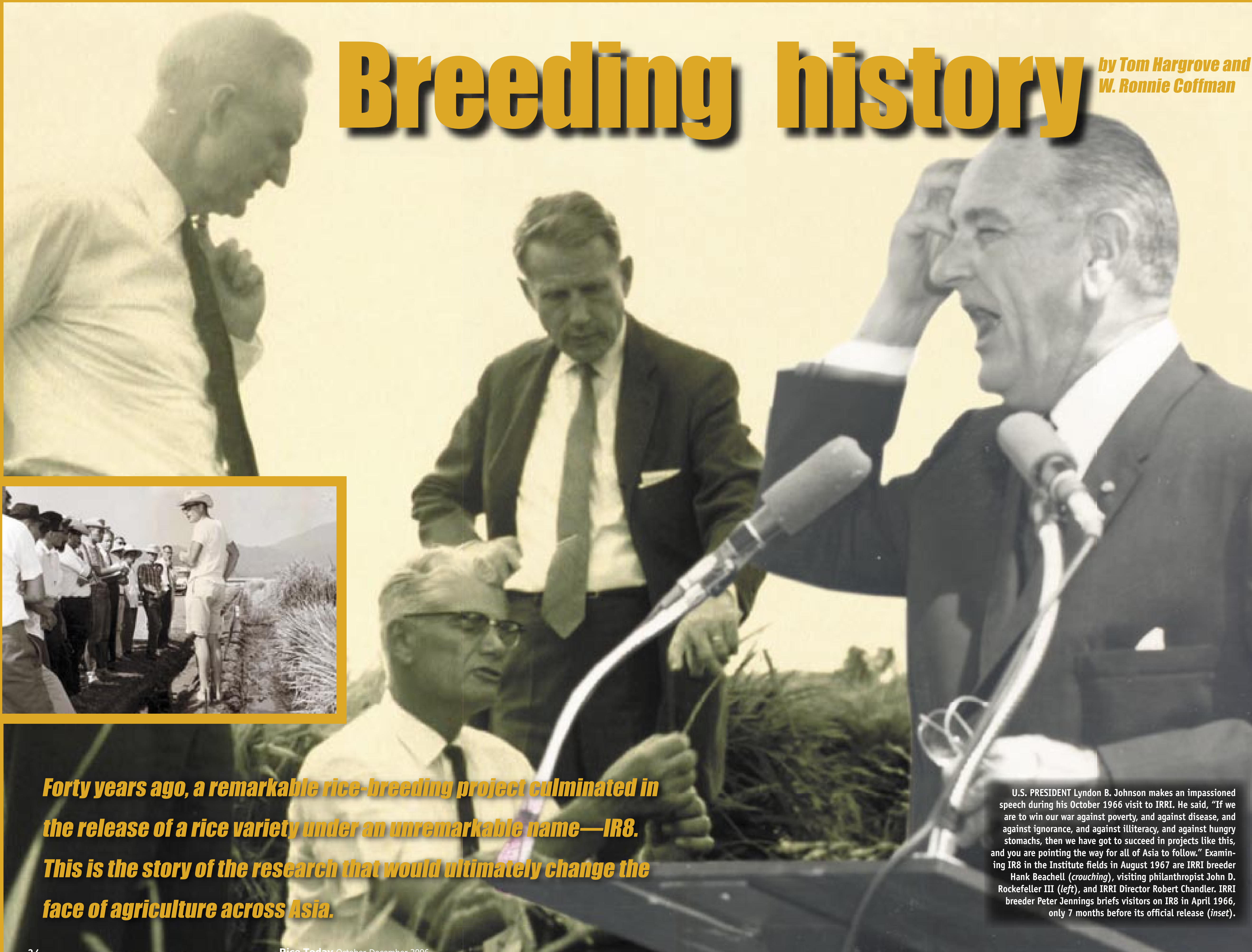
Breeding history

by Tom Hargrove and W. Ronnie Coffman



Forty years ago, a remarkable rice-breeding project culminated in the release of a rice variety under an unremarkable name—IR8. This is the story of the research that would ultimately change the face of agriculture across Asia.

U.S. PRESIDENT Lyndon B. Johnson makes an impassioned speech during his October 1966 visit to IRRI. He said, "If we are to win our war against poverty, and against disease, and against ignorance, and against illiteracy, and against hungry stomachs, then we have got to succeed in projects like this, and you are pointing the way for all of Asia to follow." Examining IR8 in the Institute fields in August 1967 are IRRI breeder Hank Beachell (*crouching*), visiting philanthropist John D. Rockefeller III (*left*), and IRRI Director Robert Chandler. IRRI breeder Peter Jennings briefs visitors on IR8 in April 1966, only 7 months before its official release (*inset*).

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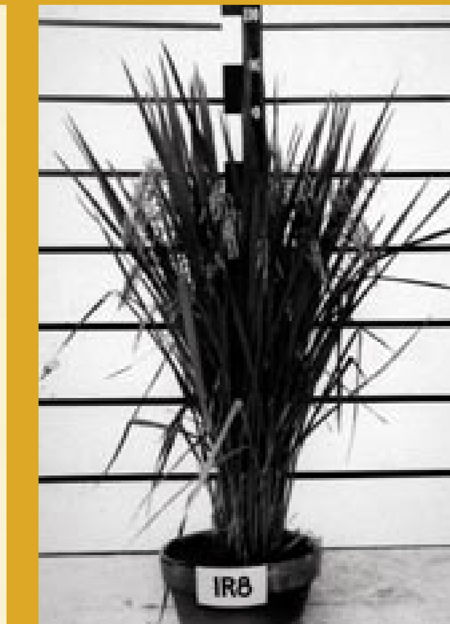

IRRI

Asia was desperate for food after World War II. Only massive shipments of U.S. grain prevented famine.

Rice was, and is, Asia's lifeblood. That's why the Ford and Rockefeller foundations pooled resources and, in 1960, established a modern research center to focus on the world's most important crop: the International Rice Research Institute (IRRI), based in Los Baños, Philippines.

Robert Chandler, IRRI's first director, assembled a team with a mission: to develop a high-yielding rice variety.

IRRI scientists knew that the architecture of the tropical rice plant was the main constraint to yield increases. Traditional rice varieties are tall, with long, weak stems. When a farmer fertilizes a tall plant, it "lodges," or falls over. Photosynthesis ceases, and grain rots in the water, or rats eat it.

A short, nonlodging rice plant that would convert nutrients to grain and hold the panicle (the terminal shoot of the rice plant that produces grain) upright—a dwarf or semidwarf—was needed to accelerate rice production.

IRRI didn't invent the dwarf concept. Scientists had already established it in other crops. Dwarf sorghum was already available. And semidwarf rice varieties

THE TALL Peta variety, one of IR8's parents, towers over its more resilient offspring. Because of its shorter, stouter stature, IR8 was less prone to lodging (falling over), which caused severe yield losses in the taller traditional varieties.

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had already been developed and released in mainland China, largely unknown to the rest of the world.

More significant, in 1946, S.C. Salmon, a geneticist with General Douglas MacArthur's Occupation Army in Japan, had sent seeds of Norin 10, a dwarf wheat variety that he found in a Japanese agricultural experiment station, to Orville Vogel at Washington State University. Within a few years, Dr. Vogel had developed Gaines, a semidwarf wheat variety that spread rapidly across the U.S. Pacific Northwest. Vogel sent seeds with the Norin 10 dwarfing gene to Norman Borlaug of the Rockefeller Foundation wheat program in Mexico. Dr. Borlaug used those seeds to breed semidwarf wheat varieties. The most successful was 8156—given that name for Dr. Borlaug's 8,156th cross. 8156 yielded bountifully and made Mexico self-sufficient in wheat production by the mid-1960s. Seeds of 8156 spread to Pakistan, where it was called "MexiPak," then to Turkey, Iran, and India.

In 1949, the Food and Agriculture Organization of the United Nations established the International Rice Commission, which commissioned an indica-japonica hybridization project based in Cuttack, India. Its mission was to cross the short japonica, or temperate, rice with taller indica, or tropical, varieties, to develop short-statured varieties with higher yield potential. Shorter rice varieties such as ADT 27 and Mahsuri, selected from the japonica × indica crosses, were widely planted across the Indian subcontinent in the 1960s.

Meanwhile, U.S. rice breeders were irradiating seeds of tall U.S. varieties, hoping to induce a short-statured mutant. Among those pioneers were Nelson Jodan of Louisiana State University's rice research center in Crowley, Louisiana, and Henry ("Hank") Beachell of the Texas A&M University rice research center near Beaumont, Texas. But their selections had high sterility and were not successful.

In 1957, the Rockefeller Foundation sent Peter Jennings, a young plant pathologist, to Arkansas, Texas, and Louisiana to learn about rice in order to develop new rice varieties for Latin America. The Rockefeller Foundation then sent Dr. Jennings to Mexico and Colombia.

Dr. Jennings and Sterling Wortman, later to become IRRI's associate director, traveled across Asia in 1960, looking at rice varieties, meeting rice scientists, and interviewing prospective trainees and staff. "Be on the lookout for a dwarf rice," Dr. Beachell recalls advising them. Dr. Beachell visited the fledgling IRRI as a consultant in 1962, then returned to Beaumont.

In India, Drs. Jennings and Wortman encountered Taichung Native 1 (TN1), a Taiwanese variety that was probably the first widely grown semidwarf variety in the tropics. TN1 yielded far better than tall varieties, but was highly susceptible to major disease and insect pests.

Dr. Jennings joined IRRI as head of the Varietal Improvement Department in 1961. Among the germplasm assembled at that time was Dee-geo-woo-gen (DGWG) from China, a parent of TN1, and clearly its source of dwarfism. But at that time the nature of inheritance of DGWG's short stature was unknown.

Dr. Chandler described DGWG as "a high-yielding, heavy-tillering, short-statured variety from Taiwan."

Dr. Jennings and Akiro Tanaka, hired from Japan as IRRI's first plant physiologist, conceptualized the semidwarf rice plant and systematically studied the causes, and effects, of lodging during IRRI's first 3 years. In his 1982 book, *An adventure in applied science: a history of the International Rice Research Institute*, Dr. Chandler wrote about lodging research:

> *By supporting tall varieties such as Peta and MTU-15 with bamboo sticks, Jennings found that tall varieties yielded essentially as well as did lodging-resistant varieties. Moreover, the lodging-susceptible varieties, when supported, responded well to nitrogen applications, whereas the unsupported plants showed a decided negative response. … This proved beyond doubt that lodging per se was the primary cause of low yields when traditional tropical varieties were subjected to modern management methods.*

Dr. Chandler made several references to IRRI's breeding objectives in the first IRRI Annual Report (1961-62). The section "Varietal Improvement" almost gives a blueprint for the

AFTER A BUMPER crop in his first season growing IR8, Indian farmer K.N. Ganesan was so moved by the new variety that he named his second son in its honor—IR-ettu in Tamil, and signed as Irettu. Here, father and son stand in a field of a different variety, IR50, in 1983.

GENE HETTEL

variety, yet to be developed, that several years later would turn rice production on its head:

> *It would seem that the following plant type might be useful in the near future throughout much of the tropics—a combination of short, stiff culms bearing erect, moderately sized, dark-green leaves; responsiveness in yield to fertilizer; mid-season maturity and in most cases, photoperiod sensitivity to permit double cropping practices. These objectives are being pursued […] with both indica by indica and indica by japonica hybridization.*

Not much was known about the genetics of tropical rice varieties at the time, so IRRI hired a geneticist—Te Tzu Chang, from Taiwan—in its first group of scientists. Dr. Chang began studying the inheritance of plant height.

Jennings made 38 crosses in late 1962; 11 of them included the dwarf parent DGWG, TN1, or I-geo-tze (IGT)—another dwarf from Taiwan.

The eighth IRRI cross—from which IR8 was eventually selected—was of Peta, a tall, vigorous variety from Indonesia, and DGWG. From that cross, 130 seeds were formed. Those seeds were planted in pots in IRRI's screenhouse and produced the first, or F_1, generation of plants. All were tall.

Seeds from the F_1 plants were sown in the field, and produced about 10,000 second-generation (F_2) plants that segregated by height in a ratio of three talls to one dwarf. Dr. Jennings immediately recognized this as a Mendelian ratio—named after Gregor Mendel, who became known as the father of genetics for his 19th-century research into the inheritance of traits in pea plants. This was a key result—it meant that dwarfism in DGWG was controlled by a single gene and was therefore simply inherited, making the job of developing a commercially usable semidwarf variety immeasurably easier.

Dr. Jennings immediately brought Drs. Chandler and Wortman to the field to see the segregating plants. He then cabled the good news to Dr. Beachell in Texas. "That's when we knew we had it [meaning that DGWG could be used to breed an improved semidwarf variety]," Dr. Beachell recalled years later.

With this discovery, Dr. Jennings persuaded Drs. Chandler and Wortman to exchange a cytogenetics position in the Varietal Improvement program for a second breeder to help with the increase in field work that would obviously come. They agreed, and Dr. Jennings suggested Dr. Beachell, who arrived in 1963.

Tall, late-maturing plants from the Peta-DGWG cross were discarded, and only short, early-maturing plants were saved. Seeds were "bulked" and planted in a nursery where they could be screened for susceptibility to the rice blast fungus. In 1963, Dr. Jennings departed IRRI for study leave, leaving the material in the hands of newly arrived Dr. Beachell. From the third (F_3) generation, Dr. Beachell selected 298 of the best individual plants. Seeds from each plant were sown as individual "pedigree rows"—the fourth (F_4) generation.

From row 288, a single plant—the third one—was selected and designated IR8-288-3. Its seeds, the F_5 or fifth generation, were grown to produce the basic IR8-288-3 seed stock.

IR8-288-3—which was eventually named as variety IR8—was a semidwarf rice, about 120 cm tall with strong stems that held the plant upright, even when heavily fertilized. It was also nonsensitive to photoperiod, or daylength, scientists would later learn. That meant it could be grown in many latitudes, at any time of the year.

"The seed [of IR8] was uniform enough for trials in other countries, but a couple of years later Dr. Beachell devoted considerable effort to producing an extremely pure strain that would serve as a uniform seed source of IR8 for the future," Dr. Chandler wrote.

Meanwhile, seeds of IR8-288-3 and other promising lines were being sent for testing by national rice programs across Asia.

"IRRI's policy was free access to all of our genetic material," Dr. Beachell said. "It was made available to the world."

In the 1966 dry season, S.K. De Datta, a young Indian agronomist who had joined IRRI in early 1964, examined the fertilizer response of IR8, along with other rice varieties. "We wanted to determine maximum yields under the best management possible," he said.

Dr. De Datta was amazed when he harvested the trials in May. IR8 averaged 9.4 tons per hectare, yielding as high as 10.3 tons per hectare in one trial. Average yields in the Philippines then were about 1 ton per hectare.

Dr. De Datta took his yield data to Dr. Jennings, then to Dr. Beachell. "Let's go see Bob [Chandler]," Dr. Beachell said.

But, at that moment, Dr.

IRRI STAFF load IR8 seeds for distribution to farmers in 1966.

IRRI

Chandler was chairing a seminar—the news would have to wait another hour. After what seemed much longer, Drs. Beachell and De Datta finally saw their director. Sensing the pair's excitement, Dr. Chandler suggested they move to his office.

Dr. De Datta showed his data, and Dr. Chandler was excited.

"The whole world will hear about this," Dr. Chandler said. "We're going to make history!" He then shook hands, congratulating Dr. Beachell for helping develop IR8 and Dr. De Datta for discovering and demonstrating the semidwarf's yield potential.

"The IR8 yield data were the most exciting thing that ever happened to me," Dr. De Datta later recalled.

Soon, similar reports of dramatic yield increases were coming to IRRI from across Asia, including 11-ton harvests in Pakistan.

Dr. De Datta prepared his widely published "yield response" graph, showing how yields of IR8 rose with increased fertilization, while those of traditional varieties actually declined (see figure *above*).

Philippine President Ferdinand Marcos heard about the new rice, and flew to IRRI by helicopter on 3 June 1966. Dr. Jennings and others briefed the president by a plot of IR8 next to Peta, a tall, traditional variety.

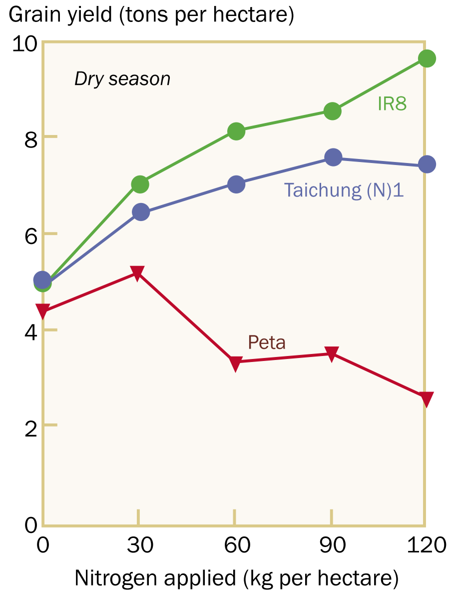
Dr. De Datta recalls President Marcos's reaction: "Do you mean that little rice can out-produce our vigorous Philippine varieties?" the president asked. Dr. De Datta assured him that it could.

"*No kidding*?" Marcos responded.

President Marcos soon ordered that IR8 seeds be multiplied as rapidly as possible. Marcos's goal was to make the Philippines self-sufficient in rice production during his first term of office.

It was. During the last half of 1966 alone, 2,359 Philippine farmers came to IRRI by bus, on bicycle, and on foot, from 48 of the country's 56 provinces, to get seeds.

The new rice yielded bountifully, but had major disadvantages. Foremost was its bold, chalky grain, which distracted from its market appearance as polished rice. The grain also had high breakage during milling. And IR8 had high amylose content, which made it harden after cooling. (Dr. Beachell remembers a young Filipina saying, "I don't like IR8 because it scratches my throat.")



THE RESPONSE TO nitrogen fertizer of two semidwarf rice varieties—IR8 and Taichung Native 1—and of Peta, a tall, traditional variety, in the 1966 dry season on IRRI's experiment farm.

Dr. Beachell recalls the consensus view of the IRRI seed committee: "We needed to move as fast as possible. There was not enough rice to go around. We had to have something to alleviate the rice shortage. Enough rice was more important than grain quality.

"So, would we release the line as a variety, or wait to improve it? We knew IR8's limitations, but also knew we had the plant type. IR8 would be the prototype for future varieties. We decided to spread it."

The seed committee decided to formally name IR8-288-3 as IR8 on 14 November 1966. The news was released on 28 November.

Dr. Chandler later wrote:

> *He [Beachell], Jennings, and Chang made a fine team. When I was asked, some years later, who, among the three senior scientists in the Varietal Improvement Department, should receive the coveted John Scott Award for the creation of IR8, I replied that the prize should be split among the three: Jennings for selecting the parents and making the cross, Beachell for identifying IR8-288-3 from among the multitude of segregating lines, and Chang for having brought to the immediate attention of IRRI breeders at the start the value of the short-statured varieties from Taiwan such as Dee-geo-woo-gen, I-geo-tze, and Taichung Native 1.*

Pioneer rice scientists such as Drs. Jennings, Beachell, Chang, and De Datta, as well as others who played key roles in developing and testing IR8—such as Dr. Tanaka and another plant physiologist, Benito Vergara—proved Dr. Chandler right. IR8, and IRRI, did indeed "make history." IR8 changed the world food situation and initiated what is now called the Green Revolution in rice.

IR8 PICTURED next to its parents: Peta, a tall, vigorous variety from Indonesia, and the Taiwanese dwarf variety DGWG.

IRRI

Tom Hargrove, a former IRRI editor, is now coordinator, Information and Communications Unit at IFDC, an International Center for Soil Fertility and Agricultural Development in Alabama, USA (Tomhar66@swbell.net).

W. Ronnie Coffman, a former IRRI rice breeder, is now international professor of plant breeding and director of international programs, College of Agriculture and Life Sciences at Cornell University in New York, USA.