PROJECT 5

Enhancing water productivity in rice-based production systems

The development of an irrigated rice production system that makes better use of water has emerged as a crucial issue in recent years. Farmers are facing ever-declining water supplies as they battle not only widespread drought but also increasingly fierce competition—from growing industrial, urban, and domestic sectors—for available water. And, as supplies diminish, the price of water is rising, either via direct costs or through the power outlay for pumping groundwater. The seriousness of the situation becomes clear in the light of Asia's dependence on irrigated rice for food security. In Asia, irrigated agriculture uses 90% of total diverted fresh water, and about half of that irrigates rice. Irrigated rice varieties, grown in continuously flooded paddies, require substantially more water to produce a given amount of grain than does any other major crop.

Not only is water-efficient rice production necessary due to dwindling resources, but it will also help farmers find relief from the rising cost of irrigation. The ability to grow rice with less water is also crucial if farmers are to mitigate the effects of drought, which in 2005 devastated many farms throughout Asia.

We have already seen good progress toward the development of water-saving irrigation techniques, such as reducing losses to percolation and seepage. But, as a water crisis looms ahead of us, we need to explore a range of new crop management strategies, such as cultivating rice in saturated soil on raised beds, along with the development of aerobic rice, which produces good yields in soils far too dry for conventional modern rice varieties.

As we strive to develop socially acceptable and economically viable irrigated rice-based systems that save water, we also need to look beyond the individual field level at system- or basin-wide scales. Knowledge of the behavior of water within whole irrigation systems will help us to optimize water use across entire farming regions.

Output 1: Strategies for enhancing water productivity at the farm level developed

Research continued on a number of water-saving technologies, including aerobic rice, which can grow in conditions too dry for commonly grown modern varieties and which is useful when rice fields cannot be flooded at all.

Alternate wetting and drying is useful under moderate water scarcity and shallow groundwater depths. Up to 20% of the water can be saved without affecting yield and the same fertilizer recommendations as for flooded rice can be followed. The water savings are mainly realized through a reduction in seepage and percolation losses, whereas evapotranspiration losses are hardly affected. In 2005, we looked at the interaction between nitrogen (N) and water, and its effect on leaf color chart (LCC) and SPAD (chlorophyll level) readings of rice under alternate wetting and drying. The linear relationship between leaf-N concentration and SPAD readings (or LCC) holds for well-watered as well as alternate wetting-and-drying treatments. We also developed a field-level monitoring system for simultaneous and continuous measurement of nitrous oxide, methane, and carbon dioxide fluxes, and evaluated general conditions of soil, soil solution, and standing water under alternate wetting-and-drying treatments during a dry season. We concluded that SPAD readings or the LCC can be used for real-time N management in rice subjected to alternate wetting-and-drying irrigation.

We assessed the potential of existing cultivars in larger-scale furrow-irrigated or supplemented irrigated systems. We tested alternate wetting and drying for five contrasting genotypes, finding no impact on grain yield. In large fields at the IRRI farm, puddled systems use about 4,000 liters of water per kg of grain yield, and nonpuddled systems use 6,000 liters per kg of grain yield. Alternate wetting and drying in puddled systems appears to be the most efficient water use. We also identified candidate traits for high performance under alternate wetting and drying on flat land. Overall, there was no significant impact on crop performance and water productivity and no significant physiological adaptation for safe alternate wetting and drying. We plan to conduct the same type of experiment under more stringent water-saving conditions.

In 2005, we evaluated water, nutrient, and crop management options for aerobic rice. In the tropics, stable wet-season aerobic rice yields of around 4 tons per hectare are feasible in field experiments and in farmers' fields with supplemental irrigation of 1–2 applications. In the dry season, yields of up to 6–7 tons per hectare have been recorded in field experiments and up to 5–6 tons per hectare in farmers' fields, but complete yield failures have also been recorded at several locations. The dry-season problems may be due to soil-borne diseases such as nematodes, fungi, and root aphids, and we have also documented micronutrient imbalances. Optimum nitrogen application rates are 70–90 kg per hectare in the wet season and 90–120 kg per hectare in the dry season, in three splits some 10–14 days after emergence, at tillering, and at panicle initiation. The optimum seeding rate is 60–80 kg per hectare. Row spacing can vary from 20 to 35 cm without a significant effect on yield or susceptibility to lodging. In the wet season, 1–2 supplementary irrigations are usually sufficient when dry spells occur; in the dry season, no optimum water application rates have been established because of problems with soil-borne diseases.

In IRRI's long-term aerobic rice experiment, a gradual and consistent yield decline has been confirmed under continuous aerobic rice cropping. Preliminary analysis suggested that the N supply of soil or N-uptake ability of aerobic rice decreased as the number of seasons progressed. However, two-season fallow and three-season flooding of fields reversed the yield decline and can offer practical management options.

In 2005, we synthesized the results of a three-year monitoring project in northern China—where aerobic rice was being tested by farmers on around 80,000 hectares in water-scarce irrigated environments—which incorporated biophysical and socioeconomic factors of early adopters of aerobic rice. Yields were 3–5 tons per hectare with 2 to 4 supplementary irrigations (200–400 mm compared with 1,100–1,300 mm in flooded rice). Economic returns were lower than for cotton and maize but, in flood-prone areas, upland crops are severely damaged when flooded and aerobic rice has higher profitability. Farmers indicated that yields need to increase to 6 tons per hectare in "normal years" to be competitive with other upland crops in water-scarce irrigated environments, but that "any yield" was good in case of flooding. Field experiments indicated that aerobic rice yields of 4–6 tons per hectare can be obtained with supplemental irrigations of 300–600 mm, depending upon rainfall. In many fields, the soil N supply is abundant, probably because of years of overfertilization, and little response to fertilizer N has been found. In the Philippines, national agricultural research and extension systems (NARES) partners incorporated aerobic rice in their own research programs. Farmers are testing aerobic rice at several pilot sites.

In 2005, IRRI hosted a *Comprehensive Assessment Workshop on Water-Saving Technologies in Rice Production*, whose ultimate aim is to influence policy and decision makers in investments in water for agriculture. The workshop outcomes have been incorporated in the *Synthesis Chapter on Water and Rice of the Comprehen-*

sive Assessment. We also developed a synthesis chapter for the *Comprehensive Assessment of Water Management in Agriculture*. The final synthesis of the *Comprehensive Assessment* is scheduled to be published in September 2006.

In 2005, we saw the completion of an Australian Centre for International Agricultural Research–supported project on irrigation and water productivity in China, which had received a 6-month extension following favorable evaluation. Project findings highlighted the need for a multiscale integrated approach to the improvement of water management at the irrigation-system level. Interventions need to combine improvements in irrigation infrastructure, supporting policies, management schemes, and farm-level technologies such as alternate wetting and drying or aerobic rice. The findings were published in a special issue of *Paddy and Water Environment Journal* and presented at the 2005 International Commission on Irrigation and Drainage Congress in Beijing. Next, we will carry out a dialogue with Chinese irrigation managers and policymakers on recommendations based on the project findings.

As part of the 2005 strategy for Theme 1 (Water Productivity) of the Challenge Program on Water and Food, a conceptual framework for the analysis and improvement of crop water productivity, using a systems-analysis approach, has been developed. This will form an umbrella for research on developing technologies to improve water productivity in 11 core projects of the Challenge Program on Water and Food.

Output 2: Interactions among the hierarchical scales of irrigation systems investigated and strategies identified for translating water savings at the farm scale into savings at the scale of irrigation systems

In 2005, a paper on "Operational and resource-use performance in the Cu Chi irrigation system" was published in the ACIAR Proceedings No. 118. This was part of our system-level studies in Vietnam. The findings showed that there was considerable water reuse within an irrigation system but the operational and resource-use performances of the system were low, which was attributed to low income from rice and a lack of incentives for farmers to reduce water inputs.

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