Crossing Rice Strains to Keep Asia's Rice Bowls Brimming

BEIJING, CHINA—While plant breeders in most of the world fear that grain yields are plateauing (see main text), Yuan Longping thinks a big jump in rice productivity is just around the corner. Yuan, the director of the National Hybrid Rice Research and Development Center in Changsha, Hunan Province, says he is on the verge of creating a superhigh-yield hybrid that promises jumps of 15% to 20% in potential rice yields over existing hybrids.

Yuan cautions that the results are based on tiny test plots and must be confirmed in larger trials over the next 2 years. Even if the new strain does live up to expectations, say other plant breeders, consumers may turn up their noses at the quality of the rice. But scientists who have heard his preliminary results think Yuan is on to something big. "When I hear Yuan Longping's enthusiasm about this and when I think about his track record, I take note of what he's saying," says Neil Rutger, director of the Dale Bumpers National Rice Research Center in Stuttgart, Arkansas. "If [the yields are] what he claims, it is a significant achievement," adds Sant Virmani, deputy head of plant breeding at the International Rice Research Institute in Los Baños, the Philippines.

Yuan's efforts make use of the fact that the first generation of hybrid plants is typically more vigorous and productive than either parent—a poorly understood phenomenon called heterosis. To take advantage of heterosis, virtually all the maize in developed countries is grown from first-generation (F1) hybrid seed. But corn is much easier to hybridize than rice. Because rice is self-pollinating, getting hybrid seed requires developing lines of plants in which the male organs are sterile and can only be pollinated by the other parental line. A third line of plants is required to provide pollen to reproduce the male-sterile line for the next growing season. The technique is not only laborious but also produces small quantities of seed. As a result, hybrid rice in most countries has taken a back seat to inbred rice, in which part of one year's crop can be kept as seed for the next.

Not in China, however. In the 1970s, Yuan made production of F1 hybrid rice seed viable with techniques that tapped his country's cheap labor. He sprayed the male-sterile plants with a growth hormone so that the panicles, or grain clusters, would emerge from the rice leaf sheath to catch pollen that was shaken loose by ropes dragged over the male-line plants. Hybrid rice now accounts for half of China's rice acreage and yields an average of 6.8 tons per hectare compared with 5.2 tons for conventional rice. By Rutger's calculation, the increased output feeds an additional 100 million Chinese every year.

China's success has inspired hybrid rice production in India, Vietnam, and the Philippines. Several more countries are developing hybrid rice varieties suited to their own growing conditions. But even higher yields will be needed to meet Asia's projected food demand.

To Yuan, the answer was to cross more diverse parent strains in order to achieve even greater heterosis and higher yields. Unfortunately, the more diverse the parents, the greater the chance that the offspring will be sterile, growing vigorously but producing little rice. But in the mid-1980s, Hiroshi Ikehashi, a plant breeder at Kyoto University in Japan, identified a gene in certain species of japonica rice native to Indonesia that promotes fertility in hybrids. This wide compatibility gene, which has proven relatively easy to transfer through crossbreeding, was the breakthrough Yuan needed.

Rather than count on heterosis alone to raise yields, however, Yuan also decided to incorporate morphological improvements. Since 1996, his group has selectively bred potential parents for long, narrow, and very erect top leaves. This configuration, Yuan believes, captures sunlight more effectively. He's also bred plants to grow large panicles that hang close to the ground, reducing the risk of lodging, or falling over. "Both hybridization and morphological improvements are important," Yuan says. "I don't think you can rely on just one or the other."

Hybrid vigor. Chinese rice breeders hope this cross between strains having narrow, erect leaves will push up yields.

In 1997, one of the crosses yielded an average of over 13 tons per hectare—well above the 10.5 tons for existing hybrids grown under ideal conditions. Although that test took place on just a fraction of a hectare, the group achieved similar results last summer in trials at four separate locations totaling more than 2 hectares. If he can get 12 tons per hectare for two consecutive years, Yuan says, "I will declare that the goal of the superhybrid rice-breeding program is achieved." He is so confident of success that he invited participants at an international conference in Cairo last fall to visit China and witness this year's harvest.

But yields aren't everything. "The value of superhybrids will very much depend on the grain quality," warns Miroslaw Maluszynski, a plant geneticist at the International Atomic Energy Agency in Vienna, Austria. Yuan agrees that hybrid rice became popular in China because people "needed calories more than quality." And quality is still critical in more affluent nations such as Japan and South Korea. "Where quality is important, hybrid rice won't sell," says Shigemi Akita, a crop physiologist at the University of Tokyo.

Still, Yuan and others are confident that hybrids will play an increasingly important role in filling Asia's rice bowls. Studies of heterosis "are still at a juvenile stage," he says. "The very high-yield potential of hybrid rice has not yet been fully tapped." **–DENNIS NORMILE**

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mon pest. "The tillers are strong but not tough," IRRI's Sheehy says. "Borers chew right through them, which poses a genuine research problem." Although he believes the new plant type will eventually be "vindicated," its progress is a sobering reminder of the difficulties of raising yield.

"We've been working on rice yields for so many years without making the kind of progress we'd like to make," Peng says. "We may be able to create the new plant type without biotech, but that is where new opportunities will have to come from in the future."

Big biotech

Peng and the other agronomists who regard genetic engineering as the key to surpassing the yield barrier have more in mind than the products of today's biotech industry, which now cover almost 20 million ha in North America alone. The vast majority of these crops are the result of single-gene transfers, in which one or more genes coding for desired characteristics—such as herbicide resistance or an antibacterial compound—are smuggled into the organism from an outside source. Such efforts, although important to raising actual yields, are unlikely to raise potential yields. To break yield barriers, the plants will have to be thoroughly re-engineered.