Dwarf Rice—a Giant in Tropical Asia

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Rice is an ancient crop, its cultivation dating back more than 4,000 years. But the most significant rice improvement of all time took place during the past 5 years in tropical Asia. And this breakthrough may influence the well-being of mankind throughout the rice-growing world, especially the tropics.

Locale of our story is the Philippines, at the International Rice Research Institute, established and supported by the Ford and Rockefeller Foundations. Let me give you some background first.

When modern methods of rice production are applied to tropical rice, results are discouraging. Use of adequate fertilizer—especially nitrogen—and adoption of good weed, insect, and water control practices cause these tropical rice varieties to grow excessively tall, to produce extra-long, drooping leaves, and to lodge or fall over. The stark facts of the case are that the average rice yield in Southeast Asia is only about 1,400 pounds an acre, compared with Japan's average of 4,400 pounds.

From evidence accumulated in Japan, Taiwan, the United States, and elsewhere, we know a key factor in obtaining high yields is that the rice plant must remain erect until harvest. Indeed, there is a direct relationship between grain yield and the number of days before harvest that a rice plant lodges. The earlier the lodging, the lower the yield.

This knowledge led plant breeders at the International Rice Research Institute to seek to develop short and stiff-strawed varieties, with relatively narrow, upright leaves—plants that would resist lodging even when heavily fertilized and intensely managed.

To do this, good men were needed and luckily were at hand. The Institute's first plant breeder was Dr. Peter R. Jennings, who had served as a rice specialist in the Rockefeller Foundation's Colombian Agricultural Program. Dr. T. T. Chang, formerly with the Joint Commission for Rural Reconstruction in Taiwan, became the Institute's geneticist. And Henry M. Beachell, who for over 30 years had served the U.S. Department of Agriculture as a rice breeder at the Texas Rice-Pasture Experiment Station in Beaumont, came to play a vital role in developing the new varieties. A consultant to the Institute for 1 month in 1962, when the breeding program was being mapped out, Beachell permanently joined the Institute in 1963.

Chang, especially familiar with the rice improvement program in Taiwan, suggested that several semidwarf *indica* varieties from Taiwan might be excellent sources of short stature. Accordingly, three varieties, Dee-geo-woo-

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gen, I-geo-tze, and Taichung (native) 1, were used extensively to develop short, stiff-strawed varieties. They were crossed with such tall, vigorous, heavy-tillering (able to produce many stems on a single plant), disease-resistant tropical varieties as Peta and Sigadis from Indonesia, H-4 from Ceylon, and BPI-76 from the Philippines.

During 1962, Jennings and his colleagues made 38 crosses, 11 of them involving either Dee-geo-woo-gen or I-geo-tze as one of the parents. Other crosses were largely between tall tropical *indica* varieties and the so-called Ponlai varieties from Taiwan, which are actually *japonica* varieties developed for the tropics and subtropics.

Several crosses made in 1962 were successful; others were soon discarded because of such inferior characteristics as disease susceptibility and poor plant type. The eighth cross, however, proved exceptional. From it came a variety, now named IR8, which has opened new vistas to rice yields and has given added hope for food sufficiency to the vast number of Asians who are dependent upon rice for their staple food.

This dramatically different rice plant was obtained by crossing Peta, a tall Indonesian variety that has disease resistance, heavy-tillering ability, seedling vigor, and seed dormancy, with Dee-geo-woo-gen, a short-statured Chinese variety. Of about 10,000 plants grown in each of the second and third generations, only a few hundred were retained for further testing. In the fourth generation, plant No. 3 in row 288 was among those selected out and was appropriately designated IR8-288-3.

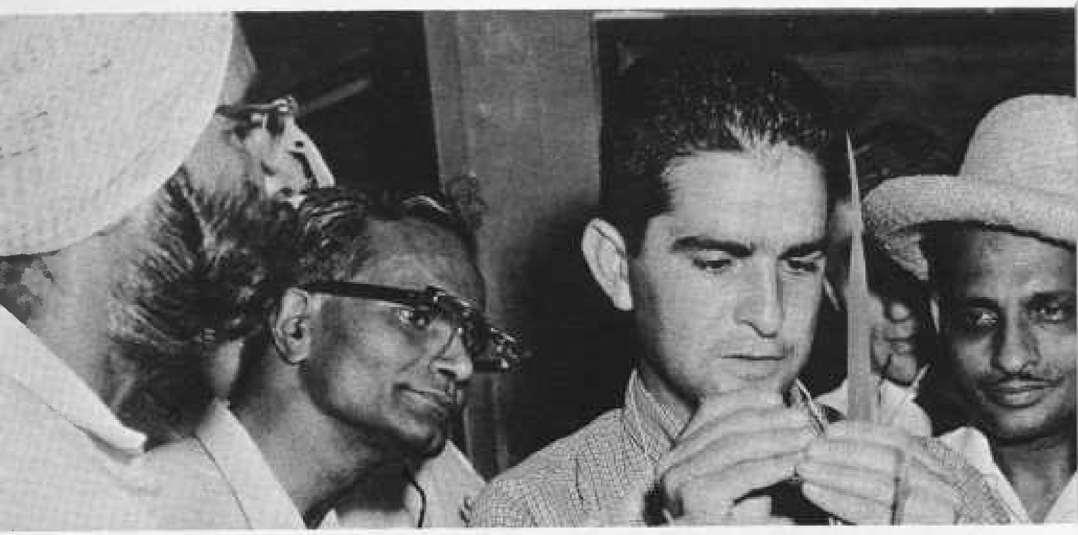
After further purification in the fifth and sixth generations, IR8-288-3 was planted in its first yield trial. This was in March 1965, less than 3 years from the date the cross was made. In July, it surprisingly produced a computed yield of about 6,000 pounds an acre. In the cloudy monsoon season in the humid tropics when plant performance is seriously limited by insufficient solar radiation, a yield of that magnitude is excellent. Later, we found that in the dry season and under high-level management, this strain could produce over 9,000 pounds an acre and would regularly yield between 6,000 and 8,000 pounds.

Moreover, we soon learned that high yield records for the new variety were being established not only in the Philippines and Southeast Asia, but in Latin America and Africa as well. Widespread adoption of this promising new rice plant seemed assured. In recognition of its general acceptance, the International Rice Research Institute, in November 1966, announced that henceforth IR8-288-3 would be known simply as IR8.

How can a new rice variety, tailored to predetermined specifications, be created so quickly? Fortunately, the short stature of Dee-geo-woo-gen is simply inherited and can easily be incorporated into the progeny of any cross. More specifically, in this Chinese variety shortness is a simple recessive characteristic. Thus, in accordance with Mendelian laws of heredity, in the second generation, one-fourth of the plants were short and three-fourths were tall. Very quickly, therefore, a large population of short plants was obtained, from which the IR8 variety could be selected.

The importance of Dee-geo-woo-gen (and of the other Chinese dwarf varieties) is comparable with that of the introduction into the United States after World War II of the Japanese wheat variety, Norin 10. That out of Asia came the dwarfing genes which drastically changed the yield potential of the world's two most important food grains is a dramatic coincidence.

Although we don't know the absolute origin of Dee-geo-woo-gen, we assume the original variety was brought to Taiwan from mainland China before the Japanese occupation. There is no clue to whether the short-stature mutation occurred in China or Taiwan. Probably, it appeared as a natural mutation and was selected by some enterprising Chinese or Taiwanese



Mexican research student demonstrates a cross-pollination method to officials from India visiting the International Rice Research Institute.

farmer before the turn of the century. (Dee-geo-woo-gen translates to "short legged, brown tipped," and is the sort of local descriptive name commonly used by Chinese farmers.)

If this variety was so outstanding, why had it not been used before? First of all, in Taiwan the Japanese—who preferred *japonica* rice to *indica*—concentrated their breeding efforts on development of the Ponlai types. Secondly, such low amounts of nitrogen were applied to farmers' fields and experimental plots that yields from Dee-geo-woo-gen were never exceptionally high. Happily, though, the Taiwan Agricultural Research Institute in Taipei kept the variety in its collection for many years and thus saved it for our use today. And the Chinese were the first to use it, Dee-geo-woo-gen being one of the parents of Taichung (native) 1, the first improved local variety in Taiwan.

With these genetic developments, there now are available types of rice that not only have a higher yield potential than ever before, but which respond positively to the improved cultural practices man can furnish. The IR8 variety shows a dramatic and continuous yield response to fertilization with nitrogen, even up to a total of 120 pounds of nitrogen per acre. Tall, tropical varieties, on the other hand, respond only to about the first 30 pounds of nitrogen, while higher amounts cause decreases in yield. This is mainly why fertilizers have not been widely used on rice in the tropics, and yields remained so low.

In contrast, IR8—which has been tried extensively on all important experimental fields in Southeast Asia—nowhere has failed to establish new yield records, usually about double those attained before. Where 4,000 pounds per acre used to be considered an exceptional rice yield, it now takes 8,000 to arouse much notice.

To make possible such dramatic increases in yield, breeders shortened the plant from the traditional height of about 180 centimeters to an astonishingly low height of 100 centimeters (39 in.). They made the leaves short and upright, so water would run off quickly and sunlight would penetrate to the lower leavcs. They retained the high tillering capacity of the tall tropical varieties, insuring that many panicles (heads of grain) would be formed on each of the plants.

Still not content, the breeders introduced into the short upright plants sufficient disease resistance to enable them to compete well with other varieties. They produced varieties with not only short straw but stiff straw, accomplishing this by selecting plants with thick stems and with leaf sheaths well wrapped around the stem.

The plants, therefore, were doubly protected against the ravages of heavy rains and winds, common hazards in the tropics.

Because of their short upright structure, the new varieties make such efficient use of energy from the sun that significantly more photosynthesis occurs between flowering and harvest (a period of only 30 days in the tropics), thereby greatly adding to grain yield. In the process of drastically changing the architecture of the rice plant, the grain-straw ratio has been increased from about 0.6 to 1.2. This means more than half the dry matter is in the form of grain. Lastly, the new varieties are earlier maturing and photoperiod insensitive, thus making it possible to plant them at any time in the tropics and, where year-round irrigation is available, to plant as many as three crops annually. Photoperiod insensitive means they flower in a given number of days after planting, regardless of the length of day and hence the latitude at which grown.

As soon as IR8 was discovered among the many thousands of genetic lines at the Institute, seed was sent to other countries for testing. In every tropical area where it was planted, the variety has shown exceptional promise. In the Philippines, in July 1966, almost every blade of IR8 was grown on experimental fields of the Institute or the adjacent College of Agriculture of the University of the Philippines. A year later to the month, it was estimated 100,000 acres were planted to the variety. It is believed that in India, over a million acres had been planted to IR8 by mid-1968. In Malaysia, the area planted was 30,000 acres in 1967. Pakistan, also, is moving ahead rapidly with the new variety. In all these countries, IR8—along with several similar new creations—is essentially doubling yields of farmers' fields.

How quickly Asia will become self-sufficient in rice remains to be seen, but the future looks brighter than ever before. Now at last the tropical rice farmer, too often struggling at a bare subsistence level, can apply fertilizers and insecticides with assurance that yield increases will more than offset costs. Although he may need twice as much money to grow the new variety, his income will at least triple.

Many agronomists estimate the average rice yield in Southeast Asia will double in the next 10 years. This 100 percent rise, formerly undreamed of, is imperative if food production is to keep pace with the population spiral.

In Asia, where rice is king, probably no single factor is more important in promoting peace and order than the rice supply. IR8 is the first giant step toward a full rice bowl for Asians.

Graph showing grain yield response to nitrogen of three typical tall, tropical rice varieties, and that of IR8, a new short, stiff-strawed variety. Data, obtained at Los Banos, the Philippines, represent average yields during the dry, sunny seasons of 1966 and 1967.