Chapter 2

Rice Varieties and Variety Improvement

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Development of superior rice varieties has been an important tool for improving rice production in Louisiana and in the United States. Release of improved varieties by public breeding programs in Louisiana, Texas, Arkansas, Mississippi and California, in conjunction with advancements in rice production technology, has provided a continuous increase in rice production and quality. Considerable genetic potential exists to improve on current rice varieties, and rice breeding efforts should continue to help increase rice yield and profitability in Louisiana.

Rice Varietal Improvement Program

In the early days, Louisiana rice production depended on varietal introductions by individuals. In 1909, the first rice breeding program in the United States was initiated when the Rice Research (Experiment) Station was established at Crowley. The rice breeding activities there were under the direction of USDA scientists from the inception of the program until the Louisiana Agricultural Experiment Station (LAES) assumed responsibility for the program in 1981. The Rice Research Station has a long history of developing new varieties that benefit the Louisiana rice industry. Additional research projects were added over time, but variety development has always been a major focus of the station's research activities. Since its inception, the program has formally released 49 improved rice varieties (Appendix Table 1).

Variety development efforts require a great deal of time, money, hard work and travel by those involved, specialized field and laboratory equipment, and a high level of cooperation with producers and other research personnel. The first step in the development of a new variety is to cross two different rice lines (parents). Depending on the choice of parents, subsequent generations will exhibit a variety of genetic combinations that will provide the basis for future yield and quality advancements. Since the rice flower is perfect (contains both the male and female flower parts), a female flower must be created artificially by removing the male flower parts (anthers) from a rice floret. First the tips of the lemma and palea (hull) are snipped off to expose the floral parts (Fig. 2-1). The pollen bearing structures, the anthers, must be removed to prevent self fertilization. Normally, this is accomplished by using a small pipette connected to a vacuum pump that vacuums the anther out of the flower (Figs. 2-1, 2-2 and 2-3). This is a very tedious process that must be done in a meticulous manner to prevent abortion of the rice seed. The next step is to introduce pollen (male) from a different line and pollinate the female flower.

Over 1,000 such crosses are typically made at the Rice Research Station each year. The resulting seed from these crosses will contain genetic information from both parents. This seed is called the F_1 generation and germinated to produce F_1 plants. At maturity, seed is harvested from the F_1 plants. This seed is bulk-planted the following growing season to produce a population of segregating F_2 plants. Segregation means there is a great deal of variation in the appearance of these plants since they are expressing traits from both parents in many different combinations. The F_2 generation will exhibit more variation than any other population in the breeding process. Selection in the F_2 populations is a very important step in the variety development process. Breeders attempt to select those plants with the best combination of traits. Selection criteria generally include (but are not limited to) seedling vigor, maturity, height, tillering (number and uniformity), panicle size, completeness of panicle exsertion, grain shape and appearance, lack of grain chalk, disease resistance and overall plant appearance. Individual panicles are selected from those plants expressing

the best combinations of the traits listed above for advancement to the next generation and beyond.

From this point on (F_3-F_n), most of the breeding material is grown as panicle (head) rows. A panicle row is a row of plants all derived from seed harvested from a single panicle. The best rows will be selected (not individual plants) to advance to the next generation. With each succeeding generation, the amount of segregation is decreased (or the level of uniformity is increased) both naturally and through the selection process. Thus, the F_4 generation is more uniform than the F_3 from which it was derived and the F_5 generation is more uniform than the F_4 generation and so on. Each year, approximately 95,000 to 120,000 panicle rows are grown at the Rice Research Station in the various breeding projects. Each of these rows is a unique genotype and any of them could theoretically become a new variety.

A tremendous amount of meticulous work must be done before these rows are planted. The seed from

Fig. 2-1. Preparing to remove the anthers with vacuum.

Fig. 2-2. Anthers being aspirated.

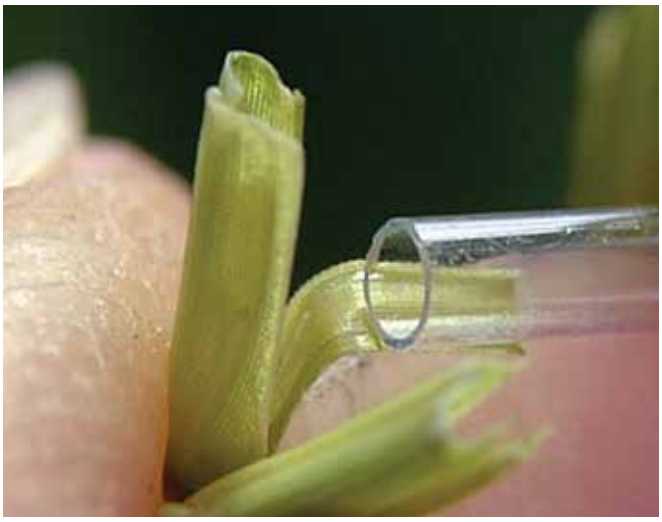

Fig. 2-3. Anthers removed. Floret emasculated.

each row must be individually threshed. A specialized panicle thresher is used to accomplish this, but it was not too many years ago that this was all done by hand. Specialized planters are also used to plant the individual rows. It requires a great many hours of careful work to prepare and arrange this seed for planting in such a way as to avoid mistakes.

Lines from most of the crosses have reached sufficient uniformity by the F_4 to F_5 generation to enter a line into a preliminary yield evaluation. Lines that are selected for potential yield evaluation are bulk harvested (after several panicles have been selected and harvested). Bulk harvesting of individual rows is done the "old-fashioned" way. Each selected row is harvested by cutting the stalks with a sickle and tying the harvested stalks with a length of twine. Each individual row is threshed, cleaned and dried on a small sample drier. Several thousand rows are handled this way each summer.

During the following winter, a number of laboratory analyses are conducted on each harvested sample (grain appearance and milling, cereal chemistry and seedling vigor), and the superior lines are entered into the initial yield testing program, which is called the Preliminary Yield Tests. Some of these are two-replication tests while a number of lines are evaluated each year in single plot tests. These trials are planted in March on the Rice Research Station. This planting time will allow a sufficient growing season to evaluate first and ratoon (second) crop performance. A "plot" in the Rice Breeding Project is seven drill rows spaced 8 inches apart 16 feet long (or approximately 75 square feet). This represents approximately 0.17 percent of an acre.

These small plots are used to keep the overall test as small as possible in an effort to minimize environmental variations that might influence the performance of genotypes (breeding lines) in the tests. It is critical that any differences expressed in these trials (yield, milling quality, height, etc.) are a result of true genetic differences and not caused by differences such as soil type, fertility or water depth.

Approximately 3 weeks after the preliminary yield trials are planted, a seed increase/purification block is planted that will include 9 to 14 headrows from each of the lines included in the yield trial. This increase block is planted later than the yield evaluations to provide time to analyze data and determine which lines may be advanced, and thus, which headrow populations should be harvested. Prior to harvest, these lines are evaluated and any segregating rows (rows with too much variation within the row) are removed from the population, 25 panicles are picked from a representative row, then the remaining seed is bulk harvested. The 25 panicles will serve as a pure seed source, and the bulked seed will provide enough seed for advanced testing in multilocation yield trials.

A typical preliminary yield test has 750 entries replicated twice for a total of 1,500 plots. These tests also include commercially grown varieties so that the performance of the experimental lines can be compared with these as well as to each other. Preliminary yield trials at the Rice Research Station utilize approximately 5 acres. If everything goes without a hitch, this test can be planted in less than a day with specialized planting equipment. However, preparing the seed for this planting (cleaning, cataloging, weighing, labeling and filling seed envelopes, laying out packets in planting order, etc.) is the result of many months of meticulous work during the winter. In addition, a great deal of data entry and recordkeeping is involved as lines move from one generation to the next.

After planting, this yield trial is managed similar to any other rice field to optimize production and uniformity throughout the test area. The process includes timely water management, fertilization and weed and insect control. Fungicides are not used in the breeding program because relative disease-resistance among the experimental lines is evaluated at every step of the variety development process.

These trials are evaluated at least twice weekly during the growing season, and data are collected for the following traits: (1) emergence date, (2) seedling vigor, (3) tillering characteristics, (4) heading date, (5) plant height at maturity, (6) disease susceptibility (any diseases present), (7) lodging characteristics and (8) harvest maturity date. When a plot reaches harvest maturity, a hand-harvested sample is taken for use in milling quality evaluation. This sample is cut with a sickle, threshed using a stationary thresher, aspirated (removing chaff and stems) and dried on a specialized sample dryer. This sample is taken this way because

the entire test will be harvested with a small plot combine when all plots have reached harvest maturity. Since there may be up to 10 days difference in maturity among lines in these trials, taking a sample from each plot at harvest maturity puts all lines on an equal footing for milling quality evaluation.

Prior to harvest, all experimental lines are evaluated for relative susceptibility to major and minor rice diseases. Because we often do not have consistent disease pressure in these tests, these lines are also planted in disease nurseries where disease pressure is maximized by inoculation (sheath blight and bacterial panicle blight) and the use of highly susceptible spreader varieties (blast).

When all lines in a trial have reached harvest maturity, the trial is harvested using a specialized small plot combine. This combine has a 5-foot header width so it fits these plots perfectly. The combine has the capability to harvest a plot and automatically obtain the grain weight and grain moisture for the rice from that plot. The seed then can be bagged and tagged for identification. Under ideal conditions, the 1,500-plot test can be harvested in 2 days.

The hand-harvested sample is milled using specialized milling equipment that will provide data on whole and total milled rice. In addition, these samples are evaluated for uniformity, chalkiness, grain shape and any other characteristic that might be a factor in the acceptability of the line as a commercial variety. The multitude of data collected will be analyzed to decide which lines will be entered into advanced trials the following growing season.

Getting to the preliminary yield testing stage normally takes a minimum of 5 to 6 years from the time the cross is made. The lines that display superior characteristics in preliminary testing are considered for advancement to the Commercial-Advanced (CA) trials, as well as the Uniform Regional Rice Nursery (URRN). Only about 5 percent of lines entered into the preliminary trials will be advanced. The CA trials are conducted throughout the rice-growing regions of Louisiana. The off-station location trials are conducted in cooperation with rice producers who are willing to provide land, land preparation, irrigation and assistance with these trials in countless other ways. The farmer will provide an area that has independent flooding and draining capabilities. The trials are planted using the same small plot equipment that is used on the Rice Research Station. After emergence, the trial is handled just as it would be on the Rice Research Station to optimize production and minimize any environmental variation that would impact the ability to evaluate true genetic differences among the lines in the trials. These trials are evaluated at least weekly, and data are collected for all characteristics just as is done on the Rice Station. These trials are harvested using the small plot combine. Trials that are harvested prior to August 15 will be ratoon cropped to provide data on this important characteristic.

The URRN is a cooperative endeavor conducted by the public rice breeding programs in Arkansas, Louisiana, Mississippi, Missouri and Texas. The nursery is a yield-testing program that is conducted at the primary research location in each of those states. The "Uniform" refers to the fact that the same rice lines are tested at each of the five locations. The test normally contains 200 rice lines (or genotypes), each representing an elite line from each breeding program. Breeders submit lines that might have the attributes that would warrant their consideration as a new release. Among the 200 entries are several currently grown commercial varieties included to provide a standard of comparison. The yield test is conducted at the research station in each state using the best cultural practices for that region. All data from the testing program are provided to each cooperator. Most of the experimental lines in the CA trials are also entered into the URRN.

Therefore, between the CA and URRN trials, the most advanced experimental lines in the Louisiana program are evaluated in numerous yield trials each year. The CA and URRN trials are extremely important in making decisions on potential variety releases. It is critical that a line be evaluated under different environmental conditions to determine its area of adaptation. In a potential new variety, one is looking for superior and stable performance. Often, a line will have excellent performance in two or three of these trials but average or inferior performance in several others. This line will be eliminated because of the lack of stability. As with the prelimi-

nary trials, all of the entries in each of these trials are evaluated for relative susceptibility or resistance to major rice diseases.

Lines that show excellent yield potential and milling quality, a high level of adaptation and good agronomic characteristics across all these diverse environments will be reentered into these trials the following year. A line that shows good potential as a future release will also be included in the statewide Variety by Nitrogen rate testing program. These lines may also be evaluated for differential response to selected rice herbicides. This research is conducted so that if a line is released as a variety, a package of agronomic recommendations for its production is also available.

If a line displays significantly better performance than the current commercial varieties, it also may be grown as a larger headrow population as a step toward potential increase. In each generation of testing, these experimental lines are concurrently being grown as panicle rows for purification and increase. A typical headrow population for a potential release is approximately 1,000 rows, which is often grown at the winter nursery facility in Puerto Rico. A 1,000-headrow increase will provide enough seed for up to a 20-acre foundation seed field on the Rice Research Station.

Generally, at least three years of CA and URRN data are required before an experimental line is considered as a new variety release. Seed will be increased on superior lines during this same time period so foundation seed is often produced during the third year of testing. If the line consistently has shown superior and stable performance after the third year of advanced testing and adequate foundation seed is available, a comprehensive data package on the line is provided to the director of the Louisiana Agricultural Experiment Station. If, after reviewing the data, the director agrees this is a candidate line for release, a committee is appointed to evaluate the data and make a recommendation on the release. The final decision rests with the director. If the decision is made to release the line as a variety, the director will ask for suggestions and approve the name for the new rice variety. Appendix Table 2 outlines the sequence of events in the development of the rice variety Catahoula as an example of the procedure described above.

Rice variety development is a long-term process that demands a great deal of time, hard work and dedication by a large number of people within the LSU AgCenter. The rice breeding project depends heavily on many cooperating projects for assistance in the development and evaluation of experimental lines. Cooperators include agronomists, entomologists, pathologists, biotechnologists, geneticists, weed scientists, food scientists and physiologists. This cooperation is essential for the success of varietal improvement efforts aimed at numerous characteristics, including but not limited to yield, milling quality, cooking quality, insect resistance, disease resistance, herbicide tolerance, seedling vigor, lodging resistance, fertilizer responsiveness, stress tolerance, earliness and ratooning.

The Rice Breeding and cooperating projects also evaluate potential varietal releases from other breeding projects (both private and public) to determine their adaptability under Louisiana growing conditions. Many rice varieties from out-of-state breeding programs are well adapted to Louisiana and are widely grown.

Rice Variety Characteristics

The two primary grain types grown in Louisiana are long grains and medium grains. Long grains are characterized by a grain length:width ratio of more than 3:1 and typically cook dry and fluffy because of a high- to intermediate-gelatinization temperature characteristic and a relatively high amylose content. Medium grains typically have a length:width ratio of between 2:1 and 3:1 (usually closer to 3:1) and cook soft and sticky because of a low gelatinization temperature characteristic and a relatively low amylose content. Southwest Louisiana producers have historically planted from 20 to 50 percent of rice acreage in medium grains, and those in northeastern Louisiana grow almost exclusively long-grain varieties. Due to market demands, the percentage of the state rice acreage planted to medium grains has continually decreased. In recent years, less than 10 percent of Louisiana rice acreage has been seeded to medium-grain varieties.

Interest in special-purpose varieties has increased in recent years. These varieties have distinctly different cooking attributes, such as aroma, elongation or unique cooking characteristics that may be favored by many ethnic populations living in the United States, as well as other consumers interested in gourmet or premium rice. The major specialty types include soft cooking aromatic Jasmine, flaky cooking elongating and aromatic Basmati, Kokuhoe, waxy, standard long-grain aromatic Della, soft cooking non-aromatic Toro and other less known gourmet types. Most specialty rice marketed in the United States is imported from Thailand, India and Pakistan. The Rice Research Station has been successful in developing and releasing a number of specialty varieties in recent years, including Della, Jasmine, Basmati and Toro types.

Development of Hybrid Varieties

Hybrid rice, produced from the first generation (F_1) of seeds between a cross of two genetically dissimilar pure line (inbred) parents, represents a relatively new option for Louisiana farmers. Commercial hybrids typically yield 10-20% more than the best inbred varieties grown under similar conditions believed to be the result of "hybrid vigor" or "heterosis" from crossing the two parents. The heterosis advantage of hybrids may be expressed by superiority over inbred varieties in grain yield, vigor, panicle size, number of spikelets per panicle, and number of productive tillers. To exploit the benefits of hybrids, farmers normally purchase seed from commercial companies for each cropping season.

Hybrid varieties are generally developed by the "three-line" or the "two-line" breeding method. For the three-line method, the Hybrid Breeding Project generates 200-300 crosses each year for development of cytoplasmic male sterile (A), maintainer (B), and restorer (R) lines used in the production of hybrids. The cytoplasmic male sterile lines do not produce viable pollen; therefore serve as the female parent in hybrid crosses. Because the A line cannot produce viable pollen it must be crossed with another source, the maintainer or B lines to provide A line seed for the future. A and B lines are crossed in an isolation plot to maintain a supply of seed of the A line. Hybrid seeds are produced by crossing an A line with a suitable R line in separate isolated plots. The R line both restores fertility to the seed harvested from the A line and provides desirable traits in the resulting hybrid.

In the two-line method, certain lines, referred to as S lines, can be either male sterile (functionally female) or male (produces viable pollen) depending upon temperature and day length. Under one set of temperature/day length combination, the S lines are crossed as females to fertile inbred lines to produce hybrid seed, while under separate temperature/day length combination, the same lines are allowed to self-pollinate and produce viable seed to maintain a source of the line. Use of S lines in this manner eliminates the need to develop maintainer B lines that are required in the three-line method but requires two different temperature/day length combinations be possible either in the field or in an artificial environment.

To develop and evaluate new A, B, R, and S lines used in producing new hybrids, agronomic and management data are collected from various nurseries and field trials located at university field plots and farmers' fields across Louisiana. The Observational/Testcross nursery evaluates 600-1000 new F_1 hybrid combinations each year at the Rice Research Station in one or more short rows along with three to five inbred and hybrid check varieties. The hybrids and checks are evaluated for grain production, height, maturity, lodging, disease and insect resistance, and milling and appearance traits to identify elite A, B, R, and S lines.

Hybrids that yield 15–20% higher than the check varieties in the Observational/Testcross nursery are advanced to the small-plot Preliminary Yield Trial at the Rice Research Station. Data on agronomic traits, yield, disease and insect resistance, and grain quality are recorded. Outstanding hybrid entries in the Preliminary Yield Trial are also screened for milling and grain appearance and cereal chemistry. Superior lines are then evaluated in Multi-location Yield Trials in five or more parishes across Louisiana. Grain yield and other agronomic data are recorded. To assess adaptation and productivity in Louisiana and other

states, superior hybrids identified from the Multi-location Yield Trials may be entered into the Uniform Regional Rice Nursery (URRN) trials.

For commercial production of hybrid seeds, an A or S line is used as a female and planted in ~ 10 rows bordered by 3 rows of fertile male plants on each side that pollinate the female. These fields must be isolated to avoid pollination from other sources. The female rows are harvested to produce bulk quantities of hybrid seed.

The potential for hybrid rice in Louisiana is good, but there are several challenges, including but not limited to, lodging, maturity, whole-grain milling yields, grain appearance, and shattering (grain retention). The Rice Research Station is currently engaged in breeding research to address these challenges.

For additional updated varietal information, check the Extension Service's publication 2270, "Rice Varieties and Management Tips," which is revised each year.

Foundation Seed Production

Once a variety has been released by the LSU AgCenter, a mechanism is needed to purify, maintain and distribute high quality, genetically pure seed of this variety to the rice industry. Seed certification accomplishes this and provides an operating procedure to guarantee a source of high quality seed to the user. The field and laboratory purity standards for seed rice certification are very strict with regard to varietal mixtures and noxious weeds. In all phases of production, therefore, great care must be exercised to prevent these impurities from contaminating the seed stocks. The foundation seed rice program at the Rice Research Station is the first step in the seed certification process.

A small amount of seed of a new variety is supplied by the breeder to the foundation seed program. Seed harvested from individual rice panicles are grown in separate identifiable rows (one panicle per row) called headrows. This allows the breeder and foundation seed personnel to purify lines and discard mixtures, off-types or outcrosses and maintain identity of potential variety releases. Acceptable headrows are combined in bulk to produce breeder seed, which is maintained by the foundation seed program and used to plant the next stage in the seed certification process. The foundation seed program plants this small amount of breeder seed from which foundation seed is harvested.

Allocation of foundation seed rice in Louisiana is directed by the Louisiana Seed Rice Growers Association. It is allocated to Louisiana producers by a formula based on the previous year's rice acreage in each parish. For example, if the acreage of a parish represents 20 percent of the total rice acreage in the state in that year, 20 percent of the foundation seed of each variety available the following year will be allocated to that parish. After these initial allocations are met in each parish, any remaining seed is offered to producers whose requests were not met initially. If any seed remains after the requests of all Louisiana producers have been met, seed then is sold to out-of-state seed growers.

Grain harvested from foundation seed is certified and sold as registered seed. Registered seed is used to produce the last generation, certified seed. In some instances, certified seed may be produced directly from foundation seed. Certified seed is used by farmers to plant rice crops for milling and cannot be used to produce seed in the seed certification process.

The official seed certifying agency in Louisiana is the Louisiana Department of Agriculture and Forestry. This agency establishes the guides for all aspects of the certification process. All levels of the certification process from breeder seed to certified seed are monitored, inspected and tested by the Louisiana Department of Agriculture and Forestry.