A New Plant for a Changed Climate

IRRI has been urged to direct its research efforts toward the creation of a new rice plant capable of thriving and producing heavier crops in a world changed by global warming.

It will be a world with higher temperatures, with more carbon dioxide and pollutants in the air, and where extremes of weather are commonplace. Less water will be available to agriculture, so the new plants will have to use less. And, because poor management of nutrients over vast tracts of rice land risks making the climate even worse, the new plants will have to use nitrogenous nutrients very efficiently.

The Institute's plant breeders have already created a new plant type in a scientific effort that has so far taken nearly 12 years' work *(see* Green Revolution Hero Bows Out*, page 42)*. It has been designed to boost the potential rice yield in the tropics, from the current 10 tons to 12 tons per hectare, as a first step toward meeting the huge additional demand for rice that will follow population increases over the next few decades. It is expected to be released in about four years. But already the Institute's biotechnicians and plant breeders have been urged to begin again, this time on a more challenging path: the creation of a more environmentally friendly rice plant that uses sunlight more efficiently to grow and produce grain.

According to IRRI crop ecologist and modeler Dr. John Sheehy, rice plants are less efficient in their use of solar energy than some other crops, such as maize. He contends that because of this there is a biophysical limit to the amount of grain a rice plant can yield.

"It is often suggested that continuation of existing trends in cereal yield will be sufficient to meet future demands for food," he says. "However, the linear trend of the past 30 years can be extrapolated only if there are no foreseeable limits to yield, and limits do exist."

He says that the potential yield is a theoretical figure never achieved on the farm. The best farmers can reach is about 80 percent of the figure, so the present practical maximum yield for rice with a 110-day growth period grown on ordinary farms in the tropics is 8 tons per hectare. With the introduction of new cultivars and improvements in agronomy, the maximum limit on the farm may be raised to 9.6 tons per hectare. But this, he says, will be the absolute limit.

"The current technology is going to run out of steam in about ten to 15 years. Present rice plants will be unable to convert any more solar energy into biomass and grain. They will have reached their limit."

Dr. Sheehy takes this scenario and places it alongside predictions of future conditions for rice farming and estimates of future demand.

"The population of Asia is expected to increase by 44 percent in the next 50 years," he says. "At present, more than half the people in Southeast Asia have a calorie intake inadequate for an active life, and ten million children die annually from diseases related to malnutrition. Yet simply to maintain our present per capita consumption, we will need 44 percent more rice within 50 years. The area for rice cultivation is continually being reduced by expansion of cities and industries, to say nothing of soil degradation. So we will need rice plants to deliver maybe 50 or 55 percent more."

Dr. Sheehy points out that more efficient farmers will soon reach the yield limit, and the job of filling future needs will depend upon the less efficient farmers lifting their productivity. This prospect, he says, casts a dark shadow over future food security.

"We're trying to improve yields against a background of climate change and increasing competition for resources such as land and water. If, by using all the tools available to modern biotechnology, we can create a new plant that addresses many of these problems, then we should be doing it."

He recalls that, in the past, higher yields have depended on increased use of organic and inorganic fertilizers to supply nitrogen to the plants. But this, he says, no longer represents the way forward because the use of organic fertilizer often stimulates the emission of methane and inorganic nitrogen fertilizers can stimulate the emission of nitrous oxide. Along with carbon dioxide, these are the two most damaging greenhouse gases and any proposal to boost rice production simply by increasing fertilizer use would risk making the world's climate even worse.

Dr. Sheehy believes, along with a growing body of scientific opinion, that the only way to achieve the rice harvests needed for the future is to change the biophysical structure of the rice plant, making it a much more efficient user of energy from the sun. Plants use solar radiation to grow—to develop leaves, roots, stems, flowers, and seeds in a process known as photosynthesis.

Rice has what is known as a C_3 photosynthetic pathway, less efficient than that of maize, which has a C_4 pathway. Converting a plant from C_3 to C_4 would involve a rearrangement of cellular structures within the leaves and more efficient expression of various enzymes related to the photosynthetic process.

"All the components for C_4 photosynthesis already exist in the rice plant," Dr. Sheehy says, "but they're just distributed differently and are not as active."

He believes that a significant part of IRRI's biotechnology and functional genomics programs should be targeted specifically at the conversion of rice to a C_4 photosynthetic pathway. Work should also begin on screening likely candidates in the more than 100,000 germplasm samples held in the International Rice Genebank for varieties that lean toward a C_4 anatomy, or that have greater enzyme efficiency.

Dr. Sheehy believes that current trends leave about 15 years in which to invent a C_4 rice, and that IRRI should be encouraging the formation of an international partnership to use all available biological tools to achieve it within that time frame.

"Plants with a C_4 photosynthetic pathway are better equipped to cope with the climate changes that are expected as a consequence of global warming," he says. "They operate well at high temperature, they're extremely water-efficient, and they require less nitrogen.

"This is the single most important change that can be made to rice, and there's no doubt that, eventually, it will happen. If IRRI doesn't do this, and others succeed, then people will be asking, 'Where were you guys?'"