"Aerobic" Rice: Preparing For a Water Crisis

Scientists at IRRI have begun the task of creating a high-yielding tropical rice plant that grows on dry but irrigated land instead of in flooded paddies. They have dubbed the new plant "aerobic rice" and given themselves five years to complete its development. But they face formidable challenges, including inexplicable "yield collapse."

The project is driven by the knowledge that water resources for agriculture are shrinking, as supplies are increasingly diverted to big cities for domestic or industrial use. Traditional rice cultivation requires that fields remain flooded for four to five months for every crop, and water losses through percolation into the soil, evaporation, and seepage are substantial.

IRRI has formed an Aerobic Rice Working Group, involving plant breeders, plant physiologists, and water and soil scientists, to meet the many difficulties of taking rice out of its natural environment and developing a complete management system for dryland crops using perhaps only half the water. Although rice varieties that grow in dry upland fields already exist, they cannot match the yield potential of conventional commercial varieties, nor do they respond to irrigation or fertilizers.

"We've got a long way to go," says water scientist Dr. Bas Bouman. "First of all, our plant breeders must come up with tropical varieties that grow in dry soil. Then we've got to understand the problem of yield collapse. After that, it's a matter of working out crop management: How much water does the crop need? How do we control weeds? And what nutrients does the crop need?"

The project has begun quickly, by studying aerobic varieties developed in northern China and Brazil. These were developed for subtropical and temperate climates, so the early aim is to test their adaptability to the tropics. They're being grown experimentally in China and the Philippines and will soon be grown in India, where water shortages are becoming a serious problem. Meanwhile, IRRI's plant breeders are working with many other rice varieties, selecting those that exhibit different reactions to drought, soil quality, and environmental conditions.

"We already have upland rice varieties that can withstand drought, but they're low yielders and they don't respond to fertilizer inputs," says water management engineer Dr. To Phuc Tuong. "Our aerobic rice must be able to withstand dry soil, respond to irrigation and to fertilizers, and deliver a high yield."

Another big problem is weeds. Normally, they're suppressed by flooding, but on dry land rice can easily lose the battle for dominance. So the working group expects weed tolerance to be a big issue.

But these problems may fade into insignificance alongside yield collapse.

In experimental dryland rice crops grown to date, the harvest is good in the first season but drops by about 20 percent in the second and may fall a further 70 percent in the third. Thereafter, plants don't develop properly, grow enough tillers, or set grain. Nobody knows why this happens, much less has an inkling of how it can be overcome.

Yield collapse doesn't occur when rice is rotated with other crops. This is how aerobic rice continues to play an important role in Brazil, where it is grown commercially under irrigation on 250,000 hectares. But IRRI plant physiologist Dr. Renee Lafitte, who is a member of the Aerobic Rice Working Group, believes that yield collapse may be a fundamental obstacle to the development of aerobic rice as a permanent, intensive crop.

"It's not simply a matter of finding the correct germplasm for new varieties that will be free of yield collapse," she points out. "I believe it's a problem of the agricultural system in which these plants are grown."

Dr. Lafitte says that among the areas that might benefit most from the development of aerobic rice is eastern India, where seven million hectares are devoted to annual crops of upland, or dry, rice. In this area, farmers who grow nothing but rice can't achieve harvests better than one ton per hectare, no matter how they try to improve their productivity.

"I believe that these low yields are actually a situation of yield collapse, and we should begin our efforts to develop aerobic rice by investigating what is happening in eastern India," she adds.

In another example, farmers in Mindanao, in the Philippines, were given a new upland variety to replace low-yielding local varieties. Many enthusiastically adopted the new variety in the first few years, and their yields grew, in some cases fourfold. Then, suddenly, they abandoned the new variety, reverting to the old ones. When asked why, they said the new variety had "broken down." This, Dr. Lafitte believes, was yield collapse.

"In some cases," she continues, "there were buildups of microscopic worms called nematodes in the soil that may explain the yield collapse. But we also see the same yield reductions in fields with no nematode problem.

"In situations where rice is grown in rotation with other crops, the problem doesn't seem to exist. So, do we need some kind of insistence upon farmers rotating their crops?"

Dr. Lafitte says that her work "at the border of plant breeding" will include intensive studies of the rice plant itself.

"Water shortages are going to become a major issue in the future," she says. "So we need to know what it is about the physiology of the rice plant that makes it demand so much water, and what it is that makes it so sensitive to fluctuations in water supply."

The imminent need for rice farmers to save water has already led to trials involving a variety of irrigation regimes and seeding techniques.

Dr. Tuong says that one technique practiced in China as an alternative to permanent flooding of rice fields involves flooding to five centimeters in depth every few days and allowing the water to recede before the next flooding. He says that conventional rice yields do not suffer under this method, and the crop uses 10 to 20 percent less water.

But aerobic rice is another thing altogether. One of the first tasks facing the working group is a geographic one. The researchers are mapping the areas where they believe their aerobic rice should be grown.

"Obviously, we'll target areas with water scarcity first, places such as northern China and some parts of India," Dr. Tuong explains. "But think of the Philippines, for instance. The dry season has only enough water to grow rice on half of the irrigated land. With aerobic rice, we could encourage farmers to make better use of their land and produce more food.

"If there is no need to flood fields, the benefits will not end with a savings in water. There will be much less effect on the environment. Water percolation from traditional flooded rice fields raises the groundwater table and can create salinity problems. If rice is grown in dry soil, much less percolation will occur."