



their income on rice alone. Consequently, as prices drop, the food security of the poor improves.

The favorable irrigated environment will remain the major source of rice supply to the rural landless and an expanding urban population. As populations increase, this demand will grow. We need to sustain the high yields already achieved in this ecosystem and, with modern science, explore possibili-

ties of a further increase in yield potential. The challenge, however, is greater than simply feeding more mouths. As populations grow, the irrigated rice production system intensifies, placing increasing pressure on limited natural resources that are, in many cases, already overexploited. A looming water crisis—fueled by increased competition from the domestic and industrial sectors as well as the constant scourge of drought—means that, in many countries, we will not have the option to increase the area under high-yielding modern rice varieties by further developing irrigation infrastructure. Farmers will need to grow more rice

with less water and learn how to operate irrigation systems more efficiently. We also need to continue our development of technologies that help maintain soil fertility and manage pests.

On top of all this, rising living standards in most of Asia are accelerating demand for high-quality rice. Not only do we need varieties with higher yield potential, multiple resistance to diseases and insects, and tolerance of problem soils, but we also need rice with superior grain quality and higher micronutrient content. Micronutrient deficiencies, especially of iron, zinc, and vitamin A, afflict millions of poor Asians—people who receive most of their nutrition from rice and who stand to benefit from consuming more nutritious rice.

PROJECT 3

3 Genetic enhancement for yield, grain quality, and stress resistance

As population growth continues to boost demand for rice, production growth in the irrigated ecosystem is approaching a plateau. In this favorable ecosystem, which produces 75% of the world's rice, IRRI is continuing its effort to increase and sustain rice productivity. Meanwhile, the irrigated rice area is shrinking, irrigation water is being diverted for other uses, agricultural labor is moving to industry, and concern is rising about the misuse of pesticides and inefficient use of fertilizers. Taken together, these developments mean that farmers will need to produce more rice using less land, water, labor, and chemical support. As well as increasing

rice production, there is a growing need to improve grain quality and nutrition and so alleviate the “hidden hunger” of micronutrient deficiency that afflicts millions of poor people across the rice-consuming world.

This project uses conventional breeding and biotechnological approaches to develop new plant type cultivars and rice hybrids with 15–20% higher yield than existing high-yielding varieties. IRRI researchers are also exploring opportunities for developing even higher yielding rice cultivars and hybrids. We use conventional breeding and techniques, such as wide hybridization (crossing modern rice varieties

with their wild relatives, for example) and marker-assisted selection, as well as genetic engineering to improve rice varieties' pest resistance. Conventional breeding and genetic engineering are also used to enhance the palatability and nutrition of rice varieties, including higher content of micronutrients such as iron, zinc, and provitamin A (needed by the body to synthesize vitamin A).

As well as developing high-yielding rice varieties and hybrids that combine desirable features, we develop suitable agronomic management practices for new plant types and hybrids to optimize their performance in farmers' fields.

Output 1: Germplasm possessing high yield, multiple resistance, and superior grain quality developed

In 2005, we identified many genetic donors suitable for direct seeding and for growing under alternate wetting-and-drying irrigation conditions. These were used in breeding programs to develop elite lines suitable for these crop management strategies.

Following testing of transplanting, spacing, rate, and timing of nitrogen (N) application, and irrigation depth for a new plant type line in the 2005 dry season, agronomic management guidelines for new plant type cultivars were developed and will be evaluated in collaboration with national agricultural research and extension systems (NARES). Breeding efforts for yield improvement of new plant type lines are

continuing. This will be followed by the development of appropriate management practices to realize the production potential of improved germplasm in farmers' fields.

Lines derived from crosses of cultivated rice (*Oryza sativa*) with wild species (*O. longistaminata*) with increased tolerance of stem borer have been identified. Field evaluation of these lines will be carried out to determine the stability of the resistance. We have identified donor parents with increased resistance to sheath blight. This offers new opportunities to develop improved germplasm and understand the mechanism of sheath blight resistance.

Genes that have the potential to confer resistance to brown planthopper, bacterial blight, and tungro are being tagged for use in marker-assisted selection, a technique that allows researchers

to rapidly search for candidate plants that possess a resistance gene.

Elite rice lines possessing the Xa21 gene (which confers resistance to bacterial blight) or the Bt gene (which confers resistance to stem borer)—were developed through genetic transformation. We field-tested variety IR72, which carries Xa21, at IRRI during the wet season.

In our work for the HarvestPlus initiative—a multi-institute program to develop nutritionally enhanced crops—we have identified donor lines for high iron and zinc content in polished rice grains, and a breeding program has begun.

In 2005, we analyzed grain quality, consumer preferences, and blast resistance of elite temperate japonica lines adapted to the tropics. We now expect that, through our Philippine research



and extension partners, the area of japonica cultivation in Bohol, Philippines, will be expanded. One indica introgression line carrying genes from *O. australiensis* has been identified as a new source for blast resistance for temperate japonica, and the resistance gene has been mapped on chromosome 6.

We have begun research to characterize genotypes for the rice plant's leaf arrangement and how that arrangement interacts with sunlight and consequently affects grain yield. Another new activity in 2005 was the characterization of brown planthopper (BPH) populations for gene deployment—that is, the cultivation of varieties possessing specific genes for resistance to different BPH populations. We analyzed variation in BPH populations and will study the genetic structure of different populations in an effort to deploy resistant rice varieties.

Output 2: Rice hybrids developed that possess stronger heterosis, improved grain quality, and multiple resistance to diseases and insects

In 2005, IRRI developed several elite hybrid rice lines that possessed good grain quality, and shared these with NARES. Four elite hybrids are being tested in the national cooperative trials—these were the top three entries in trials of about 20 hybrids bred by both private and public institutions conducted during the previous seasons by the Philippine Rice Research Institute (PhilRice). We are analyzing causes of chalkiness with emphasis on starch structure; overcoming chalkiness would lead to better grain quality. Next, the genetics of chalkiness will be studied in collaboration with China and other NARES.

Elite two-line hybrids were developed using the thermosensitive genetic male sterility (TGMS) system and three



elite hybrids are under evaluation in the 2005 International Rice Hybrid Observational Nursery by the International Network for Genetic Evaluation of Rice (INGER).

We developed several cytoplasmic male sterile (CMS) lines possessing higher outcrossing (meaning that it is easier to produce more hybrid seed from these lines). Consequently, a large number of hybrids that were derived from the CMS lines and that possessed improved grain quality were subjected to preliminary replicated yield trials. Transgenic CMS lines possessing the Xa21 gene or the Bt gene have also been developed.

We identified several elite hybrids suitable for growing in a water-saving alternate wetting-and-drying irrigation system. This activity has now been transferred to Project 7.

Through our efforts to improve crop and nursery management, we developed crop establishment guidelines for direct seeding and transplanting hybrid rice varieties. We also evaluated broadcasting seeds at a low seed rate (25 kg per hectare) and developed crop management strategies for high hybrid seed yield. We evaluated hybrid rice under different N management

conditions and studied their influence on disease development. High total N rate and excessive late application of N considerably increased the incidence and severity of sheath blight due to increased relative humidity inside the rice canopy.

Direct seeding of rice helps farmers save water and labor. In 2005, IRRI identified physiological attributes of elite hybrid rice that make it suitable for direct seeding. This involved adaptation of the plant's spatial leaf arrangement in response to competition to capture more light. We analyzed the simultaneous impact of spatial leaf arrangement on total leaf area and shoot dry weight and next we will measure the impact on grain yield as well as assess a wider range of genotypes.

Hybrids possessing cold tolerance at the seedling stage and salinity tolerance were identified for cultivation in the dry season. We are evaluating commercial rice hybrids for increased iron content in the polished grains.

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