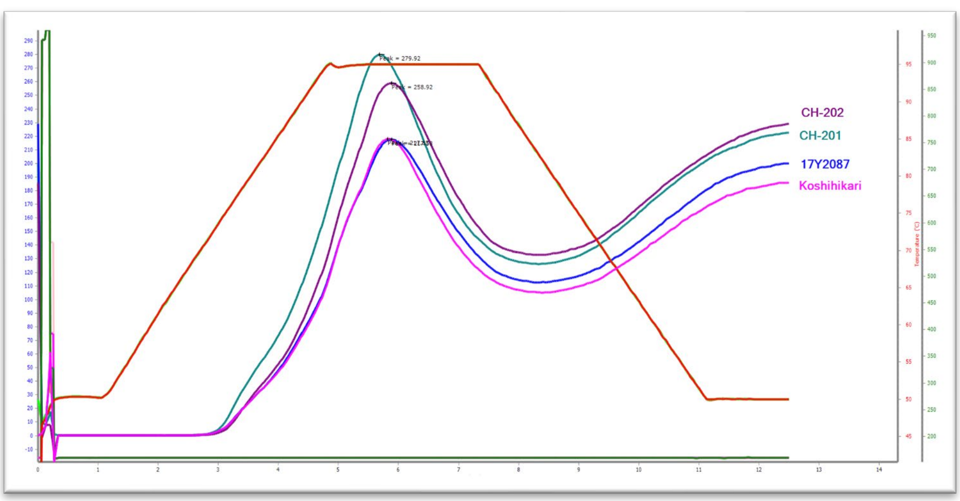

Figure 10. Amylographic profile of CH-202, CH-201, 17Y2087, and Koshihikari (2022 data).

Table 28. List and addresses of external grain quality evaluators of 17Y2087.

Company	Address	Response to Market Acceptability of 17Y2087
Kitoku Shinryo Co. Ltd.	2-8 Kanda-Ogawamachi, Chiyoda-ku, Tokyo 101-0052, Japan	Yes
Tamaki Rice Corp.	1701 Abel Rd, Williams, CA 95987	Yes
Gordon Wylie	Colusa Rd 68, Willows, CA 95988	Yes
Yasuko Tsumura	C/0 Gordon Wylie	Yes
Shozo Sato	2910 Valley Brook Dr. Champaign, IL 61822	Yes
Japan House	2000 S. Lncoln Ave., Urbana, Illinois, 61802	Yes
Single Thread Farms	131 North St. Healdsburg, CA 95448	Yes
California Family Foods	P.O. Box 1230, Arbuckle, CA 95912	Yes
Lundberg Family Farms	P.O. Box 369, Richvale, CA 95974	Yes
InHarvest	1277 Santa Anita Ct, Woodland, CA 95776	Yes
The Sun Valley Rice Company	7050 Eddy Road, Arbuckle, CA 95912	No
American Commodity Company	6133 Abel Road, Williams, CA 95987	No
Farmers' Rice Cooperative	P.O. Box 15223, Sacramento, CA 95851	No Response
Far West Rice, Inc	P.O. Box 370, Durham, CA 95938	No Response
SunWest Foods, Inc.	1550 Dres Avenue, Suite 150, Davis, CA 95616	No Response

Panicle Blanking and Disease Screening

The San Joaquin Cold Nursery and refrigerated greenhouse at RES were used in cold-induced panicle blanking or cold tolerance screening of advanced breeding lines. At the San Joaquin Nursery, 17Y2087 had low panicle banking that ranged from 0.5 to 3% from 2018 to 2022. Similarly, CH-202 had panicle blanking that ranged from 0.5 to 4.5% while CH-201 had 1 to 5.3%. Overall, the average panicle blanking of 17Y2087 (1.6%) was slightly lower than CH-202 (1.8%) and CH-201 (2.2%), indicating its higher cold tolerance. At RES, pots of experimental lines were placed inside the refrigerated greenhouse once they entered the panicle initiation stage. Cold night temperature treatments were imposed on the lines until maturity with temperature set at 50-55^{o}C for 6-8 hours. In the refrigerated greenhouse, 17Y2087 had panicle blanking that ranged from 24-73% from 2018 to 2022. In contrast, CH-202 ranged from 13-92% and CH-201 ranged from 16-77%. Over the five-years of the greenhouse evaluations of the three premium short grains, 17Y2087 and CH-201 were both slightly more cold tolerant than CH-202 (47% vs 53%). Table 29 summarized the yearly performance and the overall panicle blanking observed among the three premium short grains in San Joaquin and at RES GH.

Table 29. Cold-induced panicle blanking of 17Y2087, CH-202, and CH-201 at the San Joaquin cold nursery and in the refrigerated greenhouse (GH) from 2018-2022.

Year	ID	Cold-induced Panicle Blanking (%)	
		San Joaquin	Refrigerated GH
2018	17Y2087	3.5	25
	CH-202	4.5	13
	CH-201	2.3	16
2019	17Y2087	0.8	24
	CH-202	0.6	42
	CH-201	1.0	25
2020	17Y2087	0.5	63
	CH-202	0.5	73
	CH-201	1.0	69
2021	17Y2087	2.0	73
	CH-202	2.0	47
	CH-201	5.3	-
2022	17Y2087	1.3	50
	CH-202	1.5	92
	CH-201	1.5	77
Mean	**17Y2087**	**1.6**	**47**
2018-22	**CH-202**	**1.8**	**53**
	CH-201	**2.2**	**47**

Disease screening for advanced lines was conducted for stem rot resistance beginning in 2018. Blast disease and aggregate sheath spot were noted when these disease symptoms were observed. For stem rot, field evaluations were conducted by forced inoculation of sclerotia to the rows of experimental lines at 60-65 days after planting. Response to stem rot disease was evaluated during maturity by scoring the severity of the symptoms from 1 to 5, with 1 as highly resistant or no infection at all, and a score of 5 as highly susceptible, with infection up to the inside culm filled with sclerotia. Table 30 summarizes the disease reaction of 17Y2087 and other premium short grain checks to stem rot, blast and aggregate sheath spot. Blast and aggregate sheath spot infection were not observed for any lines. Based on DNA marker analysis for RM208 (*Pi-b*), 17Y2087, CH-202, and CH-201 do not carry the desirable allele for blast resistance. Therefore, in the event of blast disease outbreak, all three lines are expected to be susceptible. 17Y2087 and CH-202 showed moderate susceptibility to stem rot (score of 3), while CH-201 is susceptible (score of 4.3).

Table 30. Disease reaction of 17Y2087, CH-202 and CH-201 to stem rot, blast, and aggregate sheath spot in 2018-2022.

YEAR	ID	Stem Rot Score	Blast	Aggregate Sheath Spot
2018	17Y2087	**3.0**	nt	nt
	CH-202	4.1	nt	nt
	CH-201	**5.0**	nt	nt
2019	17Y2087	3.3	nt	nt
	CH-202	2.5	nt	nt
	CH-201	5.0	nt	nt
2020	17Y2087	3.3	nt	nt
	CH-202	2.8	nt	nt
	CH-201	4.0	nt	nt
2021	17Y2087	3.0	nt	nt
	CH-202	3.0	nt	nt
	CH-201	4.0	nt	nt
2022	17Y2087	2.3	nt	nt
	CH-202	2.0	nt	nt
	CH-201	3.7	nt	nt
Mean	17Y2087	**3.0**	**nt**	**nt**
	CH-202	**2.9**	**nt**	**nt**
	CH-201	**4.3**	**nt**	**nt**

Stem rot scores, 1-5 with 1 as resistant and 5 as susceptible or 1=all but 1 leaf sheath penetrated, 3=all leaf sheath penetrated but not the culm, 5=100% infection, culm filled with sclerotia. Blast and Aggregate Sheath Spot score, nt= not tested.

SHORT GRAIN BREEDING

Frank Maulana

The short grain breeding project aims at developing high yielding and stable short grain rice varieties with high milling yield, and excellent taste and cooking quality according to its market class. The program also focuses on developing short grain varieties with high seedling vigor, very-early to early-maturity, lodging resistance, cold tolerance, disease resistance and herbicide resistance. In 2022, the breeding effort of the project was divided into 34% premium quality short grains (SPQ), 32% regular short grains (S), 20% sweet or waxy short grains (SWX), 6% Arborio or bold-grains (SBG), 5% low amylose short grains, and 3% herbicide-resistant short grains (SH).

The summary of the short grain breeding program composition for 2022 is presented in Table 31. In Spring and Summer of 2022, a total of 479 crosses were made. The project also evaluated 293 F_1's, 444 F_2 populations and 14,694 F_3- F_7 progeny rows in the field at Rice Experiment Station (RES). Including check varieties, a total of 200 entries were entered in the preliminary yield trial (PYT), 164 entries in the advanced yield test (AYT), and 12 entries in the University of California Cooperative Extension (UCCE) statewide (SW) yield test. For the PYT, the entries were water-seeded in 10′ × 10′ field plots, while for the AYT and SW yield test, the entries were water-seeded in 10′ × 20′ field plots. The total number of entries for cooking, milling yield plots, seed maintenance, and headrows for the short grain breeding project are shown in Table 31. Promising experimental short grains from the progeny rows were selected and entered in the 2022-2023 Hawaii Winter Nursery to increase seed and advance the generation of the lines. Overall, in 2022, a total of 25,498 entries, including rows and plots, were evaluated for the short grain breeding project.

Table 31. Short grain breeding program activities and composition in 2022.

Generation/Experiment	SPQ	SWX	S	SLA	SBG	SH	Total
Crosses (Spring)	33	87	31	18	23		196
Crosses (Summer)	106	85	58	20	14		283
F1 rows	123	50	61	28	28	3	293
F2 rows	880	470	818	147	161		2,476
F3-F7 rows	5,587	2,346	4,634	536	893	698	14,694
Preliminary YT plots	98	158	64	14	10		344
Advanced YT plots	186	108	144	45	9		492
Statewide YT (7 Locations)-plots	112	84	56	56	84		532
Milling Yield Plots	39	51	65	17	6		175
Cooking Strip Demo-plots	4	2	2	2	3		13
HR-Purification plots	4	1		1	1		7
Seed Maintenance (rows)	900	960	1,315	255	170		3,600
San Joaquin Rows (Cold Nur)-rows	469	396	501	119	42		1,527
Cold GH (Cold tolerance study)-plots	156	204	260	68	24		712
Genomic Selection- Training Pop	16	36	78	6	18		154
Total	**8,713**	**5,038**	**8,087**	**1,332**	**1,486**	**701**	**25,498**

SPQ, premium quality short grain; SWX, sweet or waxy rice; S, regular short grain; SLA, low amylose short grain; SBG, short bold grain or Arborio type; SH, herbicide resistant short grain; PYT, preliminary yield test; AYT, advanced yield test; HR, head rows.

Grain Yield and Agronomic Performance of Short Grain Check Varieties in the RES and Statewide Yield Tests

In 2022 experiments, seven commercially grown short grain check varieties were evaluated, including S-102 and S-202 for regular short grains (S), Calhikari-202 (CH-202) and Calhikari-201 (CH-201) for premium quality short grains (SPQ), Calmochi-101(CM-101) and Calmochi-203 (CM-203) for sweet or waxy short grains (SWX), and Calamylow-201(CA-201) for low amylose short grains (SLA). S-102 is a very early maturing variety with a large kernel, pubescent, and cold tolerant variety released in 1996. S-202 is an early maturing, very high yielding variety released in 2019. CH-202 is a semi-dwarf, early maturing, with high grain quality, and excellent cooking and taste attributes premium short grain released in 2012. CM-101 is a very early maturing sweet rice with desirable grain qualities and cooking characteristics. CM-203 is a very high yielding sweet rice released in 2015. CA-201 is an induced mutant of CH-201 released in 2006. It contains an apparent amylose content of 7% that keeps it soft and ideal for refrigerated sushi. The check varieties were included in all 2022 short grain experiments to compare their performance with the experimental lines.

The summary of the grain yield and agronomic performance of short grain check varieties in 2022 SW yield test and at RES is presented in Table 32. In 2022, there were seven locations in UCCE SW yield test. The RES yield means presented in Table 32 were pooled across three RES maturity group experiments. There was significant variation in grain yield and agronomic trait performance of the check varieties in the RES and UCCE SW yield test. S-102 had an average yield of 7,228 lb/A at RES and 7,508 lb/A at SW. In contrast, S-202 had an average yield of 8,670 lb/A at RES and 8,917 lb/A at SW. S-202 reached days to 50% heading 13 and 10 days later than S-102 at RES and SW, respectively, while S-102 was taller than S-202 at both RES and SW. At RES, both S-102 and S-202 had the same lodging potential (6%), while at SW, S-102 had a 3% higher lodging potential than S-202.

For premium quality short grain check varieties, CH-202, had a RES average yield of 7,921 lb/A and SW yield of 7,808 lb/A, which was lower than the 2021 yield average by 336 lbs. The average yield of CH-201, another premium quality short grain, at RES was 8,174 lb/A, while it was 8,090 lb/A at SW. As expected CH-201 had a higher seedling vigor rating than CH-202 at RES and SW. However, CH-202 was earlier flowering than CH-201 at both RES and SW and also it was shorter than CH-201 by 6 cm at RES and by 4 cm at SW. At RES, CH-202 had a lower lodging potential (16%) than CH-201, but it expressed higher lodging potential at SW (52%).

Table 32. Mean grain yield and agronomic characteristics of short grain check varieties in RES and Statewide yield tests in 2022.

Variety	Grain type	Grain yield (lb/A, 14% MC)		Harvest MC (%)	Seedling vigor (1-5)	Days to 50% heading	Plant height (cm)	Lodging (%)	% Panicle blanking (SJ)	% Panicle blanking (GH)
		STATE	RES							
S-102	S	7,508	7,228	11	4.8	85	94	40	2	66
S-202	S	8,917	8,670	16	N/A	94	91	37	4	73
CM-101	SWX	7,202	6,935	13	4.8	87	91	43	2	41
CM-203	SWX	8,570	8,040	16	4.9	87	98	44	3	61
CH-202	SPQ	7,808	7,921	13	4.8	89	86	52	2	92
CH-201	SPQ	8,090	8,174	14	4.9	93	90	45	2	77
CA-201	SLA	6,345	6,303	14	4.8	90	92	48	4	87
Mean		**7,777**	**7,610**	**14**	**4.8**	**89**	**92**	**44**	**3**	**71**

S, regular short grain; SWX, waxy short grain; SPQ, premium quality short grain; SLA, low amylose short grain; MC, moisture content; RES, Rice Experiment Station; SJ, San Joaquin; GH, greenhouse; N/A, data not available

Moreover, CM-101, a waxy short grain variety, yielded 6,935 lb/A at RES and 7,202 lb/A at SW. In contrast, CM-203, another waxy short grain check variety, yielded 8,040 lb/A at RES and 8,570 lb/A at SW. Among all check varieties, CA-201 had the lowest yield both at RES (6,303 lb/A) and the SW (6,345 lb/A) yield test. Overall, the average grain yield of the check varieties was 7,777 lb/A at SW, while it was 7,594 lb/A at RES. Moreover, on average, all check varieties started flowering at 89 days after planting, had a plant height of 92 cm, lodging potential of 44%, tolerance to cold-induced panicle blanking of 3% at San Joaquin cold site and 71% under greenhouse conditions at RES (Table 32).

Grain Milling Yield Performance of Short Grain Check Varieties at RES in 2022

The short grain check varieties are evaluated annually for milling yield performance. Table 33 summarizes milling yield performance of short grain check varieties at RES in 2022. Among the check varieties, CA-201, the low amylose short grain, had the highest head rice (66%) when it was harvested at an average moisture content of 16%. For S check varieties, S-102 had 1% higher head rice (60%) and total milled rice (70%) than S-202 (59/69% head/total) when harvested at an average moisture content of 19% compared to S-202 which was harvested at 20% moisture content. For SWX check varieties, when harvested at an average moisture content of 21%, CM-101 had significantly higher milling yield (64/70% head/total) than CM-203 (54/68% head/total) which was harvested slightly at lower moisture content (20%). As for SPQ check varieties, both CH-202 and CH-201 had the same percentage head rice when harvested at 17-18% moisture content with CH-202 having 1% higher milled total rice**.** Overall, the check varieties had an average milling yield of 62% head rice and 70% total milled rice.

Table 33. Grain milling yield performance of short grain check varieties from milling yield test plots at RES in 2022.

Variety	**Grain type**	**Moisture content (%) at harvest**	**% Head rice**	**% Total milled rice**
S-102	S	19	60	70
S-202	S	20	59	69
CM-101	SWX	21	64	70
CM-203	SWX	20	54	68
CH-202	SPQ	18	65	72
CH-201	SPQ	17	65	71
CA-201	SLA	16	66	71
Mean		**19**	**62**	**70**

Promising Premium Quality Short Grains (SPQ)

The short grain breeding program focused on 34% of its breeding activities towards the development of premium quality short grains (SPQ) in 2022. The project entered 82 premium quality entries in PYT, 34 in AYT and 1 in the SW yield test. 17Y2087, a high-yielding SPQ, which had consistently shown superior performance in multiple years of SW yield tests, was entered in 2022 SW yield test for the last time before it was proposed for variety release. In all years of SW yield tests, its performance was compared to the performance of the standard SPQ check varieties, CH-201 and CH-202, for grain yield, milling yield and grain quality (Table 34). Because of its superior performance in the UCCE SW yield tests over multiple years compared to the commercially grown SPQ varieties, line 17Y2087 was approved for variety release as Calhikari-203 (CH-203) by the Board of Directors of California Cooperative Rice Research Foundation (CCRRF). Table 34 summarizes the performance of 17Y2087 in SW yield test in 2022.

Every year, the short grain breeding project evaluates experimental lines, selected from the PYT, in the advanced yield test (AYT). Lines that perform better agronomically than the standard checks in the AYT are further selected for UCCE SW yield test to assess their adaptation and stability across SW locations. In 2022, two high yielding SPQ entries

(21Y2031 and 22Y2119) were identified from AYT as potential candidates for SW yield test in 2023. Table 35 summarizes the performance of promising AYT entries compared to check varieties, CH-202 and CH-201. For grain yield, line 21Y2031 showed 17% yield advantage over CH-202 (9,675 lb/A vs 8,106 lb/A) and CH-201(9,675 lb/A vs 8,267 lb/A). In addition, it had slightly better seedling vigor than CH-202 (5.0 vs 4.9), but like CH-201 (5.0), which suggests that this line can be a suitable candidate for organic farming. Moreover, it started flowering 1 day earlier than CH-202 and 3 days later than CH-201. Line 21Y2031 was also slightly taller than the check varieties. When harvested at moisture content between 18-22%, its milling yield was 66/73% (head/total), which was higher than for CH-202 and CH-201, 65/72% (head/total). Again, its milled grains were longer, wider, and heavier with larger length/width ratio than CH-202 and CH-201 milled rice. Chalkiness is an undesirable trait in rice because it affects the appearance of the grain and quality. Analysis for chalkiness revealed more chalky kernels (3.2%) for 21Y2031 than CH-202 (1.0%) and CH-201 (2.4%). Compared to CH-202, it had also higher taste value due to its lower protein content which has been known to be associated with high taste value in rice.

Line 22Y2119 is another SPQ that had good grain yield and quality performance among the 2022 AYT entries. It had 16% yield advantage over CH-202 (9,617 lb/A vs 8,106 lb/A) and CH-201 (9,617 lb/A vs 8,267 lb/A) with higher milling yield and similar seedling vigor to CH-202, but lower than CH-201. However, it started flowering 83 days after planting compared to 80 for CH-202 and 82 days for CH-201. As for plant height, it was 5 and 3 cm taller than CH-202 and CH-201, respectively. Its milled rice grains were longer, wider, and heavier than CH-202, but shorter and narrower than CH-201 milled rice. In comparison to the check varieties, its grains were slightly more chalky (1.5%) than CH-202 (1.0%), but less than CH-201 (2.4%). Lines 21Y2031 and 22Y2119 will be considered for SW yield test in 2023.

Table 34. The performance of premium quality short grain line, 17Y2087, compared to check varieties, CH-202 and CH-201 in UCCE statewide yield test in 2022.

Trait	**Premium Quality Short Grains (SPQ)**		
Agronomic attributes	**17Y2087**	**CH-202**	**CH-201**
Grain yield (lb/A, 14% MC)	8,637	7,808	8,090
Yield advantage (%) over CH-202 and CH-201	11(7)		
Lodging (%)	31	52	45
Seedling vigor (1-5)	4.8	4.8	4.9
Days to 50% heading	91	89	93
Plant height (cm)	90	86	90
Panicle blanking (%), SJ	2	2	2
Milling yield attributes			
Harvest MC (%)	19	18	17
Head rice (%)	70	65	65
Total milled rice (%)	74	72	71
Grain attributes			
Length (mm)	4.8	4.7	4.9
Width (cm)	2.6	2.5	2.7
Length/width ratio	1.83	1.90	1.80
1000-seed weight (g)	19.9	18.3	19.3
% Chalky area	9.6	9.5	12.8
% Chalk	1.1	1.0	2.4
Whiteness	123.8	123.0	128.7
Vitreosity	117.4	117.0	120.8
Protein white rice (%)	7.4	7.3	6.3
Satake taste value	66	66	73

Number in parenthesis is a grain yield advantage (%) over CH-201; SJ, San Joaquin; MC, moisture content.

Table 35. The performance of the promising AYT premium quality short grains (SPQ), 21Y2031 and 22Y2119, compared to check varieties, CH-202 and CH-201 at RES in 2022.

Trait	**21Y2031**	**22Y2119**	**CH-202**	**CH-201**
Agronomic attributes				
Grain yield (lb/A, 14% MC)	9,675	9,617	8,106	8,267
Yield advantage (%) over CH-202 and CH-201	17(17)	16(16)		
Lodging (%)	30	25	27	48
Seedling vigor (1-5)	5.0	4.9	4.9	5.0
Days to 50% heading	79	83	80	82
Plant height (cm)	95	94	89	91
Panicle blanking (%), SJ	3	6	10	2
Milling yield attributes				
Harvest MC (%)	19	19	18	17
Head rice (%)	66	66	65	65
Total milled rice (%)	73	72	72	71
Grain attributes				
Length (mm)	5.4	4.8	4.7	4.9
Width (cm)	2.7	2.7	2.5	2.7
Length/width ratio	1.96	1.81	1.90	1.80
1000-seed weight (g)	23.8	19.5	18.3	19.3
% Chalky area	15.0	9.2	9.5	12.8
% Chalk	3.2	1.5	1.0	2.4
Whiteness	128.6	123.0	123.0	128.7
Vitreosity	119.0	116.9	117.0	120.8
Protein white rice (%)	6.9	7.6	7.3	6.3
Satake taste value	69	65	66	73

Numbers in parentheses are grain yield advantages (%) over CH-201; SJ, San Joaquin; MC, moisture content.

Promising Regular Short Grains (S)

In 2022, 32% of the short grain breeding project focused on the development of regular short grains (S). A total of 49 regular short grain entries were entered in PYT, 60 in AYT and 2 in the SW yield test. In 2021 SW test, line 20Y2001, was selected for further SW yield test in 2022 because of its superior performance. Figure 11 shows grain yield of 20Y2001 at each SW location and across SW locations in 2022. The summary of grain yield, milling yield and agronomic trait performance of the SW promising entries in 2022 is presented in Table 36. In the SW yield test, the performance of line 20Y2001 was compared to commercially grown regular short grain check varieties, S-202 and S-102. Across the seven SW locations in 2022, 20Y2001 outyielded both S-102 and S-202. On average, it had 8 and 28% yield advantage over S-202 (9,633 lb/A vs 8,917 lb/A) and S-102 (9,633 lb/A vs 7,508 lb/A), respectively. Compared to S-202 and S-102, line 20Y2001 was more adapted to different SW locations because grain yield results show that it was the highest yielding line at six out of the seven UCCE SW locations, including Glenn, North Butte, South Butte, RES, Sutter, and Yuba. Furthermore, at San Joaquin Cold

Tolerance Nursery, it ranked second with grain yield of 11,048 lb/A after S-202 which yielded 11,884 lb/A, while S-102 was the lowest yielding at 9,151 lb/A (Figure 11).

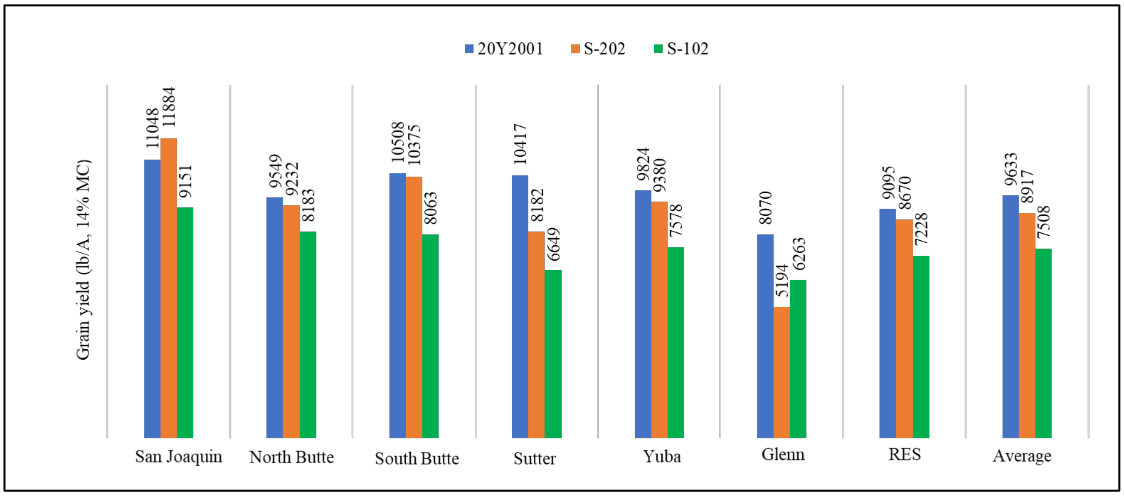

Figure 11. Grain yield of the promising regular short grain line, 20Y2001, at each SW location and across seven locations compared to regular short grain check varieties, S-202 and S-102 in UCCE SW yield test in 2022.

Regarding milling yield, it had high milling yield compared to S-202 and had similar percentage head rice to S-102 when harvested at 18-22% moisture content. It was also later flowering and was shorter than the check varieties. For lodging potential, generally it expressed high lodging potential compared to S-202 and S-102. Also, 20Y2001 had more chalky grains (2.6%) than S-202 (2.0%) and less than S-102 (4.1%). Disease screening data from 2021 at RES also revealed high stem rot resistance with a disease rating score of 1.8 for this line. As for cooking properties, the RVA profile results indicate that 20Y2001 requires 93°C temperature to cook compared to S-202 (94°C) and S-102 (95°C). In addition to its pasting temperature, it has a higher water holding capacity than S-202 (122 cP vs 109 cP), but lower than S-102 (122 cP vs 129 cP). Moreover, its cooked rice is more viscous than S-202 (224 cP vs 214 cP), but less than S-102 (224 cP vs 230 cP) as shown in Table 36. Line 20Y2001 will be considered for further SW yield test in 2023.

Among the entries entered in the 2022 AYT, two high yielding regular short grains, 20Y2008 and 20Y2072, were identified as top performers based on agronomic performance. Lines 20Y2008 and 20Y2072 outyielded the standard check varieties at RES. Table 37 summarizes the performance of the promising AYT entries compared to the check varieties in 2022. For grain yield, line 20Y2008 had 28% yield advantage over S-202 (10,593 lb/A vs 8,251 lb/A) and 53% over S-102 (10,593 lb/A vs 6,902 lb/A). Besides it had good milling yield when harvested at 18-22% moisture content, good seedling vigor like S-102 and was cold tolerant like S-202. But it was slightly taller than S-202 and S-102 by 10 and 4 cm, respectively. Regarding grain dimensions, its milled rice grains were longer, wider, and heavier than S-202. Although the grain yield of 20Y2008 was higher than S-102, its milled grains were shorter, narrower, and lighter than S-102 milled rice. In addition, its milled grains appeared to be more chalky (4.2%) than S-202 (2.0%) and S-102 (4.1%). Owing to its lower protein content (6.5%), 20Y2008 had higher taste value (73) than S-202 (68) and S-102 (67).

Another high yielding regular short grain line selected is 20Y2072. This line showed 23% yield advantage over S-202 (10,143 lb/A vs 8,251 lb/A) and 47% over S-102 (10,143 lb/A vs 6,902 lb/A). Besides its high yield potential, it had good milling yield when rice samples from milling yield plots were harvested at 18-22% moisture content, good seedling vigor and cold tolerance. However, it was slightly taller than the check varieties. As for grain attributes, it had long and heavy grains compared to S-202, but similar grain width and length/width ratio to S-202. Although it was high yielding, its grains were shorter, narrower, and lighter than S-102 milled rice. Grain quality analysis by S-21 scanner revealed high chalkiness for 20Y2072 (2.8%) compared to S-202 (2.0%), while it was less chalky than S-102 (4.1%). Lines 20Y2008 and 20Y2072 will be included in the UCCE SW yield test in 2023 to assess their adaptation to low and high yielding environments in California.

Table 36. The performance of promising regular short grain (S) line, 20Y2001, compared to check varieties, S-202 and S-102 in UCCE statewide yield test in 2022.

Trait	**Regular Short Grains (S)**		
Agronomic attributes	**20Y2001**	**S-202**	**S-102**
Grain yield (lb/A, 14% MC)	9,633	8,917	7,508
Yield advantage (%) over S-202 and S-102	8 (28)		
Lodging (%)	46	37	40
Seedling vigor (1-5)	4.8	N/A	4.8
Days to 50% heading	89	94	85
Plant height (cm)	90	91	94
Panicle blanking (%), SJ	4	4	2
Milling yield attributes			
Harvest MC (%)	21	20	19
Head rice (%)	60	59	60
Total milled rice (%)	69	69	70
Grain attributes			
Length (mm)	5.1	5.0	5.5
Width (cm)	2.8	2.8	3.0
Length/width ratio	1.8	1.8	1.8
1000-seed weight (g)	20.8	20.6	27.1
% Chalky area	14.6	13.9	24.5
% Chalk	2.6	2.0	4.1
Whiteness	131.8	131.7	138.9
Vitreosity	123.0	123.1	124.3
Protein white rice (%)	7.8	7.1	7.4
Satake taste value	64	68	67
RVA properties			
Pasting temp (°C)	93	94	95
Peak (cP)	258	231	229
Trough (cP)	122	109	129
Breakdown (cP)	136	122	100
Final viscosity (cP)	224	214	230
Setback (cP)	-34.1	-17.3	1.1

Number in parenthesis is a grain yield advantage (%) over S-102; SJ, San Joaquin; MC, moisture content.

Table 37. The performance of the promising AYT regular short grains (S), 20Y2008 and 20Y2072, compared to check varieties, S-202 and S-102 at RES in 2022.

Trait	20Y2008	20Y2072	S-202	S-102
Agronomic attributes				
Grain yield	10,593	10,143	8,251	6,902
Yield advantage (%) over S-202 and S-102	28(53)	23(47)		
Lodging (%)	16	27	6	19
Seedling vigor (1-5)	5	5	N/A	5
Days to 50% heading	82	84	89	73
Plant height (cm)	99	98	89	95
Panicle blanking (%), (SJ)	3	4	4	2
Milling yield attributes				
Harvest MC (%)	20	19	20	19
% Head rice	60	60	59	60
% Total milled rice	69	69	69	70
Grain attributes				
Length (mm)	5.2	5.1	5.0	5.5
Width (cm)	2.9	2.8	2.8	3.0
Length/width ratio	1.8	1.8	1.8	1.8
1000-seed weight (g)	22.1	21.9	20.6	27.1
% Chalky area	15.5	14.2	13.9	24.5
% Chalk	4.2	2.8	2.0	4.1
Whiteness	132.7	130.4	131.7	138.9
Vitreosity	123	121.5	123.1	124.3
Protein white rice (%)	6.5	7.4	7.1	7.4
Satake taste value	73	66	68	67

Numbers in parentheses are grain yield advantages (%) over S-102; SJ, San Joaquin; MC, moisture content.

Promising Sweet Short Grains (SWX)

Breeding activities for waxy short grains occupied 20% of the short grain breeding project in 2022 experiments. Including the check varieties, 44 entries were entered in the PYT, 48 in the AYT and 1 entry in 2022 SW. The waxy short grain line included in the SW yield test was designated 20Y2124. Table 38 summarizes the agronomic performance of 20Y2124 compared to the SWX check varieties, CM-203 and CM-101 in the SW yield test. Results show that 20Y2124 had an average yield advantage of 5 and 25% over CM-203 (9,021 lb/A vs 8,570 lb/A) and over CM-101 (9,021 lb/A vs 7,202 lb/A). Although its average yield advantage over CM-203 was only 5%, it had wider adaptation than CM-203 and CM-101 across the state as it yielded the highest at four out of seven SW locations, including Glenn, North Butte, RES and San Joaquin (Figure 12). Moreover, it was the second highest yielding at South Butte, Sutter and Yuba after CM-203. Statewide, its lodging potential was similar to CM-203 and CM-101. Other agronomic attributes of 20Y2124 indicate that it had lower seedling vigor and started flowering 4 days later than

CM-203 and CM-101. As for plant height, it is semi-dwarf and was 2 and 9 cm taller than CM-203 and CM-101, respectively. Cold-induced panicle blanking results from San Joaquin Cold Tolerance Nursery show that 20Y2124 is cold-tolerant like CM-203 and CM-101.

For milling yield performance, when rice samples of 20Y2124, CM-203 and CM-101 were harvested from the milling yield test plots at RES at 18-22% moisture content, results showed that 20Y2124 had higher head rice (58%) than CM-203 (54%), but lower than CM-101 (64%) with similar total milled rice to CM-101(70%). Regarding grain attributes, the length and width of 20Y2124 milled rice were similar to CM-203, but longer and wider than CM-101. In addition, its grains were heavy compared to milled grains of CM-203 (26.4g vs 24.9g/1000 grains) and CM-101(26.4g vs 20.9g/1000 grains), which may be one of the contributing factors to its high grain yield potential (Table 38). The taste of cooked rice when chewing is desirable trait for consumers. So, as a standard all promising lines are analyzed for taste value using the Satake Taste Analyzer and their values are compared with those of the check varieties. Compared to CM-203 and CM-101, line 20Y2124 had slightly a higher taste value as related to its lower protein content. For RVA properties, results indicate that 20Y2124 requires cooking temperature of 73ºC like CM-203 and CM-101. Other RVA properties also show that 20Y2124 has almost similar water holding capacity and final viscosity like CM-101 but has higher and is more viscous than CM-203 (Table 39).

Among the AYT SWX entries in 2022, some lines performed significantly better than the standard checks, and hence they were selected to be considered for SW yield test in 2023. Two high yielding SWX lines designated as 22Y2159 and 22Y2135 were selected as potential candidates for further testing statewide. The agronomic performance results of the promising lines compared to the check varieties, CM-203 and CM-101, are presented in Table 39. Line 22Y2159 had 18 and 26 % yield advantage over CM-203 and CM-101, respectively. As for milling yield, it had high percentage head rice compared to CM-203, but slightly lower than CM-101 when harvested at 18-22% moisture content. In addition, it had good seedling vigor like CM-101, but lower than CM-203. It reached days to 50% heading later than both CM-101 and CM-203. Also, it had similar plant height to CM-203, while it was 4 cm taller than CM-101. Besides it expressed tolerance to cold-induced panicle blanking at San Joaquin. Line 22Y2135 had a 17% yield advantage over CM-203 and 26% over CM-101. In addition to its yield advantage, it had good seedling vigor at RES and cold tolerance to panicle blanking at San Joaquin Cold Tolerant Nursery. Lines 22Y2159 and 22Y2135 will be considered for SW yield testing in 2023.

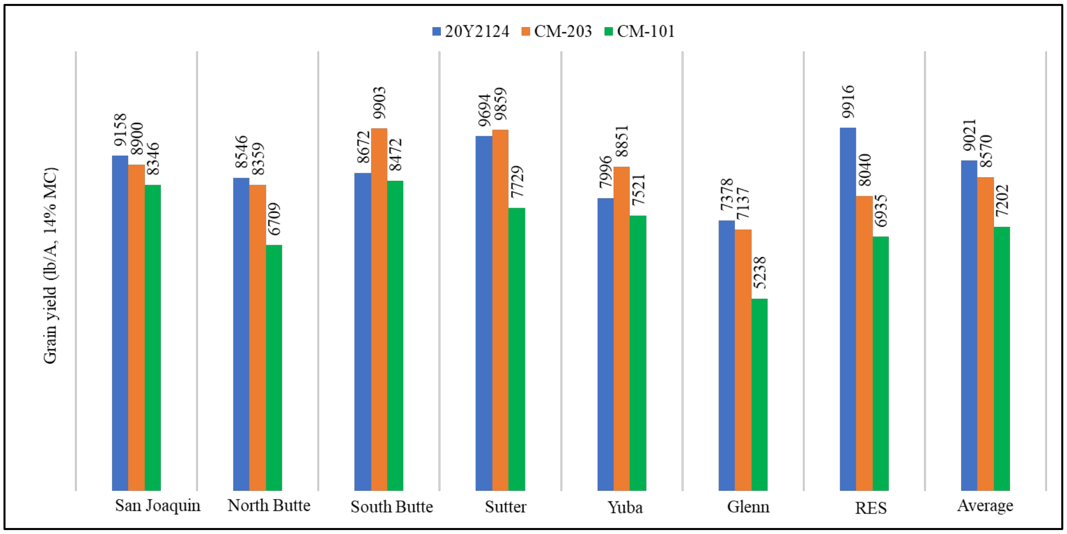

Figure 12. Grain yield of the promising waxy short grain line, 20Y2124 at each SW location and across locations compared to waxy short grain check varieties, CM-203 and CM-101 in UCCE SW yield test in 2022.

Table 38. The performance of promising waxy short grain (SWX) line, 20Y2124, compared to check varieties, CM-203 and CM-101 in UCCE statewide yield test in 2022.

Trait	20Y2124	CM-203	CM-101
Agronomic attributes			
Grain yield (lb/A, 14% MC)	9,021	8,570	7,202
Yield advantage (%) over CM-203 and CM-101	5(25)		
Lodging (%)	44	44	43
Seedling vigor (1-5)	4.7	4.9	4.8
Days to 50% heading	91	87	87
Plant height (cm)	100	98	91
Panicle blanking (%), SJ	5	3	2
Milling yield attributes			
Harvest MC (%)	22	20	21
Head rice (%)	58	54	64
Total milled rice (%)	70	68	70
Grain attributes			
Length (mm)	5.4	5.4	5.1
Width (cm)	3.0	2.9	2.7
Length/width ratio	1.83	1.80	1.90
1000-seed weight (g)	26.4	24.9	20.9
% Chalky area	77.3	78.9	73.8
% Chalk	91.7	91.9	92.9
Whiteness	172.1	177.1	167.8
Vitreosity	98.9	97.9	101.4
Protein white rice (%)	9.2	11.1	9.5
Satake taste value	54	49	49
RVA properties			
Pasting temp (°C)	73	73	73
Peak (cP)	125	111	112
Trough (cP)	48	43	50
Breakdown (cP)	77	66	63
Final viscosity (cP)	64	58	65
Setback (cP)	-61.2	-53.5	-47.2

Table 39. The performance of the promising AYT waxy short grains (SWX), 22Y2159 and 22Y2135, compared to check varieties, CM-203 and CM-101 at RES in 2022.

Trait	22Y2159	22Y2135	CM-203	CM-101
Agronomic attributes				
Grain yield (lb/A, 14% MC)	9,903	9,846	8,389	7,832
Yield advantage (%) over CM-203 and CM-101	18(26)	17(26)		
Lodging (%)	40	43	25	19
Seedling vigor (1-5)	4.9	5	5	4.9
Days to 50% heading	82	81	77	76
Plant height (cm)	96	96	96	92
Panicle blanking (%), SJ	5	5	3	2
Milling yield attributes				
Harvest MC (%)	22	21	20	21
Head rice (%)	62	50	54	64
Total milled rice (%)	69	67	68	70
Grain attributes				
Length (mm)	5.4	5.2	5.4	5.1
Width (cm)	2.8	2.8	2.9	2.7
Length/width ratio	1.9	1.9	1.8	1.9
1000-seed weight (g)	23.6	23.3	24.9	20.9
% Chalky area	76.3	77.7	78.9	73.8
% Chalk	93.4	96.0	91.9	92.9
Whiteness	172.0	173.8	177.1	167.8
Vitreosity	101.6	100.1	97.9	101.4
Protein white rice (%)	11.6	11.2	11.1	9.5
Satake taste value	48	50	49	49

Numbers in parentheses are grain yield advantages (%) over CM-101; SJ, San Joaquin; MC, moisture content.

Promising Low Amylose Short Grains (SLA) and Arborio Type (SBG)

The short grain project continues its effort to develop improved low amylose and Arborio short grains. In 2022, 13 experimental lines were entered in PYT, 15 in the AYT and 2 in the SW for low amylose short grains. For Arborio rice, the project entered 8 lines in the PYT, 3 in the AYT and 1 in the SW. For four years, 16Y2028, a low amylose short grain line, has consistently performed better agronomically than the check variety, CA-201, in all UCCE SW yield tests. Owing to its consistent superior performance, 16Y2028 is a potential candidate for future variety release to replace CA-201 which is inherently low yielding. CA-201 is an induced mutant of CH-201, a premium quality short grain developed in 2006. Compared to waxy short grains, CA-201 is less sticky and its cooked rice looks creamy and shiny with cloudy kernels. Its apparent amylose content ranges from 7 to 10%.

Line 16Y2028 has been in the UCCE statewide yield tests since 2017 and it continues to outperform CA-201. Across all SW locations in 2022, the average grain yield of 16Y2028 was 8,468 lb/A compared to 6,356 lb/A for CA-201, representing an average yield advantage of 34% over CA-201. Results from 2022 UCCE SW yield test indicates that 16Y2028 was widely adapted to all seven SW locations compared to CA-201. It was higher yielding that CA-201 in all SW locations with yield advantage over CA-201 ranging from 2% to 48%. Among the SW locations, the highest yield advantage was recorded at San Joaquin Cold Tolerance location (48%) indicating its resilience to panicle blanking due to cold stress, and it was followed by Sutter (44%), South Butte (38%), RES (36%), Yuba (36%), North Butte (23%) and Glenn (2%) (Figure 13).

Although in 2021, 16Y2028 had a low lodging potential like CA-201, in 2022 SW test it was more susceptible to lodging than CA-201 (68 vs 48%) as shown in Table 40. However, it had good seedling vigor and it started flowering 90 days after planting like CA-201. In addition, it was slightly taller than CA-201 by 9 cm and was cold tolerant as indicated by panicle blanking data at San Joaquin Cold Tolerant Nursery. Milling yield samples for 16Y2028 were harvested when the moisture content was at 21%, while CA-201 was harvested at 16% moisture. As a result, it was noted that percentage head rice of 16Y2028 was 5% lower (61/71% head/total) than for CA-201(66/71% head/total). As for grain attributes, overall, the milled rice grains of 16Y2028 were longer (5.1 vs 4.6mm), wider (2.9 vs 2.6mm) and heavier (23.6 vs 18.4g/1000 grains) than CA-201. Moreover, it had higher taste value than CA-201 (68 vs 63) since it had low protein content than CA-201. RVA properties show that both 16Y2028 and CA-201 require cooking temperature of 75ºC. Moreover, line 16Y2028 has higher water holding capacity (88 cP vs 80 cP) and is more viscous (133 cP vs 122 cP) than CA-201. Cooked rice of 16Y2028 appears whiter and slightly more firm with shininess, stickiness, mouthfeel, and taste similar to CA-201 (Figure 14).

Among the SLA lines that were entered in the AYT, 22Y2082 was found to be a very high yielding experimental line with 51% yield advantage over CA-201 (9,988 lb/A vs 6,596 lb/A). Although it was very high yielding, its milling yield was lower than CA-201 as indicated in Table 40. Again, compared to CA-201, line 22Y2082 was more susceptible to lodging at RES in 2022. Also, it had slightly lower seedling vigor rating and flowered 1 day later than CA-201 (83 vs 82 days). However, both 22Y2082 and CA-201 expressed good tolerance to cold-induced panicle blanking at San Joaquin Cold Tolerance Nursery (Table 40). Based on grain attributes results, it appears its high yield potential can be attributed to its long, wide and heavy grains compared to CA-201.

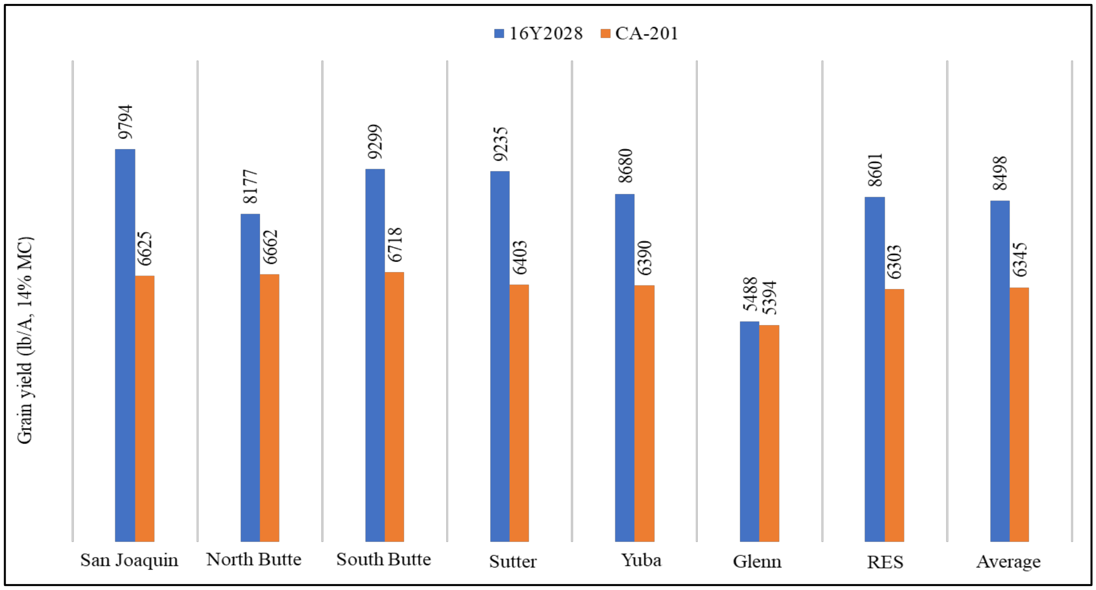

Figure 13. Grain yield of the promising low amylose short grain line, 16Y2028, at each SW location and across locations compared to low amylose short grain check variety, Calamylow-201(CA-201) in UCCE SW yield test in 2022.

Field at RES in 2022, **16Y2028** vs **CA-201**

Paddy, brown and milled rice
CA-201 vs **16Y2028**

Milled rice
CA-201 vs **16Y2028**

Cooked rice
CA-201 vs **16Y2028**

Figure 14. Grain and cooking characteristics of promising low amylose short grain line, 16Y2028 compared to the check variety, Calamylow-201(CA-201).

Table 40. The performance of the promising low amylose short grains, 16Y2028 and 22Y2082 compared to check variety, CA-201 in 2022.

Trait	Statewide (SW)		Advanced yield test (AYT)	
	16Y2028	CA-201	22Y2082	CA-201
Agronomic attributes				
Grain yield (lb/A, 14% MC)	8,498	6,345	9,988	6,596
Yield advantage (%) over CA-201	34		51	
Lodging (%)	68	48	50	20
Seedling vigor (1-5)	4.8	4.8	4.9	5.0
Days to 50% heading	90	90	83	82
Plant height (cm)	101	92	101	94
Panicle blanking (%), SJ	4	4	3	4
Milling yield attributes				
Harvest MC (%)	21	16	18	16
Head rice (%)	61	66	51	66
Total milled rice (%)	71	71	67	71
Grain attributes				
Length (mm)	5.1	4.6	4.8	4.6
Width (cm)	2.9	2.6	2.8	2.6
Length/width ratio	1.7	1.8	1.7	1.8
1000-seed weight (g)	23.6	18.4	20.3	18.4
% Chalky area	95.0	71.6	44.9	71.6
% Chalk	84.4	51.2	37.4	51.2
Whiteness	148.6	141.9	147.1	141.9
Vitreosity	121	123.7	120.8	123.7
Protein white rice (%)	6.7	7.3	8.3	7.3
Satake taste value	68	63	61	63
RVA properties				
Pasting temp (ºC)	75	75	-	-
Peak (cP)	259	243	-	-
Trough (cP)	88	80	-	-
Breakdown (cP)	171	164	-	-
Final viscosity (cP)	133	122	-	-
Setback (cP)	-125.3	-121.1	-	-

Genomic Selection

The Rice Experiment Station (RES) breeding program has successfully bred new and improved rice varieties for California growers using pedigree breeding method. The station also employs marker-assisted selection (MAS) for blast resistance, grain quality traits, and herbicide resistance. The whole variety development takes about 10-12 years or longer, from the time the cross was made until variety release. While the pedigree method is proven effective, it is time-consuming, labor-intensive, and costly.

For MAS, the station has been using DNA markers to select plants with disease and herbicide resistance to improve breeding efficiency. However, MAS is more useful for selecting simple traits, such as blast resistance, but it is less useful for selecting complex traits, including grain yield and grain quality. New breeding tool, such as genomic selection (GS), is emerging and may ensure that complex traits are selected with improved accuracy and precision. Genomic selection, in principle, is another form of MAS. However, instead of using fewer markers for high heritable traits like MAS, GS uses all markers spread across the genome to predict the performance of lines with genotypes only without phenotypes. One of the advantages of GS is that it can reduce breeding cycle by earlier selection of potential parents for new crosses with improved chance of obtaining superior lines. In addition to reducing breeding cycle, it can reduce phenotyping costs by scaling down the frequency of field phenotyping by predicting the performance of lines before field testing. In this case, breeding lines with low predicted phenotypes can be discarded and only those with high values can be considered for extensive field testing thereby reducing expenses associated with phenotyping both superior and inferior lines.

The goal of this project is to integrate GS, as a complementary breeding tool to MAS, into the RES breeding program to make the program more efficient. The station's roadmap to achieve the goal involves three major steps. First, a population, that represents the genetic diversity of the RES breeding program, was assembled and has been undergoing field phenotyping since 2020. This population will also be genotyped with genome-wide DNA markers. Once it has been phenotyped and genotyped, it will be used as a training population for initial assessment of the potential of GS in RES breeding program. Second, a suitable marker set, that is cost-effective and can discriminate the RES germplasm, will be developed for use routinely in genotyping GS materials (training set and prediction set). The third step will be to assess the prediction accuracy of the GS prediction model for selecting complex traits prior to integrating GS into the RES breeding program.

A total of 360 lines, consisting of advanced breeding lines and released cultivars of all grain types (medium, short and long grains), were selected to be phenotyped for grain yield and agronomic traits, and genotyped to form a training population. This population represents the genetic diversity of the germplasm of the RES breeding program because most of them have been routinely used as parents in the program. In 2022, the population was drill-seeded at RES in a randomized complete block design replicated twice. Agronomic traits, including seedling vigor, lodging potential, days to 50% heading and plant height were collected. Grain yield data was not collected due to the breakdown of a combine during harvest time. Table 41 summarizes the average, range, and heritability of agronomic traits of the population in 2022. Agronomic performance results showed no much variation in seedling vigor among the entries, except in lodging potential, days to 50% heading and plant height. Broad-sense heritability estimates, based on the phenotype, ranged from 0.64 for seedling vigor to 0.88 for days to 50% heading, indicating good predictability for these agronomic traits. This experiment will be repeated in 2023 so that grain yield data can be collected. In addition to field evaluation, the population will be genotyped with genome-wide single nucleotide polymorphism (SNP) markers to assess the potential of GS in the RES breeding program.

Table 41. Trait performance parameters of the training population at RES in 2022.

Statistic	Seedling vigor (1-5)	Lodging (%)	Days to 50% heading	Plant height (cm)
Mean	5.0	9.6	94	100
Range	4.9-5.0	3.0-0.72	86-109	72-138
Min	4.9	3.0	86	72
Max	5.0	0.72	109	138
Broad-sense heritability (H^2)	0.64	0.69	0.88	0.72

LONG GRAIN BREEDING

Nirmal Sharma

The long grain breeding program continues its research and breeding efforts to develop superior long grain varieties of four major classes for California, including: 1) conventional long grain, 2) Jasmine, 3) Basmati, and 4) aromatic classes. Milling and cooking quality improvements of conventional and specialty long grains are a high priority objective in this program as is improving yield potential and agronomic performance and introducing important traits like resistance to disease and resistance to cold-induced blanking.

A summary of 2022 long grain breeding line evaluations are shown in Table 42. This year 504 crosses were made in spring and summer for long grain project. The project evaluated a total of 19,804 breeding lines which included 339 F1, 426 F2, 11,810 progeny rows, 938 yield trial plot, 1360 headrows and 2750 seed maintenance rows.

Performance of Long Grain Varieties

Test materials in the 2022 statewide tests were compared to the long grain check varieties L-207, L-208, Calaroma-201, Calmati-202 and A-202 for grain yield and agronomic performance. Milling characteristics, grain quality, blanking, and disease reaction of these checks were also analyzed.

L-207 is a conventional long grain variety released in 2016 with higher yield, intermediate height, early-maturing date, and 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. Physicochemical testing of L-207 by the USDA Rice Quality Lab confirms its similarity to southern long grains with intermediate amylose, intermediate gel type, and moderate RVA profile. L-208 is the newest conventional long grain and was released in 2020. Agronomic characteristics, adaptation, milling, and cooking qualities of L-208 are similar to L-207.

Based on 2022 statewide experiments, L-208 and L-207 had higher yield at other statewide locations compared to Rice Experiment Station (RES). The average yield at statewide/RES was 9,953/9,877 lb/A for L-208 and 9,551/9,411 lb/A for L-207 (Table 43).

The new variety, L-208, had approximately a 4.0% yield advantage over L-207 in 2022. The variety L-208 performed better and had higher yield in five out of seven statewide experiments except for Glenn and RES locations (Figure 15). L-208 was 94 cm tall, 7 cm shorter than L-207. L-208 reached 50% heading around 87 days, three days earlier than L-207.

Table 42. Long grain breeding lines evaluated in 2022.

Generation/Expt	Plots/Rows/Entries
Crosses (Spring)	239
Crosses (Summer)	265
F_1	339
F_2	426
Progeny Rows (F_3-F_5)	11,810
Preliminary Yield Trial	304
Advanced Yield Trial	354
Statewide Yield Trial	280
Milling Yield Plots	300
Cooking Strip Demo	19
Head Rows	1360
Seed Maintenance	2,750
San Joaquin F_2	88
San Joaquin rows (Cold Nur)	782
Cold GH	488
Total	19,804

Calaroma-201 is a Jasmine-type long grain variety released in 2018 which has an aroma like typical aromatic long grains, but the taste characteristics are closer to Thai Jasmine quality. Calaroma-201 has a similar adaptability as L-207 and should be avoided in colder growing locations. It has low gel type and thus cooks softer than a typical long grain. Calaroma-201 had higher yield at RES compared to other statewide locations in 2022 (Table 43). The average yield was 8,439 lb/A in the statewide trial and 9,064 lb/A at RES. Calaroma-201 was 87 cm tall and headed around 95 days.

A-202 is a conventional aromatic variety that was released in 2014 as a replacement for A-301. A-202 is earlier, taller, and has a significantly higher seedling vigor score than A-301, but still has the same flavor sensory profile as A-301. The RVA profile 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. A-202 is not recommended to be grown in the colder rice areas, as it showed 95% blanking in greenhouse cold experiment and 12% blanking in San Joaquin (Figure 16). A-202 had higher yields at other statewide locations as compared to the RES location. The average yield was 7,907 lb/A at RES and 8,268 lb/A at other statewide test locations in 2022 (Table 43). A-202 was 99 cm tall and reached 50% heading in 91 days. A-202 showed highest lodging (31%) at the statewide location in 2022.

Calmati-202 is a true basmati variety released in 2006. It is an early maturing, semi-dwarf, pubescent, aromatic, and elongating long grain. Grain and cooking qualities of Calmati-202 is considerably closer to imported basmati. However, milled rice kernels are slightly shorter than imported basmati rice available in the US market. Timely harvest and proper handling is recommended to preserve milling as well as cooking quality of this variety. Due to the slender grain shape and pubescent hull and leaf, the drying rate of the grain at harvest is significantly faster than standard varieties. Recommended harvest moisture is 18 percent. Calmati-202 had higher yield in RES than other statewide locations. The average yield was 6,129 and 6,229 lb/A for the statewide and RES locations, respectively. The variety reached 50% heading in 94 days and the height was 89 cm in 2022 (Table 43).

Table 43. Average grain yield and agronomic characteristics of long grain check varieties in all statewide locations and RES in 2022.

Variety	**Grain Yield (lb/A 14% MC)**		**Harvest MC (%)**	**Seedling Vigor**	**Days to 50% Heading**	**Plant Height (cm)**	**Lodging (%)**	**Panicle Blanking at SJ (%)**	**Panicle Blanking in Greenhouse (%)**
	State	**RES**							
L-208	9,953	9,877	15	5	87	94	22	6	32.5
L-207	9,551	9,411	15	5	90	101	18	6.5	20
CJ-201	8,439	9,064	13	5	95	87	13	6	30
A-202	8,268	7,907	16	5	91	99	31	12	95
CT-202	6,129	6,229	14	5	94	89	5	7	30

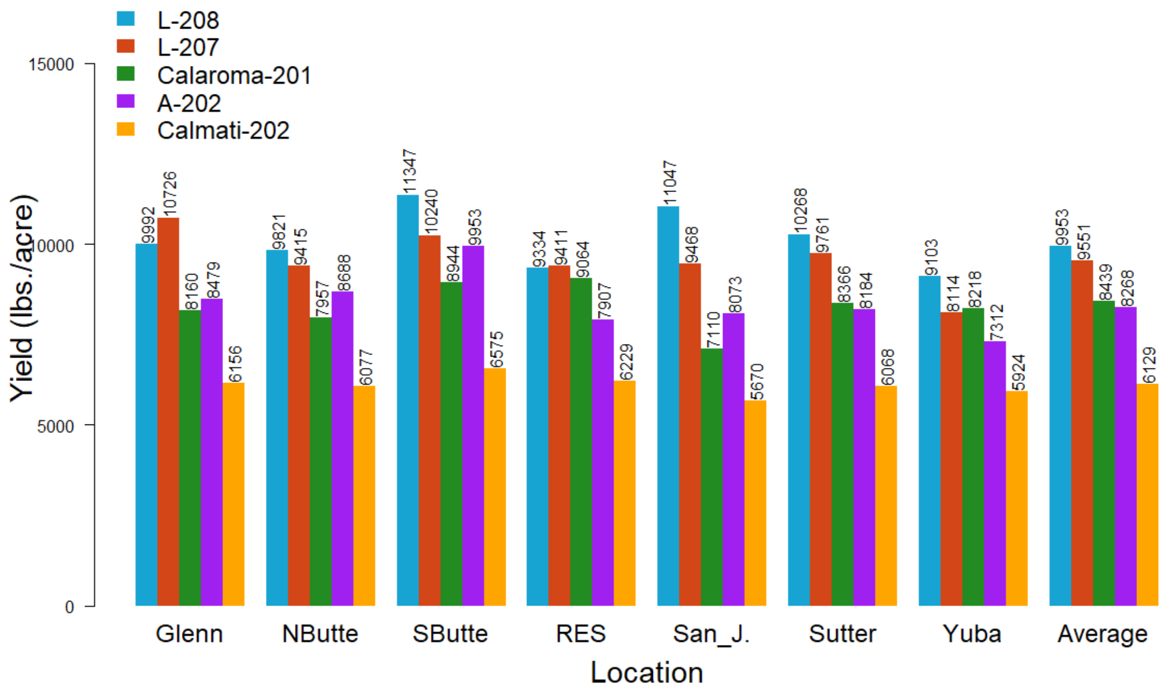

Figure 15. Yield performance of long grain checks at various statewide locations in 2022.

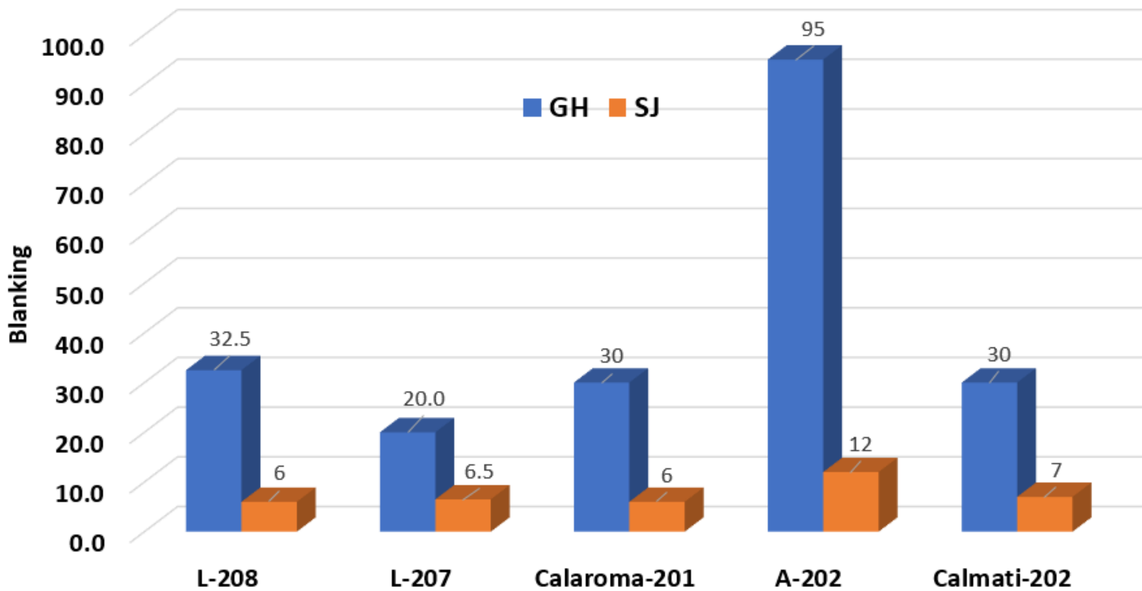

Figure 16. Average blanking of long grain checks in Greenhouse cold experiment and at the San Joaquin Statewide experiment in 2022.

Grain Quality of Long Grains

Long grain varieties had an average milling yield range of 52.2-62.9% head rice and 65.7-70.1% total rice across all harvest moistures (Table 44). L-207 showed higher average head rice (61.7%) compared to L-208 (60.8%). Calaroma-201 showed the highest average percent head rice which was 62.9 (Table 44). Based on milling yield trends, the long grain check varieties showed highest head rice near at 20% moisture content except Calaroma-201, which showed highest head rice at 18-19% moisture content (Figure 17). L-207 had the most stable grain quality at 15-24% MC. The best milling yields in 2022 were observed when harvested at 20% grain moisture content. The August-September heatwave affected the long grain varieties L-208, L-207 and A-202 in terms of chalkiness and showed 4.42%, 5.48% and 6.65% whole chalky kernels, respectively. However, the long grain varieties Calaroma-201 (0.72%) and Calmati-202 (0.42%) showed very trace amount of chalkiness.

Table 44. Average milling characteristics of long grain check varieties in 2022.

Variety	Whiteness	Whole Chalky %	Length (mm)	Width (mm)	L/W ratio	% Head rice	% Total rice	Protein (%)	Taste value
L-208	141.60	4.42	6.97	1.94	3.60	60.8	69.1	6.5	73.0
L-207	139.92	5.48	6.79	1.95	3.49	61.7	69.9	6.6	73.0
CJ-201	134.71	0.72	6.83	1.94	3.52	62.9	69.6	6.0	76.0
A-202	140.65	6.65	6.87	2.11	3.26	60.2	70.1	6.8	71.5
CT-202	129.96	0.42	6.94	1.91	3.64	52.2	65.7	7.7	64.0

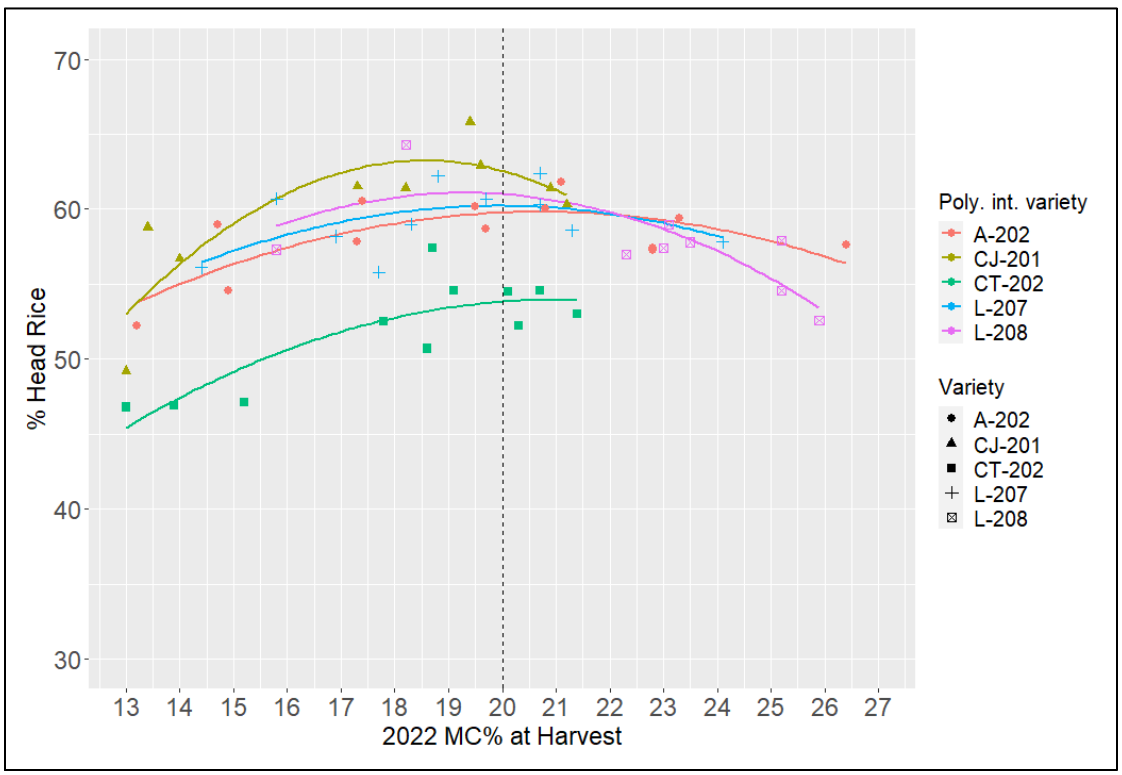

Figure 17. Milling yield trends of long grain check varieties in 2022 at RES.

Promising Long Grain Lines

There were ten advanced lines (19Y1018, 19Y1071, 21Y1002, 20Y1008, 20Y1029, 20Y1058, 20Y1080, 20Y1101, 20Y1102 and 20Y1117) in the 2022 statewide yield trial and out of those 3 lines (19Y1018, 20Y1029, 20Y1008) showed promising for future release.

The advanced line 19Y1018 is a regular long grain placed in the statewide trial for the second time. The line was planted in seven locations and out yielded L-208 and L-207 by 1.7% and 5.7% (Figure 18). The average RES and statewide yield of 19Y1018 was 10,013 and 10,123 lb/A, while L-208 was 9,877 and 9,953 lb/A, as well as L-207 was 9,411 and 9,551 lb/A respectively (Table 45). Line 19Y1018 had less panicle blanking compared to Calaroma-201 in San Joaquin. The line grew 92 cm tall in, which was similar to L-208 and 7 cm smaller than L-207. 19Y1018 is 2 days and 6 days early than L-208 and L-207 in 50% heading. Based on milling yield trends, the line 19Y1018 showed stable head rice performance, which can be harvested from 18-26% moisture content (Figure 19).

20Y1029 is another promising regular long grain planted in four statewide locations for the first time in 2022. The average yield of the line in statewide experiments and RES was 9,916 and 10,221 lb/A, respectively. In the RES experiments, the line outperformed L-208 (9,877 lb/A) by 3.4%. The line grew 99 cm, which was 8 cm taller than L-208 (Table 45). The line reached 50% heading in 89 days, which was 4 days earlier than L-207.

20Y1008, another 2022 statewide newcomer, is a regular long grain and was planted in seven statewide locations. The line had an average yield of 9,941 lb/A in RES and 9,837 lb/A in statewide test locations. In the statewide experiments, the line outperformed L-207 (9,551 lb/A) by 2.9%. 20Y1020 was 95 cm tall, 4 cm smaller than L-207 (Table 45). The line reached 50% heading in 87 days which was comparable to L-208.

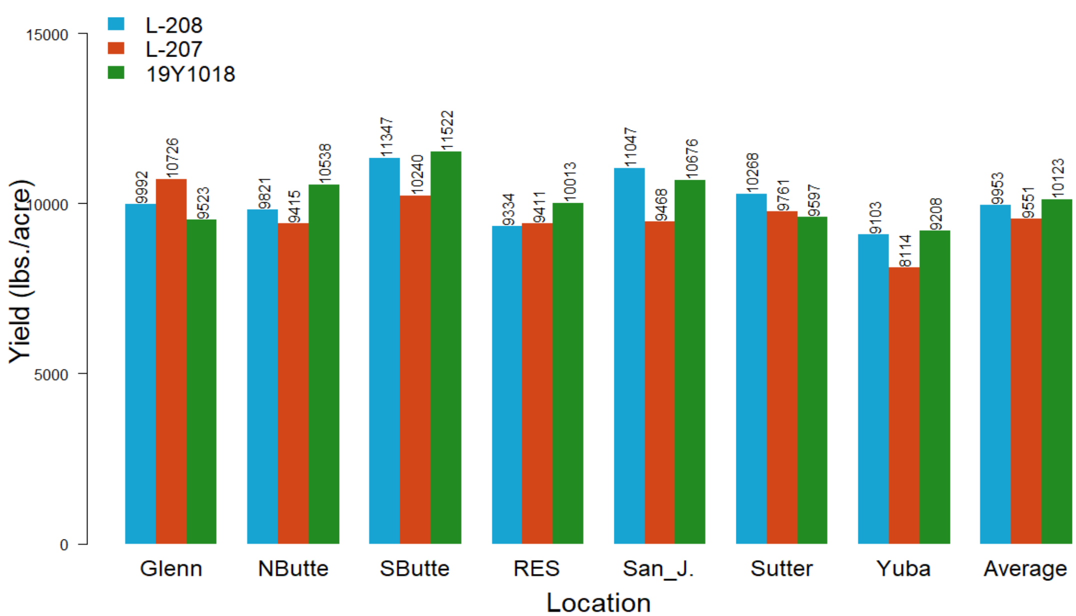

Figure 18. Yield performance of 19Y1018, L-207 and L-208 at SW locations in 2022.

Table 45. Average grain yield and agronomic characteristics of long grain check varieties and promising lines in the statewide (yield) and RES location in 2022.

Entry No.	Identity	Type †	Grain Yield (lb/A 14% MC)		SV	Days to 50% Heading	Height (cm)	Lodging (%)	Panicle Blanking at SJ (%)	Panicle Blanking in Greenhouse (%)
			State	RES						
36	19Y1018	L	10,123	10,013	4.8	86	92	22	6	35
34	L-208	L	9,953	9,877	4.9	88	91	22	6	32.5
51	20Y1029	L	9,916	10,221	4.8	89	99	16	6	15
52	20Y1008	L	9,837	9,941	4.8	87	95	28	7.5	45
35	L-207	L	9,551	9,411	4.8	92	99	18	6.5	20
54	20Y1117	L	9,421	10,174	4.8	97	92	15	4.5	40
50	20Y1058	L	9,397	10,170	4.8	97	98	20	4	27.5
53	20Y1101	L	9,332	9,880	4.8	98	97	18	5	12.5
57	21Y1002	L	8,965	8,781	4.8	96	90	15	6.5	17.5
12	19Y1071	LJ	8,807	9,744	4.9	98	105	18	10	87.5
55	20Y1080	L	8,545	9,523	4.8	99	90	16	7.5	20
13	CJ-201	LJ	8,439	9,064	4.9	95	87	13	6	30
55	20Y1102	L	8,315		4.8	97	94	25	9.5	27.5
48	A-202	LA	8,268	7,907	4.9	91	99	31	12	95
49	CT-202	LB	6,129	6,229	4.8	94	89	5	7	30

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

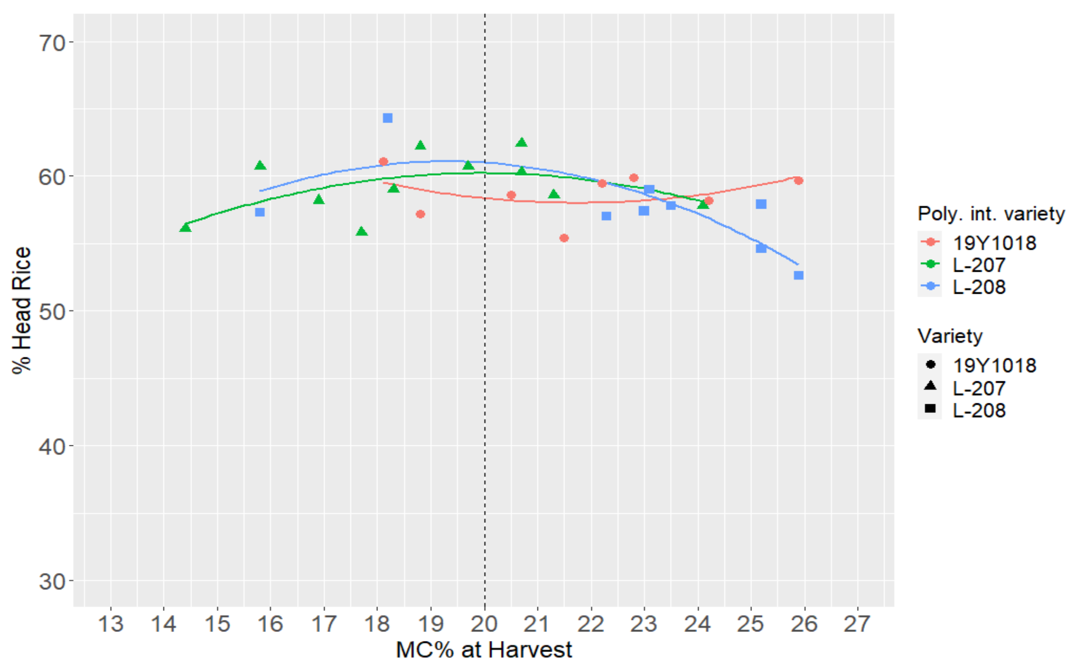

Figure 19. Milling yield trends of 19Y1018, L-207 and L-208 in 2022 at RES.

GENETICS LABORATORY SUMMARY

Gretchen M. Zaunbrecher

The main purpose of the RES Genetics Lab continues to be to provide the breeders with genetic marker information for the selection of potential and advanced lines as well as maintaining the purity of our released varieties. The generation of genetic data is facilitated using various DNA purification, amplification, and analysis equipment. Throughout the year breeders submit leaf samples from F_1, head rows, and ROXY trait lines. There are also occasions when off-types appear in fields on the station and in fields from area producers that are genetically identified through marker analysis (Table 46). This year 2,497 parental and F_1 plants were analyzed to determine true crossing. Over 88% of the F_1 crosses were determined to be true while the other 12% self-fertilized plants were removed from future selection. Head row purity was verified in over 3700 samples which included short, medium, long, and specialty lines. Several of these lines are nearing release and were analyzed with more markers to ensure purity. The presence of the oxyfluorfen herbicide tolerant trait (ROXY) was determined for approximately 765 plants whose response to the herbicide was atypical. Off-type rice plants were found in RES fields and several producers fields. Results of DNA analysis of off-type (taller/more mature) samples present in M-211 fields verified the M-211 genotype. The other fields, however, showed contamination with other genetic populations and outcrosses in various concentrations. Kent McKenzie submitted 19 samples for analysis of parentage or ROXY trait presence. Overall, approximately 7,469 samples were analyzed with a total of 33 markers, 31 SSR's and 2 SNP's (ROXY trait), generating 36,668 data points (Table 47).

Table 46. Genetic evaluations from the RES Genetics Lab in 2022.

Purpose/DNA Source	Samples	Primers	Data Points
F1 Cross Validation			
Parental Lines	109	10	1090
F1 Crosses (88% True)	2388	1	2388
Head Row Purity Verification			
Short Grain	1366	15	14106
Medium Grain	1000	11	7823
Long/Specialty Grain	1392	5	5768
Roxy Trait Confirmation			
ROXY Test Plot	765	2	1478
Off-Type Identification			
M-401 Field RES	384	9	3414
Dave Lohman(M-211)	6	5	30
Lundberg-Bosworth-Conant(CJ-201)	34	12	393
Kent Off-Types	19	14	154
M-211 Field RES	6	4	24
TOTAL	**7469**		**36668**

Table 47. Markers used for Genotyping.

AP5930A	RM247	RM3392
B7-5	RM276	RM3689
RM44	RM331	RM5556
RM72	RM333	RM6100
RM164	RM340	RM6329
RM190A	RM345	RM7076
RM206	RM404	RM7200
RM208	RM505	RM8213
RM224	RM518	RM25681
RM225	RM527	Rox1.1Mut SNP
RM234	RM3372	Rox1.1WT SNP

With the eventual release of a ROXY rice variety, an efficient and repeatable assay to certify the presence of the trait was developed. The Association of Official Seed Analysis (AOSA) guidelines were followed in the development of the protocol. The concentration of oxyfluorfen, length of exposure, and length of seed growth before analysis was determined and experiments are underway to verify the results. Once the protocol is verified it will be sent to an independent laboratory who will perform the same experiments for validation and future certification of ROXY trait seed.

The oxyfluorfen tolerant rice that is currently being advanced and studied is a result of ethyl methanesulfonate (EMS) exposure of M-206 seeds. EMS exposure results in the random mutation of nucleotides throughout the genome. Selection with various protocols allows for the identification of plants exhibiting favorable phenotypes. Selection with an oxyfluorfen herbicide resulted in the identification, advancement, and development of the ROXY rice variety tolerant to the chemical. In a similar way, M-211 seeds (M_0) were exposed to EMS in June of 2022. The seeds (M_1) were grown in the greenhouse and the seeds (M_2) harvested were planted in the winter nursery in Hawaii and the greenhouses at RES. These plants (M_2) are currently growing. The seeds (M_3) collected from these plants will be planted in the 2023 growing season where they will either be increased or enter into selection protocol studies.

CRISPR technology has been used successfully in the lab to verify the oxyfluorfen resistant phenotype as well as to explore the targeting of other useful traits. An organism generated by CRISPR technology is considered a genetically edited organism and not a genetically modified organism. The difference is important in both consumer acceptance and government regulation. Genetically edited organisms do not have foreign DNA in their genome. The change in their phenotype is a result of a targeted change in their own DNA. This change could happen naturally and therefore is managed and regulated the same as conventionally bred organisms. The change in phenotype of genetically modified organisms is the result of the addition of DNA from another organism. This change could not happen naturally, so these organisms are managed and regulated in a stricter manner. This additional regulation is a major deterrent in the development and production of genetically modified rice varieties. The majority of the major rice exporting and importing countries of the world consider genetically edited plants a non-regulated commodity and once CRISPR rice varieties become available, will allow free trade of the product (Figure 20). The European Union (EU) decreed in 2018 that genetically edited organisms would be regulated in the same manner as genetically modified organisms. However, there is increased pressure on the EU agriculture ministers to reconsider the ruling and it is expected that the EU will overturn their decision and significantly relax the restrictions and regulations on genetically edited organisms to a level similar to the rest of the world. CRISPR technology is being developed and tested in the RES Genetics lab and when CRISPR rice varieties are introduced in the future it is hoped that RES will be able to enter the market in a timely manner.

In December 2020 CCRRF authorized the purchase of new analytical equipment for the RES Genetics Lab. This will allow for the transition from SSR marker-based analysis to a SNP marker approach. The two techniques are similar in many ways which will result in a smooth transition. The difference is in the speed in which SNP marker results can be collected and analyzed. SSR markers rely on size difference between alleles at a given location in the rice genome. In order to elucidate these differences, the PCR products must be run on a gel matrix that will separate the products by size. SNP markers identify single nucleotide changes in alleles. Allele specific primers tagged with a uniquely colored fluorescent dye are used during PCR. These dyes are then visualized and recorded with a fluorescent plate reader that will determine which allele is present in the sample. The running and identification of polymorphic alleles using SSR’s averages 3.5 hours with the equipment available in the lab. With the purchase and use of the plate reader and SNP markers the average time to identify polymorphic alleles will be less than 30 seconds. This increase in speed of analysis will significantly increase the lab’s ability to process and genotype samples in a timely manner. This will benefit the breeders greatly in that they will have access to more genotypic data to aid in the selection of superior germplasm to advance for future release. There are considerably more SNP’s present in the rice genome compared to SSR’s and the databases of SNP sequences in rice continues to grow and are widely accessible. This will allow the lab to develop a unique catalog of SNP markers for use on the germplasm grown in California and will easily accommodate the adaption of new germplasm in the future.

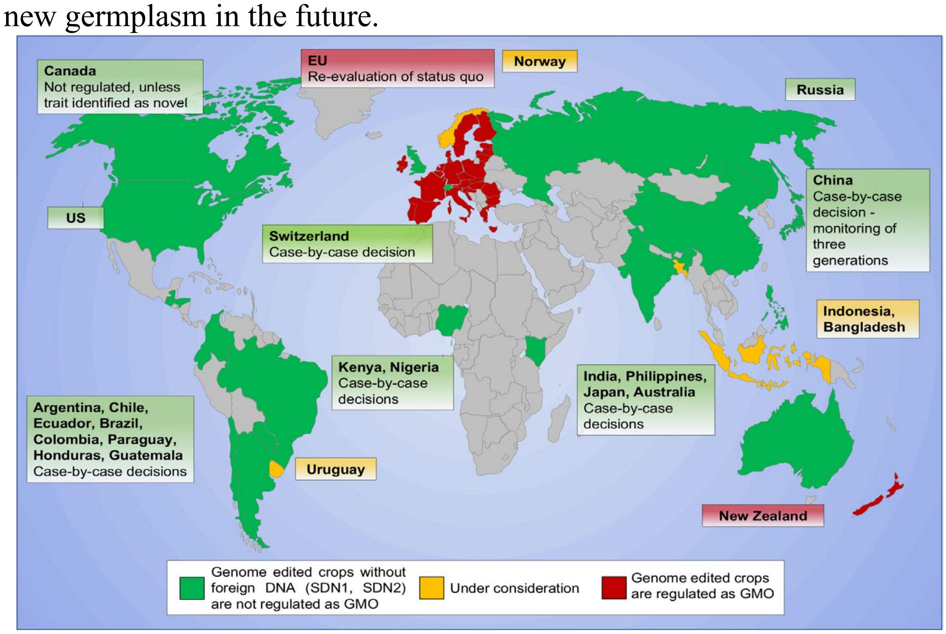

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Figure 20. Current regulation status of CRISPER technology.

SPECIAL RESEARCH PROJECT

Kent McKenzie

Herbicide Tolerant Rice

The RES Rice Breeding Program initiated a special project in 2014 to bring non-GMO herbicide tolerant rice technology to California rice growers. The ROXY® trait was recovered in the variety M-206, California's most widely grown Calrose variety. Extensive research and discovery on the genetics and mechanism of this trait by conventional breeding and the RES Genetics Laboratory revealed that it is controlled by a single recessive gene and is a new mechanism for rice herbicide tolerance. US patent 11,180,771 B2 (Oxyfluorfen Resistant Rice Lines) was granted to CCRRF November 23, 2021. This non-GMO rice trait provides tolerance to the post patent herbicides ALB2023 and ALB2024 (oxyfluorfen) and is joined together in what will be known as the ROXY® Rice Production System (ROXY® RPS). A "shared partnership" and commercial agreement has been reached between Albaugh LLC and CCRRF on the commercial development and launch of ROXY® RPS. Albaugh LLC is a global leader in the production and sale of post patent crop protection products and currently markets this herbicide. Albaugh LLC is a privately-owned US company with experience in developing and marketing herbicide tolerance technology, having launched a similar grower-owned non-GMO herbicide tolerant wheat, CoAXium® Wheat Production System.

- Submission to EPA for herbicide registration for rice with a concurrent review by the California Department of Pesticide Regulations was made by Albaugh in 2021. EPA has requested and accepted a PRIA Extension to June 2023.
- CCRRF has also applied for Plant Novel Trait approval from The Canadian Food Inspection Agency and Public Health Canada for the ROXY® trait in 2021. This approval is to confirm the safety of novel traits in crops for growers, marketers, and consumers. It involves extensive analysis of the nutritional components of the rice, detailed understanding of the trait, and allergenicity testing. This approval is a standard step followed in the approval for herbicide tolerant rice and other crops for commercialization. Health Canada has notified CCRRF of their approval and approval by the other agency is expected in 2023.
- Albaugh has been conducting multi-location efficacy testing throughout the California rice growing regions with rice weed control research groups and the UC since 2020. ROXY® RPS trials will continue with strategic partners to help position and educate the market on performance, establish BMPs (best management practices) and prepare the market for the 2024 launch of the ROXY® RPS.
- Eight years of research involving multiple locations shows that ALB2023 applied preplant in a water-seeded system provides high levels of rice weed control with a ROXY® traited rice. Albaugh continues to position the ROXY® RPS with ALB2023 as a base program utilizing best management practices for weed control and weed resistance management. It is also effective in drill-seeded rice with a post-plant and post-emergence applications and may have potential in other rice growing regions.
- The ROXY® RPS offers several very attractive features for rice weed control:
    - Oxyfluorfen provides a Group 14 (PPO) mode of action for use pre- and post-plant in rice weed management. This novel mode of action is needed to manage weed resistance toward Group 1 (ACCase) and Group 2 (ALS) herbicides, which comprises three quarters of the herbicides registered on rice.

- Tolerance is specific to oxyfluorfen and not to other currently registered Group 14 rice herbicides and has a better weed control spectrum.
- ALB 2023 in combination with the ROXY® trait provides early season control of yield robbing grass & broadleaf weeds with activity on proven resistance weeds biotypes in California rice fields.
- New tool to broaden BMP's in rice production and is compatible with most currently registered post emergence rice herbicides.
- As an herbicide tolerance trait, conventional rice varieties have tolerance to the herbicide at low rates, thus the risk of damage to neighboring rice fields is minimal.
- The preplant application system allows the application in sensitive area areas with adjacent crops where other products are restricted or not available.
- Will provide growers with enhanced herbicide performance and value.
- May be an integrated management tool to address weedy red rice.

RES Efficacy Testing

The 2022 season presented difficult challenges is conducting ROXY® research at RES and Albaugh sponsored efficacy testing throughout the state. Drought condition and water restrictions reduced availability and suitability for off-station testing and had research contractors struggling to find research sites. In addition, application and water management challenges impacted experiments off-station as well and at RES.

In the RES ROXY® nursery ALB 2023 herbicide rate studies gave very good weed control. Ricefield bullrush (heavy pressure at RES) emerged in open areas and plot alley ways. Increasing rate from 1.5 to 2.0 pints/acre all gave good control compared to the Abolish check. The delay in rice emergence increased with increasing ALB 2023 rates to 6 days at the highest rate. Seedling vigor scores of 0 in Tables 48-50 were given because the rice had not yet emerged from the water. 50% heading was 3 days later at the 2 and 2.5 pts./acre rate but not significantly different from the Abolish check at the lower rates. Grain yields were low and not significantly different in any of the treatments, except for the susceptible M-206 entry at the higher rates of ALB 2023. Lodging was severe by harvest, and there was a "lot of rice on the ground" that was not recovered by the plot harvester.

Application of ProGib (gibberellic acid) did not enhance seedling emergence in a rate study in the nursery as well as in strip trials in the foundation breeder seed and off-station small plots (Table 49). ALB 7000, a proprietary biological seed soak, did show a slight "visual" enhancement in seedling vigor score at ALB 2023 treatments of 1.75 to 2.5 pts. and there was a slight yield advantage at 2.0 pts./acre (Table 3). A test of 19Y4000 and 3 breeding lines was conducted at a 2.5 pts./acre identified a two-gene line that had significantly better seedling vigor score (emergence) than 19Y4000 at the 2.5 pts./a rate and its yields were higher but not significantly different. This vigor advantage was also observed in small plot seedings in the Albaugh tests at the Colusa County Farm Supply tests at the Meridian and Willows sites. Inspection of "weedy red rice simulations plots" with 20 % Koshihikari mixtures found only 3 plants at the 1.5 pts./acre, and none were found in the 1.75 to 2.5 pts./acre basins. This is the third year of simulated weedy red rice tests showing promising control results.

The performance of the ROXY® Rice Production System using 19Y4000 gave historically consistent weed control results at RES and off-station and was very effective as a base program for rice weed control as it has been envisioned. A post-emergence herbicide application (e.g., propanil) was included in the program in the 2022 testing.

Table 48. Large plot water-seeded herbicide rate test of tolerant 19Y4000 and susceptible M-206 at RES in 2022.

Entry	ALB2023	REP	SV1	SV 2	HD days	HT cm	LOD1 %	LOD2 %	MC %	Yield lbs./a
M-206	Abolish	4	4.8	5.0	84	104	35	85	19	8280
19Y4000	Abolish	4	4.8	5.0	83	102	5	75	18	7750
M-206	1.5 pts./a	4	0.0	1.2	90	102	8	48	20	7540
19Y4000	1.5 pts./a	4	4.6	4.8	84	101	35	100	20	7830
M-206	1.75 pts./a	4	0.0	0.0	91	101	10	28	20	6907
19Y4000	1.75 pts./a	4	4.4	4.7	85	97	53	95	20	7750
M-206	2.0 pts./a	4	0.0	0.0	92	93	0	0	17	4440
19Y4000	2.0 pts./a	4	4.2	4.7	87	101	98	95	23	7540
MEAN			2.8	3.2	87	100	30	66	20	7240
LSD (.05)			0.1	1.2	1	6	29	18	3	1570
CV (%)			1.3	25.7	1	4	66	19	11	15

SV1 seedling vigor 1-5 score evaluator 1; SV2 seeding vigor 1-5 score evaluator 2; HD days to 50% heading; HT height in cm; LOD1 % lodging before rain; LOD2% lodging before after rain; MC harvest moisture; Yield at 14 % moisture.

Table 49. Large plot water-seeded herbicide rate test of tolerant 19Y4000 and susceptible M-206 at RES with seed soak of gibberellic acid (ProGib).

Entry	ALB2023	REP	SV1	SV2	HD	HT cm	LOD1 %	LOD2 %	MC %	Yield
M-206 w/GA	Abolish	4	4.8	5.0	85	96	30	63	18	6770
19Y4000 w/GA	Abolish	4	4.8	4.9	85	96	30	40	17	7240
M-206 w/GA	1.5 pts/a	4	0.0	0.0	90	103	10	33	20	6060
19Y4000 w/GA	1.5 pts./a	4	4.6	4.8	85	101	38	95	14	5920
M-206 w/GA	1.75 pts./a	4	0.0	0.0	91	103	3	35	21	5520
19Y4000 w/GA	1.75 pts./a	4	4.3	4.7	85	101	3	85	20	7930
M-206 w/GA	2.0 pts./a	4	0.0	0.0	93	96	0	0	18	3220
19Y4000 w/GA	2.0 pts./a	4	4.1	4.7	87	102	53	90	21	7510
MEAN			2.8	3.0	88	100	21	55	19	6270
5%LSD			0.1	0.0	1	4	29	24	5	2470
CV (%)			1.4	0.9	1	3	97	30	20	27

SV1 seedling vigor 1-5 score evaluator 1; SV2 seeding vigor 1-5 score evaluator 2; HD days to 50% heading; HT height in cm; LOD1 % lodging before rain; LOD2% lodging before after rain; MC harvest moisture; Yield at 14 % moisture.

Table 50. Large plot water-seeded herbicide rate test of tolerant 19Y4000 and susceptible M-206 at RES with seed soak of ALB 7000.

Entry	ALB2023	REP	SV1	SV 2	HD days	HT cm	LOD1 %	LOD2 %	MC %	Yield lbs./a
19Y4000-T	2.5pts./a	2	4.0	4.7	88	100	20	70	21	8940
19Y4000-U	2.5pts./a	2	3.7	4.6	89	104	70	100	21	9240
19Y4000-T	2.0 pts./a	2	4.0	4.8	87	99	80	100	20	8650
19Y4000-U	2.0 pts./a	2	3.8	4.8	86	98	55	100	21	8043
19Y4000-T	1.75 pts./a	2	4.5	4.8	85	100	20	100	19	8780
19Y4000-U	1.75 pts./a	2	4.0	4.7	85	102	15	100	18	9000
19Y4000-T	1.5 pts./a	2	4.7	4.9	84	101	20	100	18	8800
19Y4000-U	1.5 pts./a	2	4.6	4.9	84	102	50	100	18	8860
19Y4000-U	Abolish	2	4.9	5.0	86	92	10	35	15	7350
19Y4000-T	Abolish	2	4.9	5.0	87	89	5	45	15	6700
MEAN		2	4.3	4.8	86	98	35	88	19	8440
5%LSD			0.4	0.1	2	5	53	36	4	2060
CV (%)			4.5	1.2	1	2	68	18	11	11

T=treated, U=untreated; SV1 seedling vigor 1-5 score evaluator 1; SV2 seeding vigor 1-5 score evaluator 2; HD days to 50% heading; HT height in cm; LOD1 % lodging before rain; LOD2% lodging before after rain; MC harvest moisture; Yield at 14 % moisture

Table 51. Large plot water-seeded herbicide rate test of tolerant lines at 2.5 pts./a ALB2023.

Entry	REP	SV1	SV2	HDG days	HT cm	LOD1 %	LOD2 %	Yield lbs./a
19Y4000	4	3.9	4.6	89	103	40	83	7,810
21Y3020	4	4.1	4.7	88	95	38	95	7,640
21Y3021	4	3.9	4.6	93	90	0	0	7,470
21Y3018	4	4.2	4.7	88	97	23	95	8,000
MEAN		4.0	4.6	89	96	25	68	7,730
5%LSD		0.1	0.0	1	5	32	21	7,70
CV (%)		1.3	0.6	0	3	79	20	6

SV1 seedling vigor 1-5 score evaluator 1; SV2 seeding vigor 1-5 score evaluator 2; HD days to 50% heading; HT height in cm; LOD1 % lodging before rain; LOD2% lodging before after rain; Yield at 14 % moisture.

SUPPLEMENTAL TABLES & DOCUMENTS

Supplemental Table 1. Mean performance of 19Y4000 and checks in Very Early Group - UCCE Statewide Test (ZONE 3).

Location/ Years	Entry Name	Grain Yield (lb/A)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-VE	19Y4000	8399.65		17	4.9	79	94	8
2019-22	M-206	8595.89	-2	17	4.9	80	95	13
	M-210	8194.15	3	17	4.9	80	94	6
SUTTER	19Y4000	8748.34		18	4.8	88	88	7
2019-22	M-206	9200.26	-5	18	4.8	88	91	4
	M-210	9246.29	-5	18	4.8	88	89	0
YUBA	19Y4000	7334.01		17	4.8	89	99	45
2019-22	M-206	7860.47	-7	18	4.8	89	100	55
	M-210	7538.42	-3	18	4.8	89	98	48
YOLO	19Y4000	8894.35		17	4.8	91	96	19
2019-22	M-206	9130.36	-3	18	4.8	91	96	22
	M-210	9066.50	-2	18	4.8	91	96	19
S JOAQUIN	19Y4000	9848.22		15	4.7	110	84	0
2021-22	M-206	9617.80	2	15	4.8	111	84	0
	M-210	9502.33	4	15	4.8	110	81	0
OVERALL	19Y4000	8511.22		17	4.8	89	93	18
MEAN	M-206	8799.09	-3	18	4.8	90	94	21
(Zone 3)	M-210	8621.45	-1	17	4.8	89	93	16
2019-22								
	MEAN	8643.9		17	4.8	89	93	18
	LSD (0.05)	593.961		2	0.0	6	5	20
	CV	10.3		13	1.1	11	9	161

Supplemental Table 2. Mean performance of 19Y4000 and checks in Early Group - UCCE Statewide Test (ZONE 2).

Location/ Years	Entry Name	Grain Yield (lb/A)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-E	19Y4000	9617		17	4.9	79	93	8
2019-22	M-206	8813	9	19	4.8	80	97	12
	M-210	9061	6	17	4.9	80	97	15
N. BUTTE	19Y4000	8882		17	4.8	88	101	56
2019-22	M-206	8624	3	18	4.8	88	103	67
	M-210	8982	-1	18	4.8	88	101	53
S. BUTTE	19Y4000	9131		19	4.8	91	100	65
2019-22	M-206	9292	-2	19	4.8	91	100	71
	M-210	9578	-5	18	4.8	91	103	66
OVERALL	19Y4000	9210		18	4.8	86	98	43
MEAN	M-206	8910	3	18	4.8	86	100	50
(Zone 2)	M-210	9207	0	18	4.8	86	100	44
2019-22								
	MEAN	9109		18	4.8	86	99	46
	LSD (0.05)	529		1	0.1	5	6	29
	CV	7		10	1.3	6	7	76

Supplemental Table 3. Mean performance of 19Y4000 and checks in Intermediate-Late Group - UCCE Statewide Test (ZONE 1).

Location/ Years	Entry Name	Grain Yield (lb/A)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-IL	19Y4000	9036.93		18	4.9	79	97	13
2019-22	M-206	8846.25	2	17	4.9	80	96	14
	M-210	8944.12	1	17	4.9	79	96	12
GLENN	19Y4000	8885.17		14	4.7	91	96	69
2019-22	M-206	9152.39	-3	14	4.8	91	98	84
	M-210	9487.16	-6	14	4.8	90	97	63
COLUSA	19Y4000	9000.13		16	4.8	89	98	35
2019-22	M-206	9294.5	-3	16	4.8	89	100	60
	M-210	9177.71	-2	17	4.8	89	98	34
OVERALL	19Y4000	8971.71		16	4.8	86	97	40
MEAN	M-206	9079.82	-1	16	4.8	86	98	52
(Zone 1)	M-210	9205.29	-3	16	4.8	86	97	36
2019-22								
	MEAN	9085.6		16	4.8	86	97	43
	LSD (0.05)	506.078		2	0.1	6	4	29
	CV	6.4		13	1.6	7	5	78

Supplemental Table 4. Mean performance of 17Y2087 and current premium quality short grains in Very Early Group - UCCE Statewide Test (ZONE 3).

Location/ Years	Entry Name	Grain Yield (lb/a)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-VE	17Y2087	8,976		15	4.9	81	88	1
2018-2022	CH-202	8,576	5	12	4.9	80	90	23
	CH-201	7,543	19	11	4.9	82	92	32
SUTTER	17Y2087	9,165		20	4.8	90	86	17
2018-2022	CH-202	8,609	6	18	4.8	89	83	79
	CH-201	8,761	5	16	4.9	94	86	32
YUBA	17Y2087	7,960		18	4.8	89	94	60
2018-2022	CH-202	6,890	16	17	4.8	88	93	85
	CH-201	6,844	16	15	4.8	88	94	66
YOLO	17Y2087	10,243		17	4.8	87	94	6
2018-2021	CH-202	9,309	10	16	4.8	86	92	59
	CH-201	9,500	8	18	4.8	86	100	68
S. YOLO	17Y2087	8,370		15	4.8	97	90	44
2018-2019	CH-202	7,865	6	14	4.7	101	86	63
	CH-201	7,725	8	14	4.7	102	86	44
S JOAQUIN	17Y2087	10,348		15	4.8	113	85	0
2021-2022	CH-202	9,818	5	15	4.6	109	79	6
	CH-201	8,218	26	15	4.9	112	79	0
OVERALL	17Y2087	9,083		17	4.8	90	90	22
MEAN	CH-202	8,390	8	15	4.8	89	88	57
(Zone 3)	CH-201	8,008	13	15	4.8	91	90	44
2018-2022								
	MEAN	8,567		16	4.8	90	89	40
	LSD (0.05)	716		2	0.1	6	5	22
	CV	13		17	1.7	10	8	88

CV=Coefficient of Variation (%), LSD=5% Least Significant Difference

Supplemental Table 5. Mean performance of 17Y2087 and current premium quality short grains in Early Group - UCCE Statewide Test (ZONE 2).

Location/ Years	Entry Name	Grain Yield (lb/a)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-E 2018-2022	17Y2087	9,158		15	4.9	82	88	0
	CH-202	8,659	6	13	4.8	79	86	14
	CH-201	8,211	12	14	4.9	84	99	58
N. BUTTE 2018-2022	17Y2087	8,691		20	4.8	88	96	55
	CH-202	7,232	20	17	4.8	87	93	99
	CH-201	7,235	20	15	4.8	92	98	95
S. BUTTE 2018-2022	17Y2087	9,595		18	4.8	94	96	65
	CH-202	8,167	17	16	4.8	90	94	98
	CH-201	8,555	12	15	4.7	95	97	89
OVERALL MEAN (Zone 2) 2018-2022	17Y2087	9,107		18	4.8	87	93	38
	CH-202	8,020	14	15	4.8	85	91	70
	CH-201	8,000	14	15	4.8	90	98	81
	MEAN	8,356		16	4.8	87	93	63
	LSD (0.05)	827		2	0.1	5	5	32
	CV	12		17	1.6	7	6	61

CV=Coefficient of Variation (%), LSD=5% Least Significant Difference

Supplemental Table 6. Mean performance of 17Y2087 and current premium quality short grains in Intermediate-Late Group - UCCE Statewide Test (ZONE 1).

Location/ Years	Entry Name	Grain Yield (lb/a)	%Yield Advantage over	Harvest MC (%)	Seedling Vigor	Days to 50% Heading	Plant Height (cm)	Lodging (%)
BIGGS-IL 2018-2022	17Y2087	9,318		15	4.9	84	88	1
	CH-202	8,380	11	13	4.9	80	89	28
	CH-201	7,893	18	13	4.9	82	94	52
GLENN 2018-2022	17Y2087	8,303		16	4.8	92	92	98
	CH-202	7,539	10	14	4.8	88	95	98
	CH-201	8,144	2	14	4.8	92	95	83
COLUSA 2018-2021	17Y2087	9,059		17	4.8	86	96	76
	CH-202	7,982	13	15	4.8	88	90	97
	CH-201	7,910	15	17	4.8	92	92	68
OVERALL MEAN (Zone 1) 2018-2022	17Y2087	8,893		16	4.8	87	92	58
	CH-202	7,966	12	14	4.8	85	91	73
	CH-201	7,992	11	14	4.9	88	94	68
	MEAN	8,218		15	4.8	87	92	68
	LSD (0.05)	933		2	0.1	5	5	33
	CV	13		14	1.7	7	7	57

CV=Coefficient of Variation (%), LSD=5% Least Significant Difference

Supplemental Table 7. Milling yield (total milled and head rice percentage) of 17Y2087, CH-202, and CH-201 at varying harvest moisture content at RES from 2018 to 2022.

Year	CH-202			17Y2087			CH-201		
	Harvest MC (%)	%Head	%Total	Harvest MC (%)	%Head	%Total	Harvest MC (%)	%Head	%Total
2022	20.5	65.5	72.6	27.7	57.4	68.3	21.5	67.6	71.9
	20.0	67.8	73.1	27.3	67.0	70.0	21.4	63.5	72.0
	19.8	64.2	70.6	25.5	63.9	71.3	21.3	65.9	70.6
	19.7	60.0	71.6	23.6	69.9	72.9	21.2	64.5	70.4
	19.6	65.4	73.3	23.6	68.4	71.6	20.4	68.8	73.8
	19.3	64.3	72.9	22.4	69.0	72.2	19.8	70.0	74.6
	19.2	67.6	73.3	21.8	70.9	71.5	19.0	67.7	73.4
	18.8	67.2	71.3	21.3	69.8	72.5	18.7	68.0	73.3
	18.4	62.1	73.3	20.2	65.9	72.8	18.3	69.3	74.5
	18.0	61.2	72.5	19.1	65.3	72.4	18.2	67.0	72.2
	18.0	63.9	73.5	17.9	59.4	71.9	17.8	68.2	73.6
	17.9	66.6	72.9	17.9	63.3	72.0	17.8	60.7	71.0
	17.7	67.1	72.8	17.7	57.5	70.6	17.7	68.2	73.5
	17.1	70.3	72.5	17.4	70.8	74.7	17.0	34.7	69.2
	16.9	63.9	73.6	15.7	55.3	72.7	16.7	65.6	73.7
	16.8	62.7	73.3	14.8	58.6	72.4	16.6	61.6	72.7
	16.8	63.5	74.0	14.6	59.3	72.0	16.2	66.1	71.7
	16.6	58.2	71.2	13.4	48.9	71.1	15.7	31.6	68.6
	16.0	61.2	72.5	13.3	51.5	73.1	15.5	64.0	72.4
	15.3	58.5	71.5				15.3	53.6	59.7
	15.2	67.2	73.8				15.2	63.3	73.2
	14.3	51.1	72.4				12.2	56.9	73.5
	13.5	58.8	72.7						
	12.5	44.6	72.5						
2021	20.6	67.1	70.7	22.3	67.4	70.1			
	20.5	64.8	67.2	20.9	66.3	70.6			
	19.0	62.4	70.3	19.8	65.0	69.7			
	18.0	66.0	71.0	19.4	65.0	70.7			
				16.8	64.8	72.6			
				16.7	63.2	71.9			
2020	20.1	63.3	70.3	23.1	69.3	72.7	19.6	65.7	72.8
	20.0	68.2	72.5	20.2	65.0	71.7	16.5	61.3	71.0
	18.6	64.4	71.0	18.1	65.6	71.7	16.1	60.9	71.4
	17.3	61.9	71.0	17.0	67.1	73.1	12.8	52.3	70.0
2019	22.7	67.0	71.1	23.0	68.1	72.0	27.2	50.0	62.3
	19.5	63.8	70.9	19.3	65.3	72.5	24.3	60.6	68.4
	17.0	64.0	72.1	16.6	63.7	73.0	21.7	66.4	71.1
	15.2	62.7	71.8	15.1	58.3	72.4	20.5	61.3	68.0
2018	19.9	67.0	71.5	21.5	67.3	72.1	19.6	65.2	71.4
	18.5	61.7	70.5	17.8	64.8	71.0	19.1	55.3	70.4
	17.0	61.2	70.4	17.4	59.4	71.0	18.0	51.5	67.2
	16.4	57.3	69.6				17.5	55.4	70.2
							17.4	64.5	70.6
							14.3	52.0	68.5
							13.9	55.9	71.4
							13.7	31.8	69.7
							13.6	50.9	70.0
							12.4	54.0	72.0
							19.5	55.5	67.8
							18.5	59.0	69.6
							16.5	54.3	69.1