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## Acronyms and abbreviations used in this report

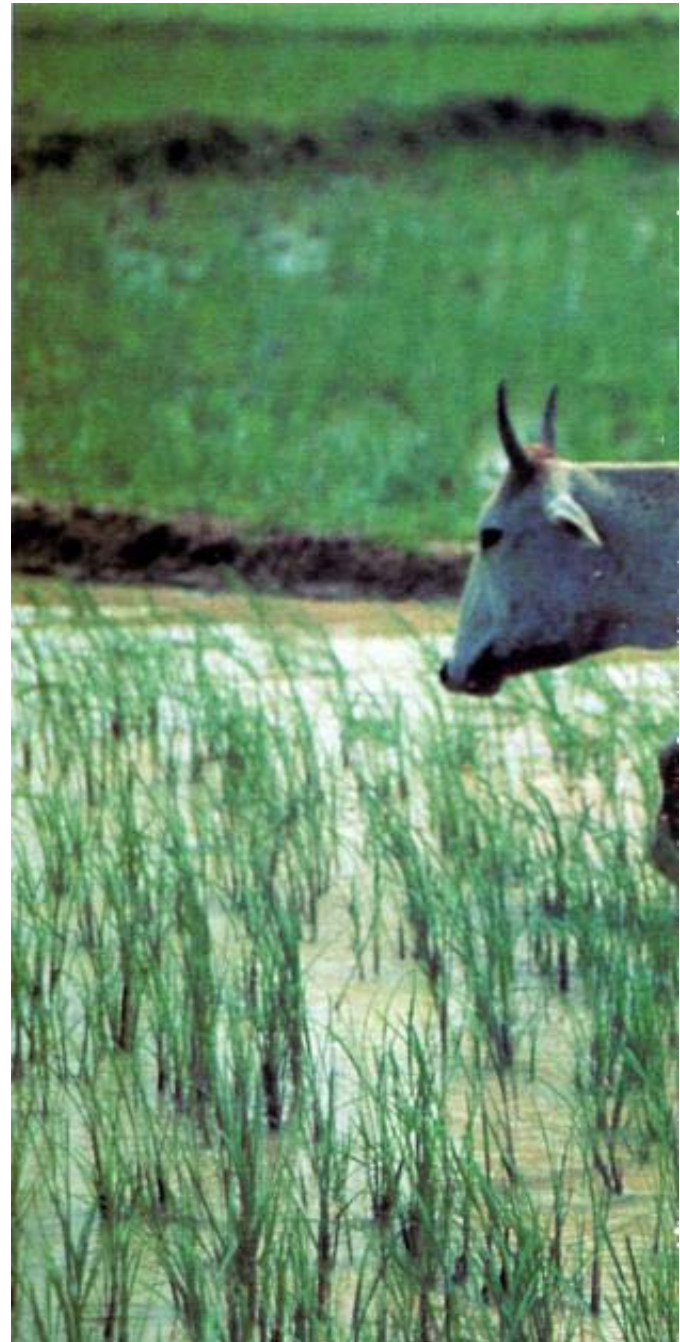
ACIAR	Australian Centre for International Agricultural Research	IDRC	International Development Research Centre (Canada)
ADB	Asian Development Bank	IFPRI	International Food, Policy and Research, Institute
AIDAB	Australian International Development Assistance Bureau	IIMI	International Irrigation Management Institute
ARBN	Asian Rice Biotechnology Network	IIT	Indian Institute of Technology
ARFSN	Asian Rice Farming Systems Network	IITA	International Institute of Tropical Agriculture
ASEAN	Association of Southeast Asian Nations	IIRR	International Institute of Rural Reconstruction
AusAID	Australian, Agency for International Development	INGER	International Network for Genetic Evaluation of Rice
BMZ	Der Bunderminister fur Wirthasliche	INSURF	International Network on Soil Fertility and Sustainable Rice Farming
CGIAR	Consultative Group on International Agricultural Research	IPMN	Integrated Pest Management Network
CIAT	Centro Internacional de Agricultura Tropical	ISNAR	International Service for National Agricultural Research
CIS	Commonwealth of Independent States	JIRCAS	Japan International Research Center for Agricultural Sciences
CNRS	Centre national de la recherche scientifique (France)	NARS	National agricultural research systems
CREMNET	Crop and Resource Management Network	NBPGR	National Bureau of Plant Genetic Resources
CSIRO	Commonwealth Scientific and Industrial Research Organization	NGOs	Nongovernment organizations
DNA	Deoxyribonucleic acid	NIAR	National Institute of Agrobiological Resources
DOASE	Department of Agriculture, Sri Lanka	NRI	Natural Resources Institute
DW	Deutsche Welthungerhilfe (Germany)	ODA	Overseas Development Administration
ECSA	Eastern, Central, and Southern Africa	ORSTOM	Office de la recherche scientifique et technique outre-mer (France)— <i>Now known as</i> Institut français de recherche scientifique pour le developpement en cooperation
EPA	Environmental Protection Agency	Lao PDR	Lao People's Democratic Republic
FAO	Food and Agriculture Organization of the United Nations	PhilRice	Philippine Rice Research Institute
FF	Ford Foundation	RDA	Rural Development Administration
FOFIFA	Foibe Fikarohana Ampiharina amon-ny Fampandrosoana ny Ambanivohitra (National Center for Applied Research on Rural Development-Madagascar)	RF	Rockefeller Foundation
GATT	General Agreement on Tariffs and Trade	RRDI	Rice Research and Development Institute
GTZ	Gesellschaft fur Technische Zusammenarbeit (Germany)	SAREC	Swedish Agency for Research Cooperation with Developing Countries
IARCs	International agricultural, research centers	SARP	Simulation and Systems Analysis for Rice Production
ICAR	Indian Council for Agricultural Research	SDC	Swiss Development Cooperation
ICIS	International Crop Information System	UNDP	United Nations Development Programme
ICLARM	International Center for Living Aquatic Resources Management	USAID	United States Agency for International Development
ICWG	IRRI CREMNET Working Group	WARDA	West Africa Rice Development Association
		WHO	World Health Organization

# WORKING TOGETHER TOWARD A COMMON GOAL

**The urgent need to produce more rice is still with us. Over the next 30 years, we will need to produce almost 70% more rice, primarily for the poor in low-income developing countries.**

**T**hirty-five years ago, the Ford and Rockefeller Foundations in cooperation with the Government of the Philippines, set in motion an unprecedented global experiment. Together they established a research center to unite within a developing country the talents of international and national scientists to raise the yield of the world's most important food crop, rice. Rice was the staple food for 90% of the world's poor people, and, the goal was to avert what was widely seen as an imminent threat of mass starvation among them.

That research center, of course was IRRI. A statement of its first director, Robert F. Chandler, Jr., in IRRI's first annual report (1961-62), exemplifies the visionary spirit that animated the Institute from the beginning. Dr. Chandler wrote that it should be possible to produce a rice plant with the characteristics needed for the necessary increased yield within five years. Only four years later, IRRI had done just that, with IR8. The new variety, followed by many others, triggered the Green Revolution, which led to a doubling of rice production throughout Asia and saved hundreds of millions of lives.



**The rainfed and less favorable ecosystems, such as the one in which this farmer works in Bangladesh, have yet to benefit adequately from the results of research.**



Today, in the atmosphere of discord and conflict in which we are continually enveloped by the media it is remarkable to reflect on the scope and extent of international cooperation the IRRI experiment has engendered.. Cooperation is, in fact, the word. that best describes IRRI's ethos. Per 35 years, scientists from a score of different countries have worked daily together toward a common goal: improving rice yield through research. Their work has been carried out in close collaboration with their colleagues in both national and other international centers. Its results have been made available throughout the world in publications and at conferences. And seeds of the new rice varieties they have developed are free for the asking to governments and ultimately to farmers everywhere. More than 100 countries have received them and, as a result. 252 varieties developed at IRRI are now grown worldwide. More than 70% of the ricelands of Asia and 37% in Latin America and. the Caribbean are planted to such improved varieties.

In this my first year as director general, I am keenly aware of the rich heritage of IRRI's past. But my task is to look to the future. The urgent need to produce more rice is still with us. The 2.7 billion people who rely on rice as their staple food today will have multiplied to some 4.4 billion by the middle of the next century. Over the next 30 years, we will need to produce almost 70% more rice, primarily for the poor in low-income developing countries.

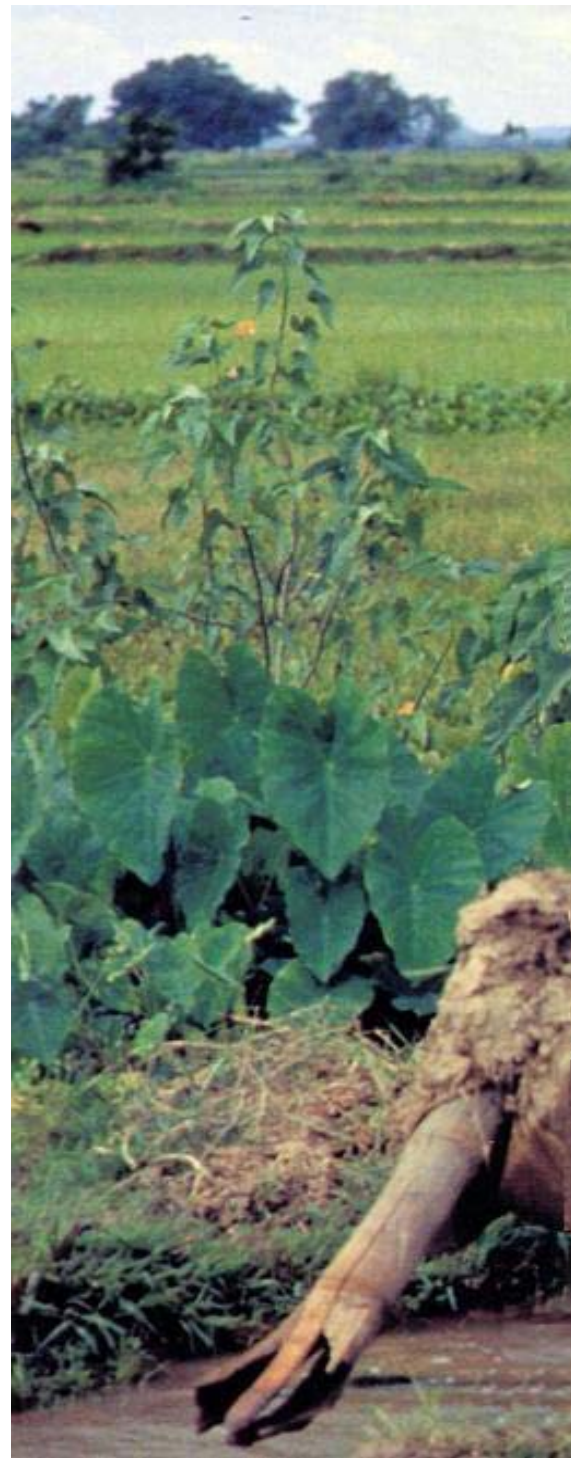
It is in those countries that the gaps are greatest between current yields and those we believe achievable. Until now, research has not made a significant impact in these areas. IRRI, in partnership with the national programs, must assist in in-

tensifying the effort to produce results that are both visible on research plots and transferable to farmers fields. For this to happen, IRRI must continue its efforts to have more of the research done in the environments for which it is designed.

A shift in research perspective is well, under way at IRRI and this must be accentuated. The emphasis is changing, for example, from the focus on development of new varieties and associated, technologies to more research on soil nutrient and water management and issues of sustainability. IRRI today is taking a broader systems approach than formerly, one that embraces everything from studies of the genetics of plants and. their pathogens, weeds, and insect pests and their interactions, through the dynamics of the entire rice ecosystem, to include ultimately studies at what we call the ecoregional level. Our task is to understand not just the individual components of these systems, but how all of them are integrated.

On a practical level, this means, for example, that our scientists do not look at a plant pest problem just through the perspective of improving the plant's genetic resistance. Rather different members of the interdisciplinary team, look at how the habitat can be modified, how beneficial insects can be introduced or conserved and how various forms of crop management can lessen the problem.

We aim to identify real needs not just at the farm level, but also at the national systems level, so that our research will be governed by these needs. This will mean that when. new technologies are developed., they will arise in response to a problem on farmers' fields rather that to one dictated by the technology itself. Changes are already being made in IRRI's relationship with its research



**A growing scarcity of fresh water, especially, will pose serious problems for rice production in future years. Much of IRRI's research will be directed at developing rice production systems with higher water use efficiency.**



India, S. Fujisaki

partners (see article on p. 46). Partnership and shared governance with the national agricultural research systems (NARS) in developing countries and other institutions are being stressed. We see the farmer more as a partner than as a client in our research. This means more researchers going more often to where the problems are. Last year, as they have done for some years, IRRI scientists

travelled to many regions when the problematic conditions could not be duplicated at research headquarters.

Land and water resources are becoming ever more scarce. To use them more efficiently, management practices must be given more attention at all levels, from the farm up. Increased efficiency in economic, agronomic, and environmental terms should also be promoted, and this

calls for a strengthening of the interaction of various disciplines through a systems approach.

A growing scarcity of fresh water especially, will pose serious problems for rice production in future years, as can be seen in our feature on p. 10. While irrigation facilities expanded rapidly in the 1970s and early 1980s in Asia's major rice-producing countries, the efficiency of

ater use in most rice irrigation systems can best be described as “dismally low,” in the words of IRRI agricultural engineer Sadiq I. Bhuiyan. Dr. Bhuiyan estimates a typical efficiency range at between 30 and 40% in the wet season and 40 and 60% in the dry season. Much of IRRI’s research will be directed at developing rice production systems with higher water use efficiency.

**With a trend toward direct seeding taking place in several Asian countries, IRRI has designed a drum seeder for wetland paddies. It is shown here undergoing testing in Cambodia.**

Integrated pest management, now firmly established as the preferred approach to pest control, involves control of more than just insects. Weeds and diseases are becoming increasingly important, but they, too, must be controlled in an environmentally friendly way. Here the plant pathologists and weed ecologists are leading the way.

Direct seeding of rice offers certain advantages over the traditional method of planting seeds in a nursery and then transplanting seedlings. It can be done under either wet or dry conditions, depending on circumstances. In direct dry seeding, the rice is seeded into moist ground. In rainfed areas, early planting of quick-maturing varieties in this way

allows farmers to plant a second crop using late season rainfall. It can also be used in flood-prone and irrigated areas, and is the only means of planting upland rice. This method uses less water and labor than either transplanting or direct wet seeding.

In direct wet seeding, seed that has already germinated is broadcast onto wet soil, with or without puddling. It is used for irrigated rice and in favorable rainfed lowland areas. Compared with transplanting, wet direct seeding requires less labor, consumes less water, and in rainfed crops makes the chances of survival better when soil dries out.

For the past 10-15 years in Southeast Asia, farmers have been shifting from transplanting to wet seeding.





K.L. Hoang

**Integrated pest management, here being carried out by field workers in Vietnam, involves more than just insects. Increasingly, as weeds and diseases become more important, they too must be managed in an environmentally friendly way.**

This shift is a rational response by the farmers to a cost-price squeeze in rice production: their production costs have been rising as market prices have been dropping.

But while direct wet seeding brings farmers advantages, it also brings problems, such as competition from weeds, poor and uneven crop establishment, and difficulties in harvesting. Rice cultivars and cultural practices adapted specifically to direct seeding are needed, as are efficient irrigation and tillage techniques.

As IRRI continues its studies of direct seeding of rice, it can profit, fortunately, from the experience of others. For example, farmers in southern Vietnam have been practicing it since 1971 and have achieved good results under dry, wet, zero-tillage, and submerged conditions.

One conclusion emerges clearly as a research priority for the years ahead: IRRI should strengthen its role in rainfed and less favorable ecosystems. These regions have not responded to research to the same degree as those in irrigated and favo-

orable ecosystems. Poor people in these environments lack the capacity to acquire food, even at lower prices, and their poverty and food insecurity are prime causes of their over-exploitation of the already limited resources.

A study carried out among experienced farmers and extension workers in a number of Asian countries shows that drought, submergence, weeds, nutrient deficiency, stem borer, blast, soil acidity, and bacterial blight account for more than 80% of the production losses in rainfed lowland and upland ecosystems. IRRI scientists will therefore focus attention on understanding the mechanisms that allow some traditional varieties of rice to tolerate such stresses, with the aim of introducing those traits into new, improved varieties.

As it has evolved over the past three and one-half decades, IRRI's research role has gradually changed, and new obligations have been assumed. One of today's most important obligations—as set out in Agenda 21 of the 1992 UN Confer-

ence on Environment and Development—is to preserve the quality of the environment and to ensure that all development is sustainable.

Recent findings from experiments begun in the 1960s show clearly that sustained increases in rice yield—which in the absence of available land must come from further intensification of cropping systems—cannot be achieved unless soil and water quality is preserved. IRRI's research agenda, therefore, will continue to be guided by concerns not only for increased production, but also for the maintenance of natural resources on which sustainable development depends.

GEORGE ROTHSCHILD  
*Director General*

# WATER: A LOOMING CRISIS





Indonesia, R. Kendrick

**“W**e never know the worth of water till the well runs dry,” went the 17th century proverb. According to some observers, we may soon know it because the world’s fresh water well is beginning to show signs of exhaustion.

Strictly speaking, this couldn’t happen: as a result of the hydrological cycle, however much water evaporates from the earth returns to it through rainfall. In this sense, there’s as much water in the world today as there ever was. But human uses of the life-sustaining fluid have increased enormously over time: between 1900 and 1990 total worldwide water withdrawals increased at twice the rate of the population increase while, compared with three centuries ago, water use rose more than 35-fold.

Moreover, water can become scarce in particular areas or regions—and in recent years, with increasing frequency, it has.

“In several parts of the world, water demands are fast approaching the limits of resources,” wrote Sandra Postel of the Worldwatch Institute in 1989. “Many areas could enter a period of chronic water shortages during the nineties, including northern China, virtually all of northern Africa, pockets of India, Mexico, much of the Middle East, and parts of the western United States.”

**“The watering of crops currently uses something like 3300 cubic kilometers of water a year—roughly six times the requirement for industrial and domestic uses... Irrigation is a wasteful process. Less than half of all irrigation water reaches the crop it is designed to water?”**

**-From: *Water: the international crisis*, Robin Clarke, Earthscan Publications Ltd., London, 1991.**



Water is a scarce resource in many parts of Asia, particularly in the arid and semi-arid regions of the north and west. In the Philippines, the Ifugao rice terraces are a UNESCO World Heritage Site. In the image, two people are wading through a flooded rice paddy field, a common sight in the region.

### Less water for Asia

That prediction is now coming true. In Asia, where water has always been regarded as an abundant resource, per capita availability declined by 40-60% between 1955 and 1990. Projections suggest most Asian countries will have severe water problems by the year 2025.

As populations increase and economic development intensifies, governments will be forced to make critical decisions in their long-term planning for regulating, allocating, and using their water resources. Disputes have already arisen between some Asian farmers and industry in their competition for water. In the future, conflicting demands will increasingly be felt between the needs for safe drinking water, sanitation, and industrial activities, particularly

in fast-growing urban centers. And such conflicts may well lead to social unrest.

Agriculture is by far the biggest consumer of water worldwide. In Asia it accounts for 86% of total annual water withdrawal, compared with 49% in North and Central America and 38% in Europe. Irrigated rice, in particular, is a heavy consumer of water: it takes some 5,000 liters of water to produce 1 kilogram of rice. Compared with other crops, rice production is less efficient in the way it uses water. Wheat, for example, consumes only 4,000 m<sup>3</sup>/ha, while rice consumes 7,650.

### Too much water, or too little

Asia's water problems are caused partly by its uneven distribution. On the one hand, about half of China

receives less than 400 mm rainfall a year, and extensive areas of north-west, central, and south Asia are drought-prone. On the other hand, the Ifugao rice terraces of the northern Philippines are situated in one of the wettest rice-growing regions of the world, with an average annual rainfall of 3,530 mm.

As a further complication, when rain comes in Asia it usually arrives in torrents over a short period, during a single monsoon that lasts from four to six months. The rest of the year is almost dry. As a result, much of the runoff simply flows into the ocean as waste, at the same time eroding the uplands, sometimes catastrophically. The monsoon, furthermore, is often erratic, so that in many countries, floods and seasonal water shortages occur concurrently.

### Environmental costs of increased rice production

Water was a critical input to the Green Revolution, through irrigation, flood control, and drainage, and it has contributed most to the growth in rice production for the past 30 years. But this expansion has been bought at a cost to the environment: a proportion of the chemicals applied as fertilizer and as pest and weed control pollutes rivers and lakes through runoff, or groundwater through leaching.

In some upland areas, intensive agricultural practices, coupled with deforestation, have resulted in high rates of soil erosion and degradation of both land and water resources in lowlands below. The effects can reach as far as coastal waters, with consequent impact on marine life.

The Manupali Watershed, which drains into Pulangi River in Bukidnon Province in southern Mindanao in the Philippines, offers an example. The upper area of this 60,000-ha watershed still has some forest cover, while the lower stretches are cultivated. More than 40% of the watershed consists of steep hills, and migration into the area from other parts of the Philippines during the 1950s and 1960s has led to a rapid population increase. This in turn has resulted in deforestation and increased agricultural activity in cleared, forest areas on the upper slopes, and siltation in the lower, rice-producing regions. Reservoir, irrigation, and drainage canal capacity there have all been seriously reduced.

Another problem involves long-standing surface water, which causes waterlogging, makes the land unproductive, and leaves soils salty as the water evaporates.

In India, about six million ha of irrigated land are known to be affected by waterlogging. Nearly 10% of Pakistan's irrigated 13.5 million ha is

## Using water more efficiently

**T**raditionally, farmers in Southeast Asia have established their ricefields by transplanting seedlings but during the past 10-15 years, many have changed this practice to sow seeds directly onto the field.

Direct seeding can be done by broadcasting pregerminated seed onto wet, puddled soil (wet seeding). Or it can involve sowing ungerminated seed onto dry or moist but unpuddled soil (dry seeding).

Wet seeding requires less water than does transplanting for both land preparation and crop irrigation. IRRI studies in the Philippines showed the amount of water used by farmers for land preparation was 27% less with wet seeding than with transplanting. That was because wet seeding required less time to complete the preparation: 6 days compared with 24. Yet the yields from the two systems were almost the same: 7 t/ha for wet seeding, 6.5 t/ha for transplanting.

During irrigation, the farmers who wet seeded again used less water than those who transplanted because they maintained shallower depths of water, especially during the post-vegetative stage of the crop. This, in turn, was because the wet seeded fields were leveled better and herbicides were used rather than deep water to control weeds. The shallow water also helped the rice plants to remain upright in strong winds.

Where water was scarce, research showed that wet seeding provided a higher yield than did transplanting. Farmers using wet seeding are aware of this advantage.

In dry seeding, seeds are broadcast before or at the onset of the rainy season and germinate when rain provides enough moisture. Almost all the early rainfall contributes to crop growth. In the Mekong River Delta of Vietnam, the whole dry seeding cycle, from land preparation to harvest, used only 700-900 mm of rainfall—nearly as much water as it took to puddle the soil for transplanting.

Dry seeding, therefore, can be used to advantage in rainfed rice areas, where for transplanting farmers have to wait to prepare the land until rainfall is adequate to saturate the soil. In these areas, farmers also often use traditional rice varieties, which take longer to become established and yield less. With these delays, there is not enough time and late-season rain to grow a second crop.

Dry seeding of modern, early-maturing varieties has already led to crop intensification in large tracts of Vietnam, Indonesia, and some parts of the Philippines. And their productivity was much higher than that of a single transplanted rice crop.

Dry seeding can also be used in irrigated systems where there is not enough water in the reservoirs for land preparation and crop establishment early in the season. There, rainfall is used to establish the crop, and irrigation supplements it later on.

How important can dry seeding be in irrigated ecosystems? In 1978, an entire transplanted crop was cancelled in Malaysia's Muda irrigation system when reservoir levels were low. Yet in 1991, when low water levels in reservoirs resulted in no water at all being used for irrigation, farmers' dry seeded crops yielded an average of 3.9 t/ha.



Philippines, R.Kendrick

**Irrigated rice is a heavy consumer of water: it takes some 5,000 liters of water to produce 1 kilogram of rice**

estimated to be affected by salinity, while northwest India and northeast China are similarly degraded.

Once waterlogging and salinization become visible, it is difficult to reverse the process, even with major investments in drainage facilities. Thirty years after commissioning of the left bank canal of the Tungabhadra irrigation project in Karnataka State, India, some 33,000 ha were waterlogged and saline: farmers abandoned about 20,000 ha there because the land was no longer productive.

#### **Pumps, wells, and water shortages**

Overexploitation of tube and shallow wells also presents problems. This is the case in large areas of India, Pakistan, and Bangladesh. The practice causes shortages of drinking water, and also pollution when aquifers are recharged with irrigation water contaminated with chemicals.

For example, in the early years of the rice-wheat rotation system in the Indo-Gangetic Plains of India, rice acreage expanded rapidly with the availability of shallow underground water resources. Centrifugal pumps and shallow wells provided cheap assured irrigation. The irrigation also reversed the trend of rising water tables and thus contributed to reclamation of saline lands. This encouraged farmers to install additional tubewells and further extend the rice-growing area.

At first there was no problem because the water tables were recharged by above-average rainfall and floods, but more recently the situation has assumed serious proportions.

“It is estimated that the groundwater table in Punjab is receding by 20 cm per annum over two-thirds of the state,” reported R.S. Narang and M.S. Gill of Punjab Agricultural University in 1993. “This is also the situation in other rice-wheat areas to varying degrees. This has reached such alarming proportions that questions are now being asked as to what extent rice cultivation should be permitted in the irrigated Indo-Gangetic Plains, and how to sustain the productivity of the region without losing the battle on the water front.”

Capital costs of irrigation systems have recently soared. Today in Sri Lanka it costs almost three times as

much per hectare of land to set up an irrigation system as it did in the 1960s; twice as much in India and Indonesia; and nearly 50% more in the Philippines and Thailand. At the same time, market prices for rice have plummeted by nearly 40% over the past 30 years, while political pressures are mounting against large-scale projects from environmental groups.

### Reducing water consumption

For all these reasons, attitudes to irrigation and appreciation of the value of water supplies are changing. In Asia which contains 55% of the World's estimated 253 million ha of irrigated land, there has been a sharp decline in the rate of growth of such areas. In East Asia, growth was 2% annually through the mid-1970s, but was virtually stagnant in the 1980s.

What this will mean for future rice production is that it will depend heavily on the development of water-efficient measures—producing more rice per unit of water input. (See “Slipping between the cracks”.) The trend now is to develop management policies for efficient operation of irrigation systems; technologies that reduce water consumption; changes in the rice plant itself and the ways in which it is grown, so as to use water more efficiently—and also to provide economic incentives to farmers to reduce water losses.

The development of rice varieties that take less time to grow, for example, would allow farmers in regions with a short rainy season to avoid early or late droughts. (Breeder have already shortened the maturation time of irrigated rice from 150 to 110 days.) And where the monsoon season is long, farmers could grow two rice crops without supplementary irrigation. Or they could grow a crop other than rice with the water left over at the end of the monsoon.

## Slipping between the cracks

**M**ore than half the water consumed in rice production often used to prepare the land—and most of this is lost in the process through percolation and seepage. A major thrust of IRRI's research is toward reducing these losses.

Most Asian farmers till a wet field rather than a dry one, because it facilitates transplanting of rice plants, helps level the land, plows under weeds and stubble, and improves the soil conditions for plant growth.

They first soak the land until the topsoil is saturated, shallow plow once or twice, and then harrow once or twice. Plowing and harrowing are carried out with water standing in the field.

Rice is usually grown in clay soil, and alternate soaking and drying produces deep and wide cracks in it. In fields with permeable subsoil, up to 60% of the water applied for soaking flows through these cracks. About 30% of the flow recharges the water table below, while 70% is lost through lateral drainage.

Experiments in the Philippines have shown that shallow surface tillage after harvesting of the previous rice crop can save about 200 mm water during land soaking and preparation the tilled layer minimizes deep crack formation and surface soil particles block water flowing into the cracks.

Water savings have also been made possible with the increasing accessibility of high-powered tractors, which makes dry tillage possible in many Asian rice areas.

The main determinant of water use efficiency in a ricefield is the reduction of percolation loss. Puddling causes the formation of a semi-impermeable layer just beneath the puddled topsoil, thus reducing loss. IRRI studies show that even a small area of nonpuddled soil increases percolation losses by a factor of five. A further 2- to 5-fold increase in percolation water loss results from movement of water from the flooded fields into the bunds and then down to the water table. Much percolation loss can therefore be prevented by reducing water flow into the bunds: same farmers do this by sealing the bund walls with mud. Decreasing the depth of ponded water also reduces percolation loss.

IRRI's work shows that maintaining a saturated soil throughout the growing season can save up to 40% of water in clay loam soil, without yield reduction. Weed control is possible through chemical, mechanical, or manual means—with the latter, often without additional cost. Farmers order to flood their land continuously, however, as insurance against future water shortages, and to control weeds without manual, mechanical, or chemical inputs.

Research shows that where weed growth is a serious problem, continuous flooding up to formation of the rice plants' panicles, and continuous saturation after that, uses 30-35% less water than the traditional practice of continuous flooding—and without any increase in weed infestation or reduction in rice yield.





**Figure 1**  
 A farmer in a rural setting, possibly a farmer, standing near a structure with a thatched roof. The person is wearing a light-colored shirt and dark pants. The background shows a field with some wooden posts or stakes.

In rainfed rice systems, which is where more than half of all Asian rice is grown, farmers have little control over their water supply, and one of their main constraints to productivity is a lack of water when needed. Drought affects 40% of rainfed lowland and all upland areas in Asia. At the same time, the potential of existing rainfall for rice growing is underutilized. Improving rainwater use efficiency to alleviate drought therefore offers tremendous potential for increased rice production. Methods of doing this include reducing field losses and collecting runoff

water in reservoirs and applying it to crops during droughts.

A parsimonious attitude toward water could really pay off. In 1990 the World Resources Institute estimated that between 65 and 70% of the water used around the world was lost to evaporation, leaks and other inefficiencies—but that it was possible to reduce these losses to 15%.

**New rice varieties will be needed**

In rainfed systems, farmers wait for heavy rains to flood ricefields before puddling transplanted seedlings: this delay may expose the crop to

drought at a productive stage. Seeding rice directly into the soil without puddling could make more efficient use of rainwater. But for this to work, new rice varieties are needed with early vigor so that they can withstand sudden submergence by early rains and can compete with weeds.

Many farmers continue to grow traditional low-yielding rice varieties in rainfed environments because of their resistance to temporary submergence and prolonged droughts. Biotechnological research is helping scientists to understand the traits in these varieties that confer such resistance, so that they may incorporate them into modern cultivars to help stabilize yields.

Dry seeding—which can avoid the waste of 400-600 mm of rainfall—is assuming an important role in rice production in rainfed areas. The early harvest of dry seeded rice can allow planting of a second crop, which makes use of rainwater that arrives later in the season. The practice also reduces risk of drought where the rainy season is short, and because dry seeded cultivars can generate more roots.

**The water-weed connection**

One reason farmers keep ricefields continuously flooded is to keep down weeds, which compete less well with rice under such conditions. But if flooding is reduced, other ways of controlling the weeds will be necessary. Chemical herbicides are becoming less socially acceptable as a result of public concern about health hazards, and some weeds are developing herbicide resistance, so new methods of weed control will have to be sought.

IRRI scientists consider that, at present, knowledge of how to manage weeds is as primitive as was the knowledge of how to manage insects

20 years ago. That is because farmers today feel compelled to rely almost exclusively on one source of control—herbicides—just as, two decades ago, they relied principally on insecticides to control insect pests.

Worldwide, farmers spend about US\$900 million each year to control weeds in rice. As labor costs for hand weeding increase, and water itself becomes more scarce and expensive, herbicide use can be expected to increase even further.

To break this herbicide dependence, IRRI scientists are turning to integrated weed management, just as they earlier turned to integrated pest management. They are examining the place of weeds in the entire rice-growing system, with the aim not simply of attacking and killing them by one means or another, but of managing them in a way that will not interfere unduly with rice production.

This involves studying the interaction of weeds with such components as water and tillage practices; and incorporating in the rice plant characteristics that increase competitiveness with weeds, such as early vigor and allelopathy (see article on p. 42). It also involves investigations of naturally occurring pathogens of weeds, and how they might be used to suppress weed growth. (See “Setting weeds’ natural enemies...” p. 40) And it involves increasing farmers’ understanding of weeds (see “Seeing is believing”... p. 51).

By such means IRRI scientists are developing, today, environmentally sound weed management systems that they hope will prevent, a decade hence, the kind of excessive reliance on chemical herbicides that happened with insecticides a decade or so ago.

### **Biotechnology offers promise**

In some 22 million ha of lowland and deepwater rice areas of the world, flash flooding leads to submergence of the plants. To cope with such hazards, some rice plants have developed, two protective mechanisms: submergence tolerance and elongation. Submergence tolerance is appropriate to rainfed lowland areas where flash flooding lasts only for about 14 days, during which plants may become either partly or completely submerged. Elongation, on the other hand, is appropriate to areas where flooding is deep and lasts for several months.

A multidisciplinary team, involving eight institutes in India, Thailand, USA, Australia, and IRRI, is researching these protective mechanisms to see if they can be introduced genetically into new plant types. This could become the first instance in which a nonbiological environmental stress on a plant is ameliorated through biotechnology. Success would be particularly exciting because, while tolerance for stresses such as insects or disease can subsequently be overcome by mutations in the pest, the inbred tolerance of a plant for an environmental stress would be permanent.

Another major research initiative is aimed at introducing drought tolerance into plants to be grown in rainfed lowlands. The stress on the plant of varying soil conditions, from drought to ponding or even submergence, is considered the most severe limitation to rice productivity in rainfed locations.

IRRI’s early research focused on irrigated and favorable rainfed environments, and the high-yielding, pest- and disease-resistant varieties produced were generally successful. As IRRI began to consider less favored environments, however, its

scientists realized that the rainfed system was more complex, and that more basic research was required to develop plants and cultural practices for these.

The research aims at characterizing the expected timing, duration, and intensity of drought stress in rainfed lowlands, and at understanding the plant’s genetic response to this stress. IRRI is collaborating with the Rockefeller Foundation, Texas Tech University, Australia’s Commonwealth Scientific and Industrial Research Organization (CSIRO), and the University of Queensland in efforts to develop molecular markers—a powerful new tool—to help find genes for root traits likely to confer drought tolerance on rainfed rice. Marker research is also being applied to upland rice.

### **As the CGIAR sees it**

So important is the water problem worldwide in the view of the CGIAR that it designated water management as a systemwide initiative beginning in 1995. The objective is to increase the effectiveness of water management research through improved coordination and enhanced collaboration among many of the 16 international agricultural research centers and the NARS in developing countries.

The International Irrigation Management Institute in Sri Lanka has been designated as the convening center for this initiative. IRRI will provide expertise and leadership in management at the farm level.

While the full import of the water supply problem to rice production has been recognized only relatively recently by the research community, it is now fully acknowledged there. Coping with its implications will be central to IRRI’s concerns in the years ahead. ■





1. *Stem*  
2. *Leaves*  
3. *Flowers*  
4. *Fruit*  
5. *Seed*



1. *Stem*  
2. *Leaves*  
3. *Flowers*  
4. *Fruit*  
5. *Seed*



1. *Stem*  
2. *Leaves*  
3. *Flowers*  
4. *Fruit*  
5. *Seed*

# RESEARCH PROGRAM HIGHLIGHTS



# A new rice variety to meet tomorrow's food production challenge



**R**ice production in intensively cropped irrigated systems has lagged behind population increases in the rice-growing world for almost 20 years. To prevent the severe food shortages that will occur if this trend is not reversed, IRRI's target is to raise the yield potential of rice by up to 50% during the next 15-20 years.

Near the end of 1994 IRRI scientists harvested the first prototype breeding lines of a new rice plant that promises eventually to produce, under ideal conditions, on the same amount of land, 25% more grain than

The plant is currently being tested on IRRI's experimental plots for fertilizer management technology and plant spacing. More than 200 new crosses were made in 1994 to introduce disease and pest resistance genes into it.

**By the time the new rice plant type is ready for planting on farmers' fields (possibly around the year 2000) its built-in disease and pest resistance is expected to obviate the need to use pesticides.**

## Irrigated Rice Ecosystem

**M**ore than 75% of all rice produced comes from irrigated land. The Green Revolution was driven by both an extension of such areas and increased yield per unit of land. But the needed yield increase of 70% by 2025 will have to come exclusively from higher yields on existing land. IRRI's scientists aim to help make this possible in an environmentally sustainable way.

By the time the plant is ready for planting on farmers' fields (possibly around the year 2000) the built-in disease and pest resistance—which will be at the same level as that of currently grown high-yielding varieties—is expected, to obviate the need to use pesticides. Planting it directly into the soil, rather than transplanting seedlings, will result in significant savings in labor costs and water use.

Farm level yields with the new plant type are expected to increase by 15-20%. The basis for such a high yield is its architecture and higher rate of photosynthesis. Today's high-yielding varieties produce 20-25 tillers (stems), but only 14-15 of them produce panicles, which bear the grains. These panicles are small each bearing about 100 grains. The new rice plant has only 6-10 stems, all of which produce panicles, each with 200-250 grains. These heavier panicles are supported by sturdier stems and more vigorous roots, which prevent the plant from falling over (lodging).

The new plant is designed to use captured sunlight more efficiently because its leaves are thicker, more erect, and darker. Some of the new lines have a maximum photosynthesis rate 10-15% higher than that of IR72, a leading high-yielding variety.

Recent measurements in leaf tissues of a new plant type line, IR65593-112-2, and IR72 confirmed that the new plant type also uses water more efficiently. It will thus be well adapted to the expected scarcity of water in irrigated systems in the years to come.

The modern high-yielding varieties grown in the tropics are all indicas. The new plant type is based on the tropical japonica germplasm, cultivation of which will add to the biodiversity of the rice system.



## Highlights

### Halting the productivity decline

Why have crop yields shown declining productivity in recent years? IRRI scientists are trying in a number of ways to find out. For example,

Studies done in IRRI's experimental plots (above) and with NARS collaborators in five key sites produced the first direct evidence that, when rice is double- or triple-cropped in submerged soil, the chemical structure of the soil organic matter changes

# Pesticide residues in drinking water: How much is too much?

RRI studies in the Philippines have shown that pesticide residues can contaminate groundwater beneath intensively cultivated ricefields, while those from a ricefield irrigation system can contaminate a nearby freshwater lake.

Few such studies have been undertaken anywhere, and little is known about how pesticide use in intensive irrigated rice culture systems affects the quality of fresh water nearby. Yet because such rice culture systems are found in more than 40 million ha in Asia, the studies suggest a potential health threat exists to both humans and animals.

There is some indication that future insecticide use may decline as farmers increasingly adopt alternatives to chemicals in insect pest management. But as costs increase for both labor in handweeding and water in submergence control of weeds, more and more rice farmers are finding it economically attractive to use herbicides.

Herbicides, moreover, are cheap: a yield increase of only about 100 kg/ha would cover the cost for a rice crop, while handweeding would cost five times as much. Thus the pesticide studies suggest herbicide contamination may pose similar hazards.

The studies were carried out in the service areas of two irrigation systems, the Upper Pampanga River Integrated Irrigation System in Nueva Ecija Province, and the Santa Cruz River Irrigation System in Laguna Province. The latter drains into the lake called Laguna de Bay.

With the exception of one farmer, all those in the area who were interviewed had used pesticides in both seasons. Fifty percent of the total pesticides used during the year were insecticides, 40% herbicides, and 10% molluscicides.

The total mean toxicity of multiple pesticide concentrations in groundwater during the wet season was not far from the maximum permissible in drinking water. Some of the pesticides are considered extremely hazardous to human health, and farmers reported using pesticides other than those analyzed.

The study said the process of pesticide movement to groundwater and pesticide persistence there are not fully understood. In-depth investigations are needed to predict immediate and long-term impacts on groundwater quality.

The situation is complicated by the fact that permissible drinking water concentrations of pesticides—especially the newest ones—are not well defined, and there is no clear guideline when many different pesticides are involved. Strict guidelines from government agencies are required, along with networks for monitoring water quality.

In the drainage into Laguna de Bay, highly hazardous pesticides were found, such as methyl parathion and carbofuran, as well as moderately hazardous ones such as endosulfan.

The study could not measure any possible dilution effects from the drainage in which the pesticides were contained, or from the waters of the lake itself, and thus was unable to estimate the potential toxic effects on the lake's water.

In another study, 270 groundwater samples were collected from 53 tubewells located within ricefields in irrigated and rainfed areas, which were used for domestic water supply. The study, carried out during 1989 and 1991 in Laguna and Nueva Ecija provinces, showed pesticide residues exceeding the limits set by some international agencies of 0.1 parts per billion (ppb) for a single pesticide, and 0.5 ppb for multiple pesticides.

By these standards, the residues were excessive, yet toxicological standards established by FAO/WHO indicated that the water was safe for human consumption.

studies done with NARS collaborators in five key sites produced the first direct evidence that, when rice is double- or triple-cropped in submerged soil, the chemical structure of the soil organic matter changes. A proportion of it becomes enriched with phenolic compounds, which appear to immobilize nitrogen-containing compounds. This reduces the capacity of the soil to supply nitrogen to the rice plants, thus lowering productivity.

The evidence was obtained using  $^{13}\text{C}$  nuclear magnetic resonance analysis. The key sites were Central Luzon, Philippines (Philippine Rice Research Institute); the Mekong Delta, Vietnam (Cuu Long Delta Rice Research Institute); Suphan Buri, Thailand (Pathum Thani Rice Research Center); Sukamandi, Indonesia (Sukamandi Research Institute for Food Crops); and the Cauvery Delta, India (Tamil Nadu Rice Research Institute).

## Adopting new fertilizer strategies

Soil tests at 11 sites in 5 Asian countries show that there is no relationship between the amounts of nitrogen fertilizers farmers apply and the ability of soils to supply these nutrients to plants. Thus farmers need reliable ways of judging how much fertilizer to apply and. When. Improved methods of predicting the actual nutrient-supplying power of the soil at any given time would help them greatly.

A chlorophyll meter was used in on-farm. trials in Calanan, Laguna, Philippines, during the 1994 wet season to determine the timing of nitrogen topdressings, compared with farmers' practices. Chlorophyll meter-guided nitrogen management yield was 6.3 t/ha with an input of 80 kg N/ha compared with 5.5 t/ha with 76 kg N/ha using farmers' practices. Use of the meter resulted in, an

## IRRIGATED RICE ECOSYSTEM

Expenditure 1994—\$4,220,000

Approved budget 1995—\$4,995,000

Budget planned 1996—\$5,130,000

Internationally recruited staff—12

Nationally recruited staff—85

### Projects

- Raising the yield plateau
- Reversing trends of declining productivity in intensively irrigated rice
- Improving nutrient management
- Identifying tillage and water interactions
- Enhancing postharvest technology
- Improving pest management
- Sustaining the lowland rice base
- Examining global climate change
- Improving rice-wheat systems
- Apomixis—ensuring equity in use of hybrid rice



A soil testing device is used to determine the timing of nitrogen fertilization.

N-fertilizer use efficiency (NFUE) of 21 kg grain/kg N applied, compared with 12 kg grain/kg N with farmers' practices. The NFUE was calculated as the increase in grain in the fertilized plot over that in the control plot per unit of N applied.

Appropriate use of this technology could reduce nitrogen requirements for a given level of yield.

### The importance of potassium

Potassium is one of the nutrients supplied by soils and chemical fertilizers that will become increasingly important if higher rice yields are to be both achieved and sustained on irrigated land in Asia.

This has become clear from long-term experiments undertaken in collaboration with national system scientists participating in the International Network on Soil Fertility and Sustainable Rice Earning (IN\*\*SURF) at

11 sites in the Philippines, Indonesia, Vietnam., China, and India.

Soil testing is widely used to identify soils in which, a response to fertilizer K application is likely. But most currently used testing methods describe only one or two of the key factors that govern, the capability of soil to supply K.

A novel method called the phytoavailability soil test (PST), used in IRRI's experiments, demonstrated its potential as a highly valuable tool for assessing soil nutrient-supplying capacity—not just for K but for most other essential plant nutrients as well. Use of tile test appears to be quite simple: its resin capsules can be directly inserted in the field.

One research objective of the irrigated rice program is to quantify the impact of intensification of rice cropping systems on the environment. The PST may serve as an important tool in measuring the impact of mod-

ern rice production technology on soil fertility and nutrient balance.

### Global warming effects on rice

To simulate global warming and associated increased levels of carbon dioxide (CO<sub>2</sub>) and to study their possible effects on rice crops, IRRI constructed a unique system of field chambers. In these it grew IR72 at four levels of CO<sub>2</sub> and two temperatures.

Some have suggested that increased levels of CO<sub>2</sub> will stimulate rice production whatever the temperature increase. IRRI's data from these field chambers, however, indicate that an increase of 4°C above ambient temperature eliminated any effect of CO<sub>2</sub> on yield. This was the result of a decline in the percentage of grain filling.

Thus the data suggest that the beneficial effects of CO<sub>2</sub> on rice grain yield may be nullified at the higher temperatures expected from global warming.

Another series of experiments showed what effects global warming might have on predator-prey relationships in rice ecosystems. *Cardiophiles philippinensis* is a parasite of the rice leaffolder, a moth whose larvae fold rice plant leaves and fasten their margins with thread-like silk. The larvae feed by scraping the green mesophyll from within the folded leaves, thereby reducing the vigor of the plant and allowing entry of fungal and bacterial infections.

In the IRRI experiments, *C. philippinensis* was shown to be vulnerable to higher temperatures (25-40°C). At 40°C, it could not survive. Global warming, therefore, could be expected to greatly reduce parasitism by *C. philippinensis*—and thus increase the rice plant damage produced by the rice leaffolder. ■

## Rainfed Lowland Rice Ecosystem

**T**he world's rainfed lowlands are a priority area for increased research by IRRI for two reasons: they have not benefited in the past to the same extent as the irrigated ecosystem, yet their potential is tremendous. Irrigated rice was the main beneficiary of the advances in the 1960s that led to the Green Revolution, and it is unlikely to show a comparable rate of increased yields in the future. Yet about 39 million hectares of riceland in Asia are rainfed lowlands, and hundreds of millions of the region's poorest people depend upon them for their livelihood.

# Getting to the root of drought tolerance

**A** rice plant's roots constitute its pipeline to its water supply and, in rainfed ecosystems, that supply almost always provides it with either a feast (flash flooding), or a famine (drought).

IRRI scientists, in collaboration with those in a number of other countries, are researching ways of designing plants that will adapt and yield, better under both conditions.

A plant's tolerance for drought depends on its roots' ability to find and extract water effectively from the soil (called avoidance) and on

the tolerance of its cells for reduced water supplies. It can also escape drought if its life cycle or the drought-sensitive stages of its growth are completed before drought begins.

Plant breeders and agronomists have succeeded quite well in utilizing the escape mechanism by minimizing the risk that the plant's sensitive growth stages will coincide with periods of drought stress. But until now, they have not been so successful in identifying and selecting traits for drought avoidance or tolerance. These include the density of the roots, together with the roots' ability to conduct water, to penetrate the



**A farmer in Bangladesh shows how drought affects his rice crop. The eventual goal of IRRI research is to develop a drought-tolerant cultivar that produces higher and more stable yields under rainfed lowland conditions**

hard subsoil layers that build up after repeated plowing of ricefields, and to establish themselves deeply in the soil.

One reason for this failure is that the effects of different combinations of traits are hard to distinguish in the field. The recent advent of the biotechnological techniques of gene mapping and molecular markers, however, has provided an indirect way of sorting out root traits. Molecular markers are variations in a plant's genetic material (DNA) associated with particular genes.

Using rice plant varieties known from years of experience to have drought-resistant properties, the scientists cross these with, other varieties and measure the root characteristics of the offspring in the

**One promising way of alleviating the drought in rainfed rice ecosystems is to store rainwater on the farm.**

greenhouse. They then analyze one genetic marker at a time in these plants to determine whether any of the markers are linked to root characteristics.

If they are, genes in the marker region can then be selected by biotechnological methods and transferred by further crosses from the donor to elite breeding lines. Using these techniques, IRRI, scientists have come up with the first indication found in any cereal that there exist specific chromosomal regions likely to contain genes associated with drought avoidance, which in turn are expressed in the plant's roots.

The problems are complex and require a multidisciplinary approach because the relationships between genetic traits and stresses are complex. Many traits are not even expressed unless the right form of stress occurs. Thus to be able to develop a better cultivar, the scientists need to understand the expected

timing, intensity, and duration of drought and how different trait combinations may confer an adaptive advantage under these conditions.

The scientists conducted experiments in the field in 1994 with parental lines differing in these drought avoidance characteristics to determine the conditions required for their expression and their impact on water uptake, nutrient capture, growth, and yield. An important new avenue in drought resistance research is to explore how soil nutrient supply can alleviate drought stress and promote root growth.

The results are now being analyzed. The eventual goal is development of a drought-resistant cultivar that produces higher and more stable yields under rainfed lowland conditions.

The gene marker project is also directed at finding drought resistance genes that could also be transferred to plants designed for use in the rainfed uplands.



## Highlights

### Progress toward the new plant type

Development of a new plant ideotype for the rainfed lowlands continued during 1994. The first steps taken were to incorporate, into already adapted traditional and semi-improved cultivars, traits such as submergence tolerance, and resistance to bacterial leaf blight and blast, which are considered essential for stability. At the same time, attributes such as good eating quality, adaptability to low fertility soils, and appropriate photoperiod characteristics were maintained. The majority of parental sources came from IRRI-based germplasm, the NARS breeding program, and the rice research program of Centro internacional de Agricultura Tropical (CIAT) in Colombia.

Because of the uncertainty of rainfall at the beginning of the monsoon in the rainfed lowlands, special attention was given to developing different photoperiod-sensitive types that could be planted either through dry seeding or transplanting. Photoperiod-sensitive rices will always be ready for harvest at the same time of year, regardless of when they are planted. This would allow farmers to dry seed when rainfall is normal, or transplant when rains arrive late and the fields become too wet for dry seeding.

The basic ideotype criteria have been retained: intermediate height (120-130 cm) and tiller number (6-8 with a minimum unproductive), dense panicles (150-200 grains per panicle) and sturdy stems. Lines with tolerance for or resistance to both abiotic and biotic stresses, along with desirable agronomic traits are routinely being selected and evaluated in target environments. More than 8,000 breeding lines were to be evaluated at key sites in the 1995

wet season, and some tested under farm conditions the same year.

### Saving rainwater for dry days

The most important factor holding back the crop yield of farmers in rainfed rice ecosystems is a lack of adequate water when needed. One promising way of alleviating the drought is to store rainwater in on-farm reservoirs.

Research on these storage systems has been conducted in Bangladesh, India, Indonesia, and the Philippines. Farmers in the rainfed lowland rice-growing areas of Central Luzon, Philippines, for example, have seen their land become more productive and their income increase after building such reservoirs.

The Luzon and Indonesian projects were two of a number reported at a meeting of the Rainfed Lowland Rice Research Consortium. The consortium includes rice research organizations in Bangladesh, India, Indonesia, and Thailand, as well as the Philippines, and is supported by the Asian Development Bank. Papers from the symposium were published by IRRI in 1994 in *On-farm reservoir systems for rainfed ricelands*.

The Small Farm Reservoir Pilot Project in Region III was started in 1991 by the Central Luzon State University, the Philippine Rice Research Institute, the Philippine Department of Agriculture and Department of Science and Technology, and other institutions.

Half of the farmers who financed their own reservoirs, and a third of those whose were subsidized through a pilot project, captured enough water for a dry-season rice crop on an area equal to about 40% of the farm. Most also raised fish for additional income.

The reservoirs were excavated by bulldozer and fed by rainfall and

## RAINFED LOWLAND

### RICE ECOSYSTEM

Expenditure 1994 — \$2,528,000

Approved budget 1995 — \$3,022,000

Budget planned 1996— \$3,064,000

Internationally recruited staff — 8

Nationally recruited staff — 42

### Projects

- Characterizing and analyzing agricultural environments
- Managing resources for enhanced productivity
- Germplasm improvement
- Rainfed Lowland Rice Research Consortium

runoff from adjacent slopes, with a surface area of less than half a hectare and embankment heights up to 3 m. The 29 self-financed reservoirs were on average 4 years old and had cost US\$465 each for bulldozer work. The project-financed, reservoirs were smaller and newer (on average 2 years old) and cost US\$360 each for bulldozer work.

About half (48%) of the farmers with self-financed reservoirs and a third (33%) of those with project-financed ones were able to plant a dry-season rice crop in addition to the regular wet-season one, but 60% of the total were unable to do so. Those who could roughly doubled their rice cropping costs and returns on a per hectare basis.

Two areas proposed for future research are how to increase the proportion of reservoir adopters able to grow a dry-season crop and how to increase the proportion of wet-season area planted in the dry season.

Following similar very promising results in Indonesia, the national government has recently decided to include large-scale support for reser-

voir construction as part of a \$10 million drought alleviation project to be undertaken by the East Java provincial irrigation office.

#### **Plant-feeding on schedule**

Controlled-release urea fertilizers offer the possibility of improving the rice plant's nutrition and thereby its tolerance for drought. The fertilizers do this by helping to synchronize the timing of nitrogen supply and demand, studies at two Philippine locations showed. The temperature and the type and thickness of polymer coatings on the fertilizers determine the release rates. Under drought conditions, a single dose of such fertilizer helped produce rice yields 25-35% higher than ordinary urea fertilizers applied in doses at three different times.

**Rainfed lowlands, such as this one in Vietnam, have not benefited from IRRI's research to the same extent as the irrigated ecosystem, yet their potential is tremendous.**

#### **Green manure as fertilizer**

In northeast Thailand, researchers found that applying fertilizer to a green manure crop grown before rice produced a consistently higher yield in the subsequent rice crop. The effect didn't last long, however: after 5 years, the only residual benefit to the soil occurred from applying P fertilizer to both green manure and rice crops.

#### **Too much: sometimes as bad as too little**

Other studies show that where high doses of nitrogen fertilizer were used at three sites in rainfed and partially irrigated, lowland ecosystems, a substantial loss of nitrate N occurred and seeped down through the root zone toward the groundwater table. Over time, such a movement could contaminate groundwater.

The sites were in Ilocos Norte, Philippines. Up to 516 kg of nitrate and 20 kg ammonium nitrate/ha were measured in soil to 100 cm depth in the dry season, and 106 kg nitrate/ha and 52 kg ammonium nitrate/ha in the wet season. Crop up-

take data showed 270 kg N/ha was leached into the soil.

#### **Restoring soil nitrogen with legumes**

The common lowland rice crop ping practice of following a wet-season rice crop by dry-season fallow causes large losses of soil nitrogen.

Planting green manure legumes between rice crops could help restore the lost nitrogen through their ability to "fix" nitrogen (make it available to plants from the atmosphere). But such legumes are not economically attractive to farmers because they provide no immediate income.

IRRI, NARS, and Australian scientists collaborated to determine whether grain and forage legumes might be planted instead, because in addition to providing soil nitrogen for subsequent rice crops, they could be used either as human food or animal feed.

They found that five of these dual-purpose legumes grown during the dry season yielded 5-9 t/ha of forage or forage-plus-grain—and left behind in the soil more nitrogen than they removed during both years of the test. Legume residues incorporated into the soil provided benefits comparable with those that would have come from applying 25-50 kg of fertilizer nitrogen.

The scientists now will encourage farmers to plant the dual-purpose legumes instead of fallowing. In addition, they want to ensure the long-term sustainability of the cropping system by suggesting farmers avoid removing more nitrogen from forage cuttings or grain harvests than the legumes fix.

Studies will be undertaken to identify specific dual-purpose legumes that will appeal to farmers in different locations and to determine the optimum number and time of clippings that should be taken from these. ■



# Coping with floods

I ncreasing the annual rice harvest in flood-prone areas is a critical social and economic challenge. Population densities there are increasing by about 2% a each year and reaching 1,000 people per square kilometer. They are, moreover, among the poorest people in the world, whose daily intake of calories averages only 62% of that enjoyed by people in developed countries.

In recent years this ecosystem has undergone dramatic changes, following development of flood control and irrigation facilities. Farmers have gradually abandoned the risky and low-yielding traditional deepwater rice. They keep their land fallow during the monsoon season, and increasingly grow high-yielding modern varieties, with irrigation through low-lift pumps and shallow tubewells in the dry season. During the past decade, the deepwater rice area has declined, substantially in Vietnam, Thailand, Bangladesh, and West Bengal, India.

## The Vietnam story

In Vietnam's Mekong River Delta, a major part of the production system was converted, from deepwater to irrigated rice. A survey conducted there by the Farming Systems Research and Development Center of the University of Cantho, in collaboration with IRRI's Social Sciences Division, showed that the development of a massive system of irrigation canals and flood, control embankments revolutionized the farmers' rice production system and increased their income.



## Flood-prone Rice Ecosystem

B esides the usual problems of drought and infertile soils faced by rice farmers in rainfed areas, those on about 20 million hectares in Asia and Africa must deal with another: uncontrolled flooding of their fields. Depending on location, floods can submerge plants for 1-10 days, cover them under 3-4 m for several months, or inundate them with tidal fluctuations during part of every day. Although the flood-prone ecosystem accounts for only 7.7% of the global rice harvested area, in delta regions it assumes great importance. New rice varieties and cropping systems must be adapted to the highly varied environmental conditions in these areas.

The flood prone rice ecosystem, like this one in Cambodia, is undergoing dramatic changes as many farmers seek ways to increase productivity.

The change in the production system was from traditional deep-water rice cropping followed by one or two upland crops such as sesame, maize, mungbean, watermelon, and vegetables to two irrigated lowland rice crops.

In 1982, the deepwater system occupied nearly 66% of the rice area in the delta, but by 1989 the share had dropped to 38%.

The increase in crop value as a result of the conversion of the system amounted to about four times the cost of the total investment by both governments and farmers. Even accounting for the diversion of labor from other activities to the intensified rice farming, the net gain, to the farming community is estimated at about 2.5 times the investment cost.

Household income from rice farming increased by about 27%, mainly because the conversion allowed greater scope for employing family labor.

Since 1980, the Vietnamese population has increased by 35%, while rice production increased by 82% and rice yield 58%. Two-thirds of that increase came from the Mekong River Delta, which occupies 44% of Vietnam's riceland.

The increase was partly a result of massive investments in development and maintenance of canals and flood, control embankments, drainage, and irrigation, by provincial and district governments and farmers. The governments paid for main and secondary canal construction, while farmers bore the cost of building tertiary canals, dikes and bunds, and the associated pumps.

All farmers in the flood-prone ecosystems used traditional deep-water rice varieties, which are low-yielding, whereas all farmers in the irrigated, system planted higher yielding, modern cultivars. All employed

direct seeding for crop establishment and mechanical threshers.

The major difference between the two systems was in their use of chemical fertilizers and pesticides: those in the irrigated system used much more.

A spectacular rice yield increase followed the conversion of the ecosystem: from 2.4 t/ha per year in flood-prone rice to 10.8 in the irrigated system. The difference in gross value is less, however, because deepwater rice has better quality and commands a higher market price.

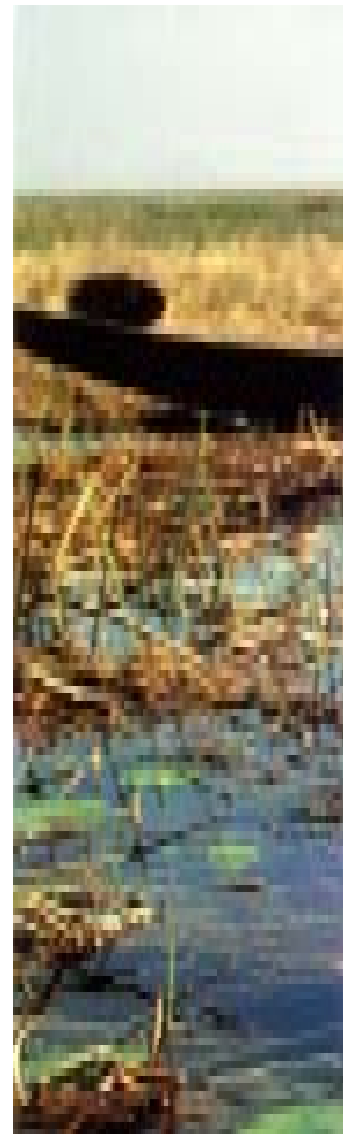
The rice yield increase was achieved at the expense of the upland crops grown after harvest of the deepwater rice. But even when this loss was taken into account, agricultural production for the year as a whole still increased 49% over the value of the produce in the flood-prone system.

The net gain of agricultural incomes from the conversion is estimated at US\$195, a rough rice equivalent of 2.35 t/ha.

The change of cropping systems had a positive effect on the rural economy as a whole, because the expanded market, not only for the rice surplus but also for nonfarm goods and services, generates additional employment and income in the rural trade, transport, and service sectors. This contributes to socio-economic equity and alleviates poverty.

The conversion has not been without its problems, however. The increased use of pesticides and fertilizers in the irrigated, system has been blamed for reduced fish production and environmental pollution. Vietnam is seeking the most sustainable production system for the remaining 600,000 hectares of deep-water rice in the Delta, and the International Center for Living Aquatic Resources Management (ICLARM), based in the Philippines, is aiding in

**Harvesting rice in flooded-and cyclone-ravaged deepwater ricefields in Bangladesh.**



the investigation of the fish production problems.

An additional problem is salinization from the influx of seawater into irrigation canals during the city season.

### **Bangladesh and West Bengal**

In Bangladesh and West Bengal, India, IRRI social scientists found in a collaborative study with NARS that topography is the crucial factor affecting the substitution of deep-water rice by boro rice. In Bangladesh in 1990, farmers practiced the boro-fallow cropping pattern in 81% of the land, flooded to a depth of 180 cm or more. But the boro-deepwater rice pattern was practiced in 92% of land flooded to a depth of 30-90 cm, and in 33% of land



flooded between 90 and 180 cm. A similar pattern was found in West Bengal.

Economic gains from adoption of the boro–deepwater rice cropping pattern, compared with those from the boro–fallow pattern, were found to be higher and the risk lower in shallow than in deep-flooded areas.

The adoption of boro rice in the flood-prone system has had an impressive impact on food availability and farmer income. Farmers now get a relatively stable yield of about 5.5 t/ha of boro compared with an unstable yield of 1.5 t/ha of deepwater rice (the deepwater rice yield depends on the seasonal flood pattern). Although the cash cost of production is almost three times higher with boro, per ton of output it is al-

most 40% lower—and the farmer’s net income is twice as high.

As food needs increase with rising populations, farmers will seek to increase the productivity of deepwater rice areas, particularly if decreasing investment in irrigation halts the expansion of the boro area. A systems approach to research for the flood-prone ecosystem is needed to explore possibilities for extending the boro–deepwater rice cropping system and to develop appropriate deepwater rice varieties and cropping methods.

Critical research areas are development of cold-tolerant, short-duration boro varieties; tall submergence tolerant deepwater varieties with early seedling vigor; and short-duration transplanted, photoperiod-

sensitive modern varieties that could be established in shallow flooded land after floodwaters recede.

## Highlights

### A long search rewarded

Zinc deficiency is the most important micronutrient disorder in two million hectares of wetland ricelands in the Philippines, despite a government-sponsored zinc fertilizer program started in 1978. The problem is widespread also elsewhere in intensively cropped parts of South and Southeast Asia.

Zinc-deficiency stress can reduce yields and when severe can kill rice plants. Rice varieties differ in their

## FLOOD-PRONE RICE ECOSYSTEM

Expenditure 1994 – \$799,000

Approved budget 1995 – \$1,070,000

Budget planned 1996 – \$1,097,000

International recruited staff – 3

Nationally recruited staff – 10

### Projects

- Germplasm improvement
- Improved crop and resource Management for flood-prone areas

ability to utilize zinc: zinc-efficient varieties yield 2 t/ha more than varieties lacking the trait.

When zinc deficiency is mild to moderate, zinc-efficient varieties can produce yields of 3 t/ha without zinc fertilizer. On marginally deficient soils, such fertilizers are not needed and can even depress yield. Where the deficiency is severe, a combination of varietal efficiency and zinc applications is necessary.

For 20 years, IRRI has been searching for a rapid, repeatable screening method of identifying zinc-efficient rice varieties. Their use would save farmers the money they

now spend on zinc fertilizers, and the country as a whole almost an estimated. \$38 million a year in foreign exchange

The current screening method, in which candidate lines are grown and replicated, in farmers' fields, is laborious and slow. It is not specific solely to zinc deficiency stress, and its accuracy is limited by the ability of observers to identify symptoms visually.

In 1990, Dr. Paul Bloom of the University of Minnesota came to IRRI as a visiting scientist and brought with him a computer program software called Geochem, which permits prediction of activities of chemical nutrients in solution. With Dr. Bloom, the University of Minnesota, Philippine research agencies, and scientists in IRRI's Soil and Water Sciences Division set up a collaborative study to use Geochem to develop a new test for zinc-efficient rices.

The new technology, in which the rice plants are grown hydroponically in a solution containing optimum amounts of all required nutrients except zinc, was perfected in 1994. It fulfills IRRI's requirements of speed and repeatability, and un-

like the formerly used method can be used under greenhouse conditions. It is also helping IRRI scientists to study the genetics and the mechanisms of zinc utilization in the rice plant.

### Improved deepwater rice produces high yield

The Thailand-IRRI collaborative regional flood-prone rice breeding program has developed several advanced lines possessing the characteristics of the new deepwater rice ideotype first proposed in 1989.

Tests conducted in Thailand with two lines yielded almost 5 t/ha while tests conducted at IRRI revealed that the modern deepwater rice types have the potential to attain yields equal to those of irrigated rice in the wet season when both are grown with 80 kg of N fertilizer.

A large number of elite breeding lines with IRRI's new tidal wetland rice plant type were also developed, and distributed to NARS for testing in target environments.

Although the lines still need to be improved for their resistance to diseases and insects, their ability to produce 3-4 t/ha yield on coastal rice soils was confirmed. One of the lines, IR52713-2B-8-2B-1-2, has been selected by the Philippines for cultivation in salt-affected coastal ricelands. ■



Examining advanced lines of deepwater rice at IRRI's research station.

## Upland Rice Ecosystem

**T**raditionally, upland rice farmers have been among the world's poorest. In Asia, where 64% of the world's upland rice is grown, most use few purchased inputs or none at all, and do most of their work by hand. Logging followed by slash-and-burn agriculture eventually results in degraded upland soils, and the resultant erosion causes problems in the lands below. But in many areas this picture is changing. As a result of the increase in population and competing demands of urbanism and industry, as well as high-value cash crop farming in the lowlands, there is a movement toward permanent agriculture and intensification of land use in the uplands. Thus, to the usual upland agricultural problems of drought and infertile soils are being added others, such as conservation of the soil and of biodiversity, and an increase in incidence and severity of weeds and diseases. Behind this evolution is the push of people toward a better way of life, to which IRRI is trying to contribute.

A typical  
Laotian upland  
rice ecosystem.

## Resisting blast in the uplands

**B**last, caused by the fungus *Pyricularia grisea*, is one of the most damaging diseases of rice (see also "Learning to outwit the wily blast fungus," p. 39) In the uplands, it is particularly important because the environment favors its proliferation. Although many traditional upland cultivars show stable resistance to blast under low-input cropping practices, these cultivars have other characteristics that make them difficult to

use in intensified systems. So, as cropping practices are intensified and improved varieties are introduced, the risk of blast destabilizing rice production increases.

To ensure that new upland varieties will have effective, more durable blast resistance, IRRI scientists have been working with colleagues in the Upland Rice Research Consortium to better understand the pathogen populations present at upland breeding sites and to identify the genes that give some cultivars their excellent resistance. An intensive study



carried out at IRRI's upland screening site in the Philippines, using DNA fingerprinting and inoculation tests, systematically analyzed. Hundreds of isolates.

By learning how different sub-populations of the blast fungus attack different rice varieties, the scientists have gained, insight into the resistance of these varieties, which helps them determine how best to deploy the genetic diversity of the rice cultivars to match the diversity of the disease. For example, they determined that even susceptible varieties can resist some attacks.

Based on the DNA fingerprinting analysis, they designed what they call "smart" and "dumb" mixtures of cultivars and lines. And, as predicted, the smart mixtures proved more effective in reducing blast disease than the dumb ones in their first year's field trial.

After 2-3 years of testing of gene mapping populations in the field at Upland Consortium sites in the Philippines and Indonesia, the researchers identified minor genes effective across sites, years, and populations.

Now they are working with IRRI's upland rice breeder, using marker data, to combine such genes with

other desirable traits for incorporation into new upland varieties.

## Highlights

### Trying to control erosion

Scientists involved in the Upland Consortium are trying to understand how upland rice farmers' cropping systems contribute to soil erosion. What they learn will be used to propose possibilities for erosion control.

The study involves analysis of how and why farmers make decisions concerning their use of the land, as well as an understanding of



The study, which began in Thailand in 1994, involves Maejo University, Chiang Mai University, the Department of Public Welfare, and the Hill Area Development Foundation in Chiang Rai Province in northern Thailand.



the contributions of various landforms and climatic factors.

The study, which began in Thailand in 1994, involves Maejo University, Chiang Mai University, the Department of Public Welfare, and the Hill Area Development Foundation in Chiang Rai Province in northern Thailand.

Previous studies in the Philippines have indicated that hedgerows of multipurpose trees, shrubs, and grasses along the contours are effective in reducing soil erosion in the uplands. But labor costs and other considerations limit their use. An alternative is to allow natural vegetative strips to develop across the contour.

Whichever method is used, the alleys between the hedges become stabilized only after a few years. During the course of terrace development, soil erosion continues, scour-

ing of surface soil from the upper slope, and accumulation of it below, produce a fertility gradient within each alley. And associated with this fertility gradient are gradients in weeds, crop growth, and crop water use.

The scientists are trying to understand this variability within terraces so as to develop management practices during and following the transition from sloping lands to level terraces.

#### **Improving the soil and dealing with weeds**

Poor soil fertility and weed infestation are major problems for upland rice farmers. A team of researchers wants to help improve farmers' practices to deal with these problems, but little is known about them and their effects on the environment and rice yield.

Starting in 1993, researchers from IRRI, Maejo University, and Chiang Mai University launched a study of the interactions between weeds, crop environmental conditions, and farmers' practices in, upper northern Thailand.

The goals are to understand the diversity of farmers' practices and decisionmaking processes and to grade the factors that limit rice crop yields.

IRRI and national scientists are also studying how fertilizer and cultural practices influence weed community dynamics. In one study on phosphorus management, started in 1994, they are investigating how weed communities change as soil fertility is improved over time. This study is being implemented in the Philippines, Indonesia, and Thailand.

## UPLAND RICE ECOSYSTEM

Expenditure 1994—\$1,066,000

Approved budget 1995—\$1,751,000

Budget planned 1995—\$1,789,000

Internationally recruited staff—5

Nationally recruited staff—19

### Projects

- Germplasm improvement
- Rehabilitation and sustainability of Upland rice-based farming systems
- Developing a perennial rice plant a sustainable system for the uplands
- Upland Rice Research Consortium
- Managing weeds using less chemicals— the role of allelopathy and biological control
- Land use systems for more sustainable And efficient use of water and soil nutrients

### Rice plants and competitiveness

Rice plant cultivars differ in their ability to compete with weeds in the field. So by planting a highly competitive cultivar and enhancing its competitive ability through good management practices, farmers may be able to reduce the number of handweeding necessary while achieving optimum yields.

Twelve rice cultivars were tested for their competitiveness against weeds in Matalom in Leyte and Tanauan in Batangas, Philippines. Weeding treatments varied, and the size and weight of weeds were tabulated against the yields and yield reductions of the cultivars.

Of the 12 cultivars, Vandana was found to be most competitive.

### Improving soil fertility

Studies carried out on upland ecosystem farms in Thailand, Laos, and the Philippines have confirmed the impression that low levels of phos-

phorus are already limiting rice crop yields under present-day on-farm conditions.

Many highly weathered upland soils are inherently low in P and are acidic. Insufficient P will limit production even if attempts are made to overcome acidity problems by adding calcium or planting acids tolerant cultivars.

The IRRI studies indicate that even subsistence level productivity may not be sustainable without P inputs from outside the soil-plant system. But with P imported, rice-legume rotations could permit stable, higher value production.

If high-value, sustainable agriculture is a future possibility, larger investments in soil conservation can be justified today. But the transition to high-value agriculture cannot occur if soil fertility and quality decrease over time. It may thus be mandatory first to improve soil fertility.

Returns on investments in soil improvement should increase over time as P inputs exceed crop needs in systems that include legumes, because of the synergistic and cyclic effects on legume-fixed nitrogen and on cycling of nutrients, particularly C, N, and P. IRRI scientists are investigating how P can be managed over the long term, in such a way that C, N, and P can be better cycled and effectively used in the system.

### Breaking the acid barrier

Subsoil acidity prevents crop plant roots from reaching subsoil moisture and nutrients in many upland areas, thus reducing yield. The problem can be remedied by incorporating lime into the subsoil, but that is not generally practical. An alternative may be to leach down the components of surface-applied lime by manipulating the soil chemistry, and us-

ing deep-rooted, acid-tolerant rice cultivars to help capture the leached components in the subsoil. Conditions may thereby be gradually improved, to the point where high-value cash crops can be grown.

In 1994, IRRI and Indonesian scientists began a series of experiments to develop a technology based on these ideas. Initially they are investigating the processes governing the rate of leaching of lime components and their accumulation in the subsoil. In particular, they are studying how the concentration of calcium cations (positively charged ions) in the soil water is affected by the nature of the accompanying anions (negatively charged ions), and the consequences for the rate of leaching.

For example, nitrate anions should maintain a higher concentration of calcium in the soil water than bicarbonate anions—the anion component of lime—and should therefore be leached faster; sulfate should be intermediate. Also, nitrate uptake by roots in the subsoil will be balanced by the release of alkali into the soil, further enhancing the acidity amelioration.

The experiments will quantify these processes so that mathematical models can be developed. The models will be used to develop practical technologies and to indicate the conditions under which the technologies might be effective.

The experiments were started at the Upland Rice Research Consortium site at Sitiung, Indonesia. French collaborators from L'Institut français de recherche scientifique pour le développement en coopération (ORSTOM) are planning similar experiments in Thailand and Vietnam. ■

# A new concept promises to increase yield and sustainability

**T**he best ideas in science are often so simple that, once they are conceived, it is hard to imagine why nobody thought of them before. This appears to be the case with a proposal to change the height of the rice plant's panicles in the canopy.

The panicles are the parts of the rice plant that bear the spikelets, which in turn form the grain. The yield of the rice plant depends on the amount of starch that fills the grains. This in turn depends primarily on the process of photosynthesis occurring in the leaves.

Photosynthesis requires sunlight as a source of energy. But the architecture of rice plants places the panicles high in the canopy, which

means that some of the leaves, paradoxically, are in the shade—and thus obviously not in the best position for maximum photosynthesis to occur. This is true not only of traditional rice plants, but also of modern, high-yielding cultivars.

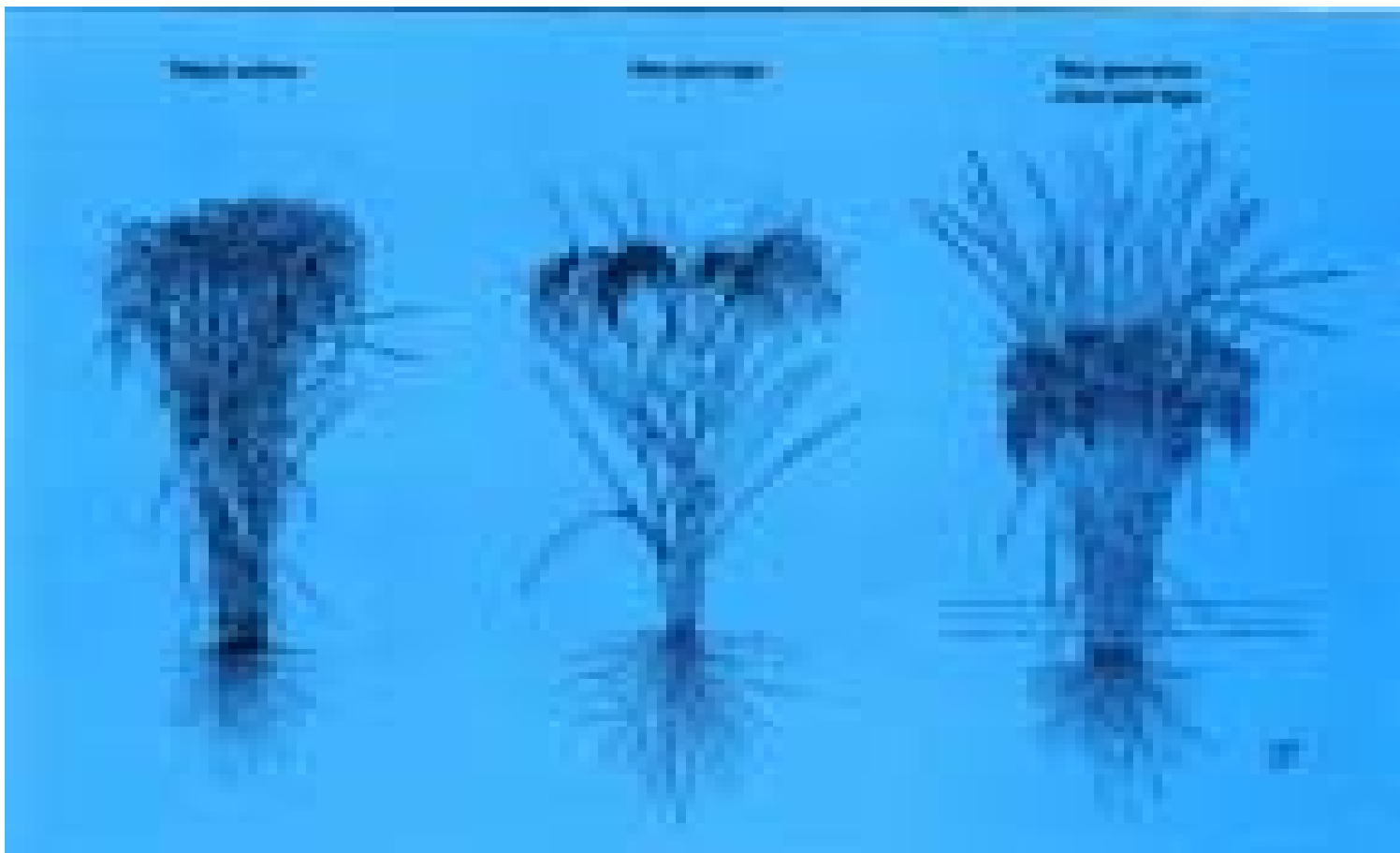
When IRRI scientists decided to imagine how it might be possible to increase a rice plant's yield by a huge amount—up to 500—it became obvious that the architecture of both traditional and modern cultivars had two serious faults. What was needed was to lower the panicles in the canopy so they no longer shaded the leaves.

In addition, the scientists saw that such a step would solve a second major problem: when yields are increased on a plant with panicles high in the canopy, the extra weight of

## Cross-ecosystems Research

**S**ome research objectives are applicable to all ecosystems and are best conducted in one program.

Here the focus is on work with a long time frame and, a large geographical reach. It involves new techniques and tools, and it integrates ever wider levels: the biological (from gene to cell, tissue, plant, ecosystem, and global community); the relationships between ecosystem components; and across several ecosystems.



the grains causes the plants to fall over (lodging), especially when it rains and the wind blows. But if the panicles were lowered, this tendency would be reduced because the center of gravity of the plant would be lowered.

To test the idea that lower panicle height would increase light interception by leaves and thus photosynthesis of rice, the scientists used six approaches. They

- removed panicles completely from plants to simulate very low panicle heights;
- made artificial panicles from oven-dried ones removed from other plants, attached these to sticks, and placed them at different heights in the plant canopy;
- manipulated plants with hormones in such a way as to increase or decrease panicle height;
- studied metabolism and yield of two pairs of isogenic lines differing only in panicle height (isogenic lines are lines identical genetically except at one point on the chromosome);
- compared photosynthesis in the flag leaf (the uppermost leaf) and in the panicle to evaluate the impact of lowering panicle height—hence irradiance—on panicle photosynthesis. (This was done to see whether changing light absorbance by the panicle would affect the rate of photosynthesis in the canopy as a whole);
- used computer models and rotational inertia equations to show the effects of different panicle heights.

All of these methods confirmed the importance of lowering panicle height to increase photosynthesis and yield, as follows:

- Cutting off the panicles in Philippine experiments resulted in an increase in canopy photosynthesis from 30 to 50%—a huge factor. With already high-yielding cultivars in Australia, the increase in photosynthesis was even higher than 50%.
- Plants with artificial panicles lowered to 60% of canopy height showed an increase in canopy photosynthesis of 32% over plants with panicles placed at full canopy height. When large amounts of nitrogen were added, the canopy photosynthesis increase rose to 150 to 240%.
- The hormone experiments (which took almost 2 years to complete) allowed the scientists to vary panicle height over a range of 15 cm without changing the height of the canopy. Plants with low panicle heights had up to a four-fold increase in light interception by leaves above the panicles, and a 42% greater canopy photosynthesis than high panicle plants.
- In the case of the isogenic lines, the scientists' calculations, based on the observed increase in photosynthesis with the low panicle height line, led them to expect a 15% yield increase. In fact the actual yield increase measured 30%.
- When the response of leaves versus panicles was measured at different levels of irradiance, some particularly important results were obtained. Reducing by half the irradiance of panicles, by lowering their height in the canopy, had little or no effect on canopy photosynthesis. However, doubling the irradiance of a flag leaf, by placing it above the panicles, nearly dou-

bled its photosynthesis. This indicated that photosynthesis going on in the panicles would not detract from that going on in the canopy as a whole.

- All the above results were consistent with the computer modeling predictions that lowering panicles from 90 to 35% of canopy height would increase canopy photosynthesis by 25-40%. However, placing panicles lower in the canopy might result in other undesirable effects: for example, the quality of the grains might be decreased due to the high humidity environment. Therefore scientists are continuing to examine to what extent the panicles can be lowered to achieve increased yield without producing other undesirable effects.

Measuring a plant's susceptibility to lodging is difficult. But by applying a mathematical formula, the scientists were able to determine that by lowering panicle height from 70 cm to about 50 cm, there will be no increase in lodging with tip to a 50% yield increase.

The significance of these findings is that lowering panicle height is a technique that breeders worldwide can apply immediately to any plant type. The yield advantage can be obtained from cultivars that have been successfully adapted over many decades to local environments, and that incorporate locally desired eating qualities. The technique can be applied equally to new or modern plant types.

One further advantage is that a plant that can increase its canopy photosynthesis by 25-40%, without requiring an augmented nitrogen supply, is displaying a high level of nitrogen use efficiency. And this means that plants with low panicles are more sustainable.

IRRI scientists are now applying this concept in a breeding program aimed at further testing and increasing the yield of modern, high-tillering, semidwarf rice.

## Highlights

### Learning to outwit the wily blast fungus

Using a combination of new biotechnology tools and traditional breeding methods, IRRI scientists are coining to grips with the complexities of one of the most serious diseases of rice: blast.

Blast is a fiendishly clever foe. Much as influenza, viruses mutate repeatedly to escape the defenses of the human immune system, the blast fungus continually adapts to enable it to overcome the genetic resistance of its rice host. To meet this challenge, rice breeders must continue to redesign new and different resistant cultivars.

Attempts to manage blast have usually employed cultivars with genetic resistance to the disease. But the results have often been unsatisfactory, with resistance breaking down after a year or more.

At least 30 blast resistance genes are known, and the scientists' task is to figure out how to use them for effective and stable protection of the crop. Of the known, resistance genes, 20 give complete protection against certain blast races (these are known as "major genes"), while the others offer lesser, but more long-lasting, protection ("minor genes").

DNA markers were used to identify the chromosomal positions of rice genes that confer resistance to blast. Both major genes and minor genes have been identified, mapped, and characterized at IRRI over the past few years. Much of the molecular genetic analysis of resistance was

focused on rice varieties considered to have particularly stable resistance.

Based on the information gained from this effort, DNA marker-aided selection was first applied to IRRI's rice breeding program in 1994. Rice lines carrying pairs of resistance genes were selected based on DNA marker data, and the "gene pyramid" lines are now being evaluated in field and greenhouse tests. The results are being used in models aimed at choosing the best long-term strategies for utilizing resistance.

As well as studying the host genetics with marker technology, IRRI scientists are studying the pathogen's genetics to help them in their selection of resistance genes for breeding. They are combining the DNA marker data with information gained through greenhouse inoculations. This provides insight into the ways in which the pathogen is likely to change and, into the ways in which the resistance genes can best be used. The goal is to learn how best to combine the various resistance genes in rice cultivars in a way that

will provide long-lasting protection against blast.

The researchers' efforts to unravel Blast's complexities and produce varieties with strong and stable resistance have given them great respect for the pathogen's adaptive abilities. Although they are confident that they can breed rice with better and more durable resistance, they have come to believe they will never be able to fashion a single variety with perfect and perpetual blast resistance.

The problem of unstable resistance results from pathogen diversity; a key part of the solution, they say,

**Much as influenza viruses mutate repeatedly to escape the defenses of the human immune system, the blast fungus, as shown here, continually adapts to enable it to overcome the genetic resistance of its rice host.**



is the small use of host diversity. Thus, current research is aimed at finding out how genetic diversity can be incorporated into rice varieties, and how farmers can diversify and deploy the varieties they plant.

**Setting weeds' natural enemies to kill them**

Weeds are the major biological constraint to rice production worldwide, and (as described on p. 42) are expected to become even more problematical as costs increase for labor and water supplies. These factors, together with the relatively low cost of herbicides, make an enormous increase in chemical control of weeds virtually certain for the future.

The danger is that this might lead to farmers' reliance on only one form of control, which could become ineffective if weeds developed herbicide resistance. There is also a potential risk that widespread use of the che-

micals might have undesirable effects on human health and the environment.

IRRI scientists are developing another, relatively new method of weed control: the deliberate infection of weeds with their natural pathogens. One version of the tool is showing promise in greenhouse and field studies.

Whether or not it is produced commercially, it appears promising as a safe and cheap form of weed control farmers could exploit directly or purchase cheaply through a cottage industry.

Gooseweed (*Sphenoclea zeylanica*) is a common annual weed of wetland rice, which competes efficiently with the crop in nitrogen uptake, causing significant yield reductions. It also interferes with harvesting. One of gooseweed's few natural pathogens (*Alternaria* sp.) which causes leaf blight, was chosen

by IRRI to use as a biological control.

The pathogen was grown on sorghum seeds and its spores placed in a liquid suspension and sprayed first in greenhouse trials and then in the field. Even at lower concentrations, most treated plants were dead in 3-5 days, and within 2 weeks all had died.. In the field tests, most treated plants were either dead or leafless after a week and, 2 weeks after treatment, excellent control of the weed was obtained.

Because the market for *S. zeylanica* is probably too small for commercial product development, IRRI is developing methodologies for on-farm or cottage industry production of the inoculum.

In 1994, further experiments were carried out with pathogens to barnyard grass (*Echinochloa crus-galli*), which is difficult to control in both



Figure 1. Rice plants showing damage from the biological control pathogen *Alternaria* sp. applied to gooseweed. The plants are dead or leafless after treatment.

irrigated and upland rice culture. A species that produced 50-80% weed kill in the field and was not harmful to rice was found. It requires relatively long wet periods after application (8-16 h) to produce high mortality, so the researchers are trying different liquid formulations to shorten this time.

This is the first time this technology has been tried in Asia, and only a few biological control agents have been produced in the United States and Canada. One reason is the high species-specificity of the pathogens and the consequently small market. Another is the high cost that would be involved in meeting regulatory specifications for commercial products.

But the work seems to have commercial potential, because barnyard grass is among the world's most widespread weeds, affecting not just rice but other major cereals.

#### **Gains and losses in land conversion**

The loss of agricultural land to urban uses results in gains as well as losses to society, an IRRI study shows.

It also disproves, at least for the Philippines, the common notion that diversion of riceland to nonagricultural uses is occurring on a grand scale.

The study, based on provincial records and farmer interviews assessed the impact of agricultural land conversion in four provinces surrounding Metro Manila: Bulacan, Cavite, Pampanga, and Laguna.

In these provinces, only 30% of the converted lands was formerly riceland. Even assuming a percentage of 50%, only 8% of the total riceland would be lost.

For the nation as a whole, the best estimate of riceland conversion amounts to only 0.6% of the total riceland, the study shows. This means an annual decline in total rice production of about 2.0%.

But while the area converted is small, the production loss is still significant because the conversions occurred mainly in high yields potential irrigated areas that are the main suppliers of rice for urban consumers.

A majority of the farmers interviewed (54%), however, saw themselves better off as a result of the conversion. About 31% rated their economic status as the same as before, while 15% felt worse off.

They received a mean compensation of \$38,840 ha for their land if it was converted, to residential sites or \$8,480 for conversion to industrial sites. Compensation usually included cash and residential lots.

Former riceland was valued almost twice as high as sugarcane areas. Landowners received much greater compensation (an average of \$66,200) for their land than tenants (\$15,280).

About half those interviewed spent part of their compensation to build or renovate a house and buy furnishings. Only 35% invested a portion into income-generating activities, while a small percentage used cash to clear debts, acquire new land, or fund their children's education.

The conversions had positive consequences for society as a whole through creation of vast employment opportunities: in Cavite alone, three big industrial estates generated about 33,000 jobs. The higher pay from these jobs also triggered development of local markets and additional

#### **CROSS-ECOSYSTEMS**

Expenditure 1994 — \$3,755,000  
Approved budget 1995 — \$4,713,000  
Budget planned 1996 — \$4,788,000  
Internationally recruited staff — 11  
Nationally recruited staff — 66

#### **Projects**

- Assessing the potential of rice germplasm
- Biotechnology tools for rice breeding
- Exploiting biodiversity for sustainable pest management
- Systems approaches for quantifying performance of rice ecosystems
- Constraints to sustainable development of rice ecosystems and technology impact and policy analysis

revenue for local and national governments through taxes.

Whether agricultural land conversion leads to a net social cost or benefit depends on a number of factors, the study notes. These include the agricultural potential of the land, the existence of alternative sources of food in the region, and the resulting increase in labor income.

Careful planning of urban expansion, guided by sustainable development principles and existing laws and regulations, will help preserve as much prime agricultural land as possible, the study concludes. A rational land use policy will help determine the most economically and socially efficient use of available lands.

As economies grow, it is inevitable that agricultural resources will be converted, to nonagricultural uses, and the question is not whether it is happening but how quickly—and also what is the quality of the land being converted. ■

# NEW FRONTIER PROJECTS

**If IRRI is to help produce the 360 million more tons of rice that will be needed by 2025, with less land, labor, water, and pesticides, it must pursue some goals that will take it to the frontiers of knowledge.**

In the financial world, high-risk investments have their place in a well-planned portfolio because of their great potential payoff. The same is true of high-risk investments in research.

If IRRI is to help produce the 360 million more tons of rice that will be needed by 2025, with less land, labor, water, and pesticides, it must pursue some goals that will take it to the frontiers of knowledge.

Four projects have been identified that fall into this category. Called New Frontier Projects, they are being undertaken because of their unusual potential to increase rice production while conserving resources and protecting the environment.

These projects will be carefully monitored, and evaluated during their lifetime and continued only if they produce worthwhile results. Two deal with rarely researched mechanisms called allelopathy and apomixis; another with the possibility of genetically transferring nitrogen-fixing capabilities to rice; while the fourth will attempt to develop a perennial rice plant. Descriptions of them follow.

#### **Rice plants that fight weeds**

More than 300 years ago, the Japanese found that rain and dew dripping from pine trees produced detrimental effects on crops planted underneath. Some gardeners are familiar with the ill effects that roots or



If farmers could use rice plants with allelopathic activity against weeds, they might be able to reduce the use of herbicides or laborious handweeding.



fallen leaves of black walnut trees have on certain nearby fruit, vegetables, and other plants. This ability of some plants to produce chemicals that interfere with the development and growth of other plants is known as allelopathy.

For some reason, it has been given little scientific attention, although researchers in Japan, the United States, and elsewhere have made some interesting findings. But with the change in rice culture to direct seeding (see “Using water more efficiently”, p.13), and the increasing use of chemical herbicides rice scientists sought alternative tools for weed control. If farmers could use rice plants with allelopathic activity against weeds, they reasoned, they might be able to reduce the need to apply herbicides.

In 1994, greenhouse tests at IRRI of 46 rice cultivars showed that 11 of them had an allelopathic effect against one weed, barnyard grass (*Echinochloa crus-galli*), nine cultivars had such an effect against another weed, rice flatsedge (*Cyperus iria*), and one against both weed species. It remains to be proved that the effects are caused by chemicals exuded from the rice plants, and the exudates must be identified and then validated against known chemicals before further research can be undertaken, but the findings are encouraging.

#### The hunt for the apomixis gene

Hybrid rices show the rapid plant growth and increased size and fertility known as hybrid vigor. They can produce up to 30% more rice than conventional varieties. In China, they helped increase rice production by nearly 200 million t between 1976 and 1991, and, tropical hybrids are now being grown by farmers in India.

IRRI has been working on rice hybrids since 1979. But rice will not cross-fertilize naturally: hybrids must be produced through induced crosses, and crosses produced in this way do not breed true. That is, they do not produce offspring with characteristics identical to the parents. They also lose their yield advantage in subsequent generations. Because of this, if farmers wanted to plant rice hybrids, they would have to buy seed for each new crop—something they probably could not afford because hybrid seeds usually cost 10-15 times more than ordinary seed.

Apomixis is a process of asexual seed reproduction—reproduction without the union of egg and male gamete—that occurs naturally in seed-bearing plants. Apomictic hybrids do breed true, so if this process could be found in rice, farmers

would be able to use seed from one harvest to plant their next crop, year after year, and thus enjoy the increased yield and vigor found in hybrid plants.

Unfortunately, although apomixis occurs in more than 300 plant species, rice appears not to be one of them. The process of apomixis has been known for 100 years, yet despite recent intensely competitive searches by scientists worldwide for a gene that expresses it in rice, such a gene has never been found. IRRI scientists are among those still searching for apomictic rice varieties, but the chances of finding one seem remote.

IRRI scientists are, however, trying to find other ways in which apomixis might be made a practical proposition for farmers. Rice is a species of grass, and many grasses

**If hybrid rice plants could reproduce through apomixis, farmers could use seed from one harvest to plant their next crop.**



are apomictic, so the scientists are seeking ways in which genes controlling the apomictic response in other grasses could be transferred to rice.

An apomictic rice plant would offer exciting possibilities for rice farmers.

### **Helping plants to generate their own nitrogen**

An important way of increasing a plant's rice yield is to enhance its capacity to manufacture carbohydrate during grain filling. This calls for maximum photosynthetic efficiency, which in turn requires adequate nitrogen in the plant's leaves.

That nitrogen must come from the soil or from chemical fertilizer. But some plants—legumes—form a symbiotic association with bacteria inside the roots that can make nitro-

gen in the atmosphere available to the plant. If rice plants, too, could be induced to better utilize the amounts of nitrogen available to them in this way, they would require less nitrogen from chemical fertilizer. With increasing populations and consequent food needs, demands for nitrogen fertilizer will continue to grow, as will consumption of nonrenewable electrical energy to produce it. Hence the importance of alternative nitrogen supplies.

IRRI scientists, in collaboration with those in Michigan State University, USA, and the Centre national de la recherche scientifique, France (CNRS), are trying to achieve invasion and colonization of rice plants by nitrogen-fixing organisms called diazotrophs. To do this, they are taking two approaches. In the first, they are seeking to identify rice vari-

eties able to harbor diazotrophs in their roots and stems and to enhance the numbers of diazotrophs so as to increase the amounts of nitrogen fixed. They have already found that some rice varieties, such as IR74, harbor diazotrophs in greater numbers than do others.

In the second approach, the researchers are assessing opportunities to develop legume-rhizobia-like symbiosis in rice. Recently they have identified rice-rhizobia couples that can interact favorably with each other to some extent, but they have not yet found full-fledged nodulation. To understand why, they are investigating the biological processes involved in the cell. The knowledge gained might make it possible to induce rice to nodulate through genetic engineering.

### **Developing a perennial rice plant**

Repeated cropping of rice in fragile upland soils causes erosion. A permanent strip of ground cover is needed to reduce this loss of soil. Contour hedgerows are now recommended for this purpose. But a perennial rice plant could be used—if one could be developed.

IRRI scientists have found that, among the 11 wild species of rice, two possess suitable perennial characteristics. They want to use the tools of biotechnology to transfer these characteristics to upland rice.

But first they must identify the mechanism that controls perenniality, tag the genes responsible, and screen a large population of wild species with other desirable traits. After that, they will try to recombine the wild species and upland cultivars.

Success could mean a more abundant food supply for some of the world's poorest farmers achieved in an environmentally benign and sustainable way. ■



# PARTNERSHIPS: MAKING THE MOST OF RESEARCH RESOURCES

**While scientists bring to on-farm research their specialized knowledge, farmers contribute their indigenous knowledge, based on centuries of collective experience. They also provide the scientists with feedback on the performance of new technologies.**

**T**he world has changed greatly since 1960 when IRRI was founded—and IRRI's role has changed with it. For more than a decade, IRRI was the only international agricultural research organization concerned with rice research, while many of the national organizations were at an embryonic stage. Since then, the research capabilities and commitments of many countries have been markedly strengthened.

As this has happened, IRRI has increased the proportion of research that it carries out in collaboration with the national bodies. It has also reached beyond them to other kinds of institutions. And with the development of emerging fields such as biotechnology and systems analysis, it has assumed entirely new research obligations, collaborating with institutions in the industrialized world that work at the frontiers of knowledge.

IRRI's first annual report, for 1961-62, shows that it has cooperated with research organizations in regional research projects from the beginning: a 3-year Ford Foundation grant of \$750,000 first provided funds for this purpose and for training young scientists from Southeast Asian countries. The same report records that IRRI scientists visited Bangladesh, Taiwan, India, Indonesia, Japan, Malaysia,



The national agricultural research systems provide the conduit through which flows feedback on farm-level constraints to rice production and opportunities for improving its productivity. Here, IRRI scientists discuss a crop with their counterpart in Zanzibar.



Sri Lanka, and Thailand, in addition to many parts of the Philippines. And the testing, evaluation, and dissemination of the first generation of modern varieties developed by IRRI were facilitated through partnerships with national research bodies.

Today, IRRI continues to seek collaborative relationships with individuals and organizations that share its goal of improving the well-being of rice farmers and consumers particularly those less well-off. “Partnership with farming communities, research institutions, and other organizations” is explicitly stated as a strategy in IRRI’s mission statement. But while national research organizations continue to be its principal partners, others are found among those outside government (NGOs), universities, advanced research institutions, the private sector, and other international agricultural research centers (IARCs).

#### **Rice farmers as co-researchers**

IRRI’s partnership with rice farmers is a special one. While scientists bring to on-farm research their specialized knowledge, farmers contribute their indigenous knowledge, based on centuries of collective experience. They also provide the scientists with feedback on the performance of new technologies.

The current view of rice farmers as “co-researchers” is a far cry from that commonly held at IRRI’s inception, when research was something that was done for farmers not with them. The product of the partnership becomes increasingly important as IRRI and the national research organizations strive to make progress in the more adverse rainfed and upland rice ecosystems. Until now, farmers there have survived

largely through their own efforts because scientists have had limited success in developing high-yielding rices that can adapt to the floods, droughts, temporary submergence, strong winds, and problem soils common to these areas.

A good example of how farmers can participate in research is found in the use, by a group of women in Tampac, Nueva Ecija, in the Philippines, of a micro rice mill that they could operate themselves. The mill, designed to eliminate the need for the laborious and time-consuming hand-pounding method still used in most rainfed remote rice-growing areas, was designed by IRRI and later modified and evaluated by engineers from the Philippine Rice Research Institute (PhilRice).

The women happened to see one of the micro mills being loaded onto a truck for testing, and asked a PhilRice engineer who was present to demonstrate it. Fascinated with the ease of operation, they took the initiative of writing and asking for one of the units from the Women in Rice Farming Systems coordinator of IRRI.

These women did not hand-pound as most in the area do, but they were obliged to waste many hours and money on transport to the commercial mill in a neighboring town.

A year’s trial showed the machine worked well: the women not only operated it but maintained it and carried out small repairs. They organized themselves into an association to manage it and the income it generated. The experiment not only provided the women with a new, remunerative skill; it also disproved the common belief that women are afraid of machines and incapable of operating them.

#### **The national agricultural research systems**

The organizations known as the national agricultural research systems (NARS)—universities, as well as government institutions—will continue to play a key role in IRRI’s research agenda, despite the broadening of the Institute’s partnership base to take in other kinds of collaborators. As the agencies through which IRRI makes contact with the farmers, NARS provide the conduit through which flows feedback on farm-level constraints to rice production and opportunities for improving its productivity. With the impressive strengthening many NARS have undergone in the past 30 years, they are increasingly helping IRRI to address national, regional, and even global research problems.

To strengthen the less developed NARS, IRRI supports what are called country programs, limited to 10 at any time. In addition, IRRI proposes to establish regional projects to support smaller NARS whose research needs do not justify country projects. The ultimate goal of these programs is that eventually they will no longer be required, the NARS involved becoming capable of collaborating as full partners with each other, with IRRI and in other programs.

With the increasing strengths of the NARS, tighter budget constraints on research institutions being imposed in all countries, and greater pressures for public accountability, IRRI’s partnerships with the NARS in the future are likely to become limited to those areas of highest priority for both parties. One way in which the NARS’ contribution could be enhanced is through adequate representation in the governance of the IARCs. To this end, IRRI proposes establishment of a Council for



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Collaborative Rice Research in Asia. Its role would be to guide and strengthen collaboration among the NARS, IRRI, and other IARCs in the region.

#### **Nongovernment organizations**

IRRI's long-standing reliance on the NARS as its principal collaborators has meant that, historically, NGOs have not played a significant partnership role with the Institute. The first major consultation of these non-profit, humanitarian organizations

with IRRI came in 1989 when certain Philippine NGOs helped sharpen IRRI's research focus on the needs of rice farmers and consumers. Since then, NGOs have become partners in a number of areas. For example, the Philippine Shell Foundation collaborates with IRRI in research on saline soil areas in Bicol, and the Freedom from Hunger Foundation of Germany provides funds for the training by IRRI of Cambodian refugees.

In 1994, IRRI set up a Committee on Collaboration, with NGOs to identify new opportunities to exploit common goals. A joint field project with a large international NGO was also planned for 1995. A growing acceptance of NGOs by governments as powerful partners in economic and social development makes it likely that IRRI and other rice research institutions will increase the number of their NGO partnerships.

#### **Advanced research institutions**

Scientific advances in industrialized countries, often only indirectly related to rice, may provide knowledge and techniques of great value to IRRI's research program. Examples are biotechnology and systems simulation and modeling. For this reason, IRRI increasingly is seeking strong links with advanced research institutions working in these areas.

Support from the Rockefeller Foundation and others, for example, has enabled IRRI to establish links with leading biotechnology institutions throughout the world, such as Cornell University, Texas Tech, and the Swiss Federal Institute of Technology. Funding from The Netherlands has made possible collaboration with simulation and modeling experts at Wageningen Agricultural University.

### **Shuttle research**

Research sometimes benefits greatly when scientists are able to work for extended periods at two different locations, shuttling back and forth between them as the work requires. For example, a scientist might be based for much of the year at an advanced research institution, using sophisticated analytical equipment, and then spend extended periods at IRRI, using its trained personnel and research facilities in tropical field conditions.

An example is the IRRI-Japan Shuttle Project, which profits from excellent scientific facilities in Japan while providing Japanese scientists exposure to tropical rice research. This initiative focuses on biotechnology, pathosystems, physiology and yield of rice, microbiology, and social science. Japanese scientists and those at IRRI can submit a proposal, for which the project may provide funds and travel expenses over a 3-year period. Another component of this project enables doctoral students to conduct their thesis research both at IRRI and in Japan.

### **The private sector**

IRRI has collaborated with the private sector since the mid-1960s, when the first semidwarf rice variety, IR8, was released by the Philippine Government: at that time, seeds were provided to the Bureau of Plant Industry and private seed producers. Later, IRRI began collaborating with manufacturers of agricultural tools and machinery.

Today, the private sector is becoming increasingly important in developing and disseminating advanced scientific techniques, many of which are subject to intellectual property protection. Where IRRI's interests and those of private organ-

izations coincide, it seeks collaboration with such partners. This is being done with due caution, taking into consideration the needs of rice farmers, consumers, and scientists; and the output of the collaborative research is regarded as a public good.

### **Other international agencies**

Collaboration among the various IARCs has been encouraged since the inception of the Consultative Group on International Agricultural Research (CGIAR) in 1972. IRRI has long collaborated with other IARCs, and recently such efforts have been stepped up. In its approach to the problems of the world's major ecoregions, the trend now is shifting from a focus on commodities and disciplines to one on entire systems.

Development-oriented institutions such as the World Bank, the Asian Development Bank, and the United Nations Development Programme are logical partners for IRRI. As key donors, they have long contributed to the Institute, not only financially but also intellectually and morally. An attempt is being made to strengthen these relationships through greater consultation and more joint projects. New mechanisms are being sought to ensure that IRRI's rice research expertise is being fully utilized in agriculture and rural development.

### **Consortia**

One of the most useful partnership mechanisms employed by IRRI is the rice research consortium—a partnership of strong national research institutions and IRRI that undertake research, training, and technology-generating activities to meet mutually agreed objectives.

Consortium members undertake research activities according to their

institutional strengths. IRRI seeks funding, facilitates sharing of research findings, and helps establish links with other relevant scientific institutions. Each consortium focuses on major research issues having applicability beyond national needs.

The advantage of the consortium concept lies in its ability to combine the individual strengths of its members in pursuit of a common goal. Examples are the Rainfed Lowland Rice Research Consortium and the Upland Rice Research Consortium, organized by IRRI and selected strong NARS. A similar model is being considered for the irrigated and flood-prone ecosystems.

To focus on conservation and management of natural resources, aimed at developing sustainable food production systems, IRRI plans to set up research consortia for different regional ecosystems with similar agroecological characteristics. These consortia will work in collaboration with NARS scientists, other IARCs, and development agencies.

### **Research networks**

Similar to consortia, but more narrowly focused on a specific set of tools, methodologies, or themes, are research networks. These link NARS scientists with one another, with IRRI, and with other international and regional centers.

There are currently three major research networks at IRRI. The Asian Rice Biotechnology Network (ARBN) was established in 1993 to ensure that biotechnology has an impact on rice improvement and productivity. IRRI also convenes the Integrated Pest Management Network (IPMN) and the Simulation and Systems Analysis for Rice Production Network (SARP).

### Technology evaluation networks

The two technology evaluation networks—the International Network for Genetic Evaluation of Rice (INGER) and the Crop and Resource Management Network (CREMNET)—facilitate exchange and evaluation of technologies developed by IARCs and NARS. INGER, established in 1975 as the International Rice Testing Program, promotes genetic diversity and improved productivity in rice crops worldwide through exchange of promising varieties and elite breeding lines. The more recently established CREMNET is, in effect, the nongermplasm equivalent of INGER, exchanging crop and resource information and technologies, with emphasis on resource management.

Rice research at IRRI and the NARS generates much new knowledge and technologies with the potential of increasing rice yields. But these must be evaluated, adapted under actual farm conditions and put to use by farmers, or they will remain, unutilized, on the shelf. INGER and CREMNET are designed to facilitate such activities and thereby promote higher productivity of rice-based systems.

### Benefits of partnerships

In all these ways, IRRI shares its knowledge and experience with others in the rice-growing world, and benefits in turn from their knowledge and experience. The advantages of partnerships in rice research are well documented: they shorten the time needed to solve problems; they speed the transfer of information and advanced research methodologies; and they enable scientific collaboration across political borders and economic barriers. Thus partnerships make the most of research resources, which in recent years have become increasingly scarce. ■

## Seeing is believing

**C**hemical insecticides work so well that it's difficult to persuade farmers who have been depending on them for 20-30 years that they are often unnecessary, as well as being possibly harmful to their health. But IRRI scientists have found a way to do just that.

The Institute's research has shown that farmers tend to attack pests that are visible, such as leafhoppers, but that if these pests are left unsprayed, they cause little damage. The plants look sick because they show effects of the pests presence such as white patches on the leaves, but the plants recover well without spraying, especially in the early stages of growth. Surveys, however, show that farmers always spray the crop during the first 40 days.

In what became known as the Barangay (village) Integrated Pest Management Project, IRRI decided to set up a three-tier experiment to test the results of different kinds of intervention aimed at reducing farmers' dependence on insecticides. In one village they initiated what they called farmer participatory research. In a second village, they set up a farmers' field school for instruction in different methods of pest control, with heavy emphasis on biological methods. In a third village, there was no intervention. The three villages were widely separated, with no communication among them.

In the village where farmer participatory research was conducted, IRRI scientists presented farmers with a simple rule of thumb: "early application of insecticides for leafhopper control is not necessary." The farmers' immediate reaction on hearing the rule was to refuse to believe it because it contradicted their long-standing practice.

The scientists then invited farmers to test the rule in their own fields—to experiment by leaving a small proportion of their land unsprayed early in the season. At the end of the season, the scientists organized another meeting to discuss the results.

IRRI monitored the barangay project in all three villages over two years and found that, in the two where the farmers' school and the participatory research were carried out, farmers' use of insecticides was dramatically reduced. Results in each of these two villages were identical for insecticide use, but differed slightly in herbicide use, the farmers' school villagers using somewhat less herbicides. In the third village, where there was no intervention, insecticide and herbicide use remained about the same as before the project was undertaken.

IRRI scientists believe that the simple rule-of-thumb method of transmitting knowledge to farmers may be an important key to the transfer of "knowledge-based technology," which will become extremely important in the future. Such technology will require farmers to make many decisions about its use on their own, rather than simply following instructions devised by the technologies' inventors. Since there are some 900 million farmers in Asia, finding ways to communicate these technologies to them is vital.

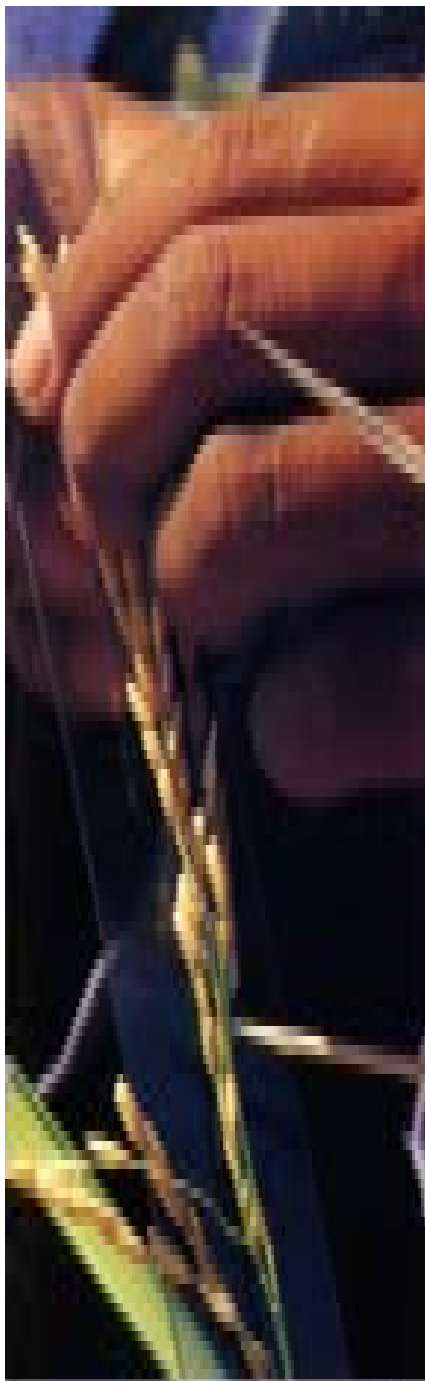
The media—especially radio—play a large part in such projects. In Vietnam, following the barangay project, the provincial government last year launched a campaign to encourage the farmers to experiment with pesticide use. Cartoon characters are used on posters and pamphlets to portray two farmers talking to each other about their experiments. On radio, actors play out the scenes depicted in the posters.

IRRI is monitoring the campaign. An awareness survey it carried out with 5,000 farmers found that 90% had heard of it.

# INTERNATIONAL PROGRAM HIGHLIGHTS



# Conserving and promoting genetic diversity



**T**wo auspicious features of 1994 for the Genetic Resources Center were the initiation of a collaborative program of germplasm collection and conservation with funding from the SDC and the start of operations in the newly constructed drying room of the genebank.

To mark the new SDC program, representatives from 16 NARS and four other international centers met at IRRI in March. Their aim: to develop an action plan aimed at accelerating the collection and conservation of cultivated and wild rices.

In the same month, recently harvested seeds from the field began to be placed directly into the new drying room. Cooling units of the Active and Base Collection storage rooms had already been replaced to attain the desired  $-20^{\circ}\text{C}$  temperature. New digital systems were connected to monitor the desired humidity and temperature conditions attained in each room, including the new working area.

## Highlights

### International Network

#### for the Genetic Evaluation of Rice

INGER promotes genetic diversity in rice crops throughout the world through exchange of seeds and evaluation of promising cultivars, elite breeding lines, and genetic donors. This is done through trials in different environments, where the seeds are grown under a variety of

**To develop improved rice varieties, scientists draw on genes in the seeds of the thousands of varieties farmers have grown for generations, and of wild species. From these, they transfer such desired characteristics as pest and disease resistance to varieties with high yields. Ironically, these irreplaceable genetic resources are threatened with extinction as farmers abandon traditional varieties in favor of the improved ones, and as wild species' habitats are destroyed. For more than 30 years, IRRI has been involved in collecting and conserving rice's genetic heritage in all its diversity. More than 80,000 samples of cultivated and wild rice germplasm are conserved in its genebank. These are shared worldwide.**

stresses. Each year INGER receives nominations from various IARCs and NARS, multiplies seeds of appropriate selections, and sends these to participating institutions for testing and evaluation under local conditions and for use in national breeding programs.

#### *Utilization of 1993 nursery entries*

- In 14 countries of Asia, Africa, and Latin America, 367 entries were used as parents in national varietal improvement programs. Some 452 entries were evaluated in follow-up yield tests in 21 countries.
- Reported in 1994, 29 INGER entries were released as varieties in 12 countries during 1993. Thirteen entries were released in four countries of Asia; 13 entries in seven countries of sub-Saharan Africa, and 3 entries in two countries of Latin America.

#### *1993 nursery distribution*

Seventeen sets of various types of global INGER nurseries were sent to Brazil, Colombia, Guyana, and Peru for evaluation. At CIAT, the INGER: LAC organized 81 sets and sent these to 14 countries in Latin America and the Caribbean. Data from 44 nurseries were returned and analyzed.

#### *1994 global distribution of nurseries*

- In 1994, 1,845 entries from 46 NARS and 4 international centers (CIAT, IITA, IRRI, and WARDA) were distributed. About 764 sets of 15 types of nurseries (9 for ecosystem-based evaluation and 6 for stress tolerance screening) were distributed to 36 countries. A total of 639 sets was distributed to 17 countries in Asia, 27 sets to 3 countries in West Asia and North Africa, 69 sets to 10 countries in sub-Saharan Africa, 29 sets to 4 countries in Latin America, 1 to Italy, and 2 to Russia.

- A joint site visit was conducted to observe INGER rainfed lowland trials in India, Bangladesh, and a variety of recommendations were made to improve trial methodology.

#### **International Rice Genebank**

##### *Exchange of germplasm and information*

- During 1994, IRG received 299 cultivated rice and 6 wild species from the [PGR Seed Handling Units in Singapore and Costa Rica, and 1,011 samples from the genebanks of the National Institute of Agrobiological Resources (NIAR) in Japan and PhilRice in the Philippines. Another six varieties, resistant to brown planthopper, were received from the Agricultural Research Station of Maruteru, Andhra Pradesh, India.
- A total of 10,682 accessions of cultivated rice was distributed to 109 scientists in 32 countries. Another 878 accessions of wild species were supplied in response to 25 requests from 13 countries. Rice germplasm was restored upon request from germplasm donor countries such as India, where 5,311 accessions of Assam Rice Collection germplasm were sent to the National Bureau of Plant Genetic Resources (NBPGR) during the year. Germplasm was also restored to the genebanks of Thailand (392 accessions) and Indonesia (416 accessions).

Other national genebanks in Egypt and Japan requested germplasm, not only for conservation but also for research and crop improvement.

##### *Germplasm characterization*

Characterization of 2,024 accessions of *O. sativa* was completed in the field. The characterization of the panicles from 1,518 *O. sativa*

accessions was completed in the laboratory.

#### Germplasm multiplication and rejuvenation

- During the 1994 dry season, more than 9,000 accessions of *O. sativa* and *O. glaberrima* were rejuvenated/multiplied on approximately 12 hectares of the IRRI farm. Seeds were dried in the new seed drying room at 15°C and 15% relative humidity. This is the latest drying process for improving the storage potential of germplasm.
- Early plantings were made at Los Baños to induce flowering in the photoperiod-sensitive materials and flowering and grain filling during the cooler weather for japonica rices, to improve storage potential.
- Seed longevity. Germplasm seed regeneration at IRRI is now undertaken during the dry season, as the climatic conditions during the wet season are unfavorable for seed production. Sowings are visually made during late November or December and seeds are harvested in April-May. Recently, a collaborative study between IRRI and the University of Reading, UK, showed that the potential longevity of japonica seeds harvested from a warmer (32/24°C, 12/12 h) seed production regime is significantly less than that from a cooler regime (28/20°C, 12/12 h). This was confirmed in a recent IRRI study while comparing the potential longevity of seeds harvested from the 1993 dry season planting with that from a controlled cooler environment (24/18°C, 12/12 h) in growth cabinets. However, the difference in longevity of seeds harvested from the two environments was not as great as that observed in the University of Reading experiments. This indi-

cated that the dry season seed production environment at Los Baños is not harsh for japonica cultivars.

- During 1994, the nursery area was renovated and fully utilized. The urgent need of space for growing and maintaining wild species has been satisfied. As a result, the plants grew vigorously and produced many seeds sufficient for long-term conservation. Cultivation practices had been modified for some species to further enhance their seed production.

#### *Germplasm conservation*

- Seed processing. During 1994, a total of 2,573 newly assigned accessions consisting of 2,105 *O. sativa*, 29 *O. glaberrima*, and 439 wild species was added to the present collection. A total of 1,596 entries from the old accessions was added to the Base Collection. At present, about 80% of the entire collection is conserved in the Base Collection.

#### *Viability tests*

- Viability testing of the Base Collection and of all wild species was the highlight of the year's activity, about 22,089 samples having been tested. ■

#### **GERMPLASM CONSERVATION, DISSEMINATION AND EVALUATION**

Expenditure 1994—\$960,000

Approved budget 1995—\$1,078,000

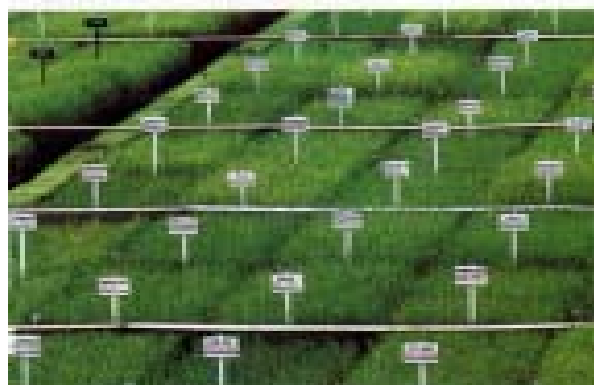
Budget planned 1996—\$1,092,000

Internationally recruited staff—3

Nationally recruited staff—16

#### **Programs**

- Conservation of rice genetic resources
- International Network for the Genetic Evaluation of Rice



Each year INGER receives nominations from various IARCs and NARS, multiplies seeds of appropriate selections, and sends these to participating institutions for testing and evaluation under local conditions and for use in national breeding programs. At left are some of these lines being grown at IRRI.



# Strengthening international partnerships program

**T**he goal of this program is to accelerate progress in a number of national research systems through country- and ecosystem-specific support programs as well as networks of multicountry collaboration.

Mutually beneficial scientific collaboration can only take place between strong, effective, and committed partners. Close working partnerships grow as the research capacity of national partners increases. Emerging partnerships with NGOs and the private sector for research and technology evaluation need innovative management approaches to derive maximum benefits for engaging partners.

## Highlights

### Bangladesh

The IRRI-Bangladesh collaboration continues, despite funding problems. Limited research on direct seeding and water management is the ongoing activity, in addition to Rainfed Lowland Rice Research Consortium work on breeding and crop management.

### Bhutan

The second five-year phase of the Bhutan-IRRI Project supported by the International Development Research Centre (IDRC) of Canada started on 1 Apr 1990 and ended on 31 Mar 1995, with significant contributions to

- the development of a national research program on rice, oilseeds, wheat, and vegetables;
- the transformation of Wangdeuphodrang Farm into an effective research station that serves the wetland production systems;
- the development of other renewable natural resource research centers (RNRRCs), specifically at Khangma and Bhur;
- enhancing research-extension linkage;
- generating farm-level impact through farmer adoption of new varieties and production technologies.

The renewable natural resource (RNR) model is now in place, but its effectiveness in addressing emerging food production problems and opportunities remains to be proven. Social science capabilities, including participatory research and impact assessment, and conserving indigenous germplasm, are to be strengthened in the next phase. These and other major challenges will be addressed in Phase 3 for which external support is crucial, at least for the next 4-5 years.

### Cambodia

The Cambodia-IRRI-Australia Project, through funding from the Australian International Development Assistance Bureau (formerly AIDAB, now the Australian Agency for International Development [AusAID]), supported rice research, training, and institutional development in Cambodia. Major accomplishments during 1994-95 were

- collection and characterization of 532 traditional rice varieties representing 95% of the native lines in 17 out of 21 provinces of the country, which will be evaluated in 1995 for drought resistance and photoperiod sensitivity, the essential characteristics for rainfed lowland rice
- characterization of 17 soil profiles in 9 provinces to develop a complementary soil classification system (useful for making soil management decisions) based on topsoil characteristics, topographical location, water regime, and in situ vegetation;
- confirmation of the local rock phosphate as a good source of P (performance similar to triple superphosphate) for rice on a range of soils;
- identification of natural enemies of rice, green leafhopper (GLH) and gall midge, and yield loss assessment due to stem borers, through survey and field studies;
- collection of insects, weeds, nematodes, and vertebrate pests specific to Cambodian rice ecosystems and their preservation in a museum for research and training purposes.

### Commonwealth of Independent States

A three-month consultant's study of CIS indicates that rice, an important secondary staple, is grown mostly under irrigation, with high chemical inputs for pest control. Grain yields range from 8 to 10 t/ha in nonsaline soils (4 t/ha in saline soils). Opportunities for collaboration between IRRI



and CIS include

- varietal improvement for cold-tolerant japonica lines suitable for CIS;
- integrated pest management to reduce chemical inputs in rice farming, especially herbicides;
- anaerobic crop establishment;
- water management; and
- biotechnology.

A specific recommendation to strengthen participation of CIS scientists in INGER is being acted on.

#### **Eastern, Central, and Southern Africa**

Evaluation team reports of this region often cite the enormous potential for increasing rice production in ECSA countries (rice area of more than 600,000 ha). Identified high priority research areas to increase pro-

duction are a) environmental characterization to stratify and prioritize rice ecologies; b) varietal improvement for abiotic and biotic stresses (drought, submergence, rice blast, rice yellow mottle virus [RYMV]), and for quality grain in collaboration with the Rainfed Lowland Rice Research Consortium; c) epidemiology of RYMV and development of RYMV-resistant varieties in collaboration with the Madagascar-IRRI Project, IRRI/Philippines, the West Africa Rice Development Association and the International Institute of Tropical Agriculture; d) research on crop establishment and soil/water/weed management; and e) human resource development.

It has been difficult to find funds for a regional project. The prospects

**Evaluation team reports from the Eastern, Central, and Southern Africa (ECSA) region often cite the enormous potential for increasing rice production in ECSA countries. These women are working in Zanzibar.**

for attracting donor support for a country in Mozambique are good. This will be pursued vigorously to enhance IRRI's involvement in this region.

#### **Egypt**

The USAID-funded. Egypt-IRRI Project ended on 30 Jun 1994 after 6-1/2 years. During the project period, rice yields in the country increased from 5.5 to 7.8 t/ha. IRRI assisted Egypt in developing a tissue

culture laboratory, an improved seed storage system, a computer data base for evaluating rice germplasm, and better weed management systems.

### India

Dr. R.K. Singh replaced Dr. P. Ghildyal as the IRRI liaison scientist in India from 16 Mar 1995. The new IRRI Liaison Office in New Delhi (CIS Friends Colony (East), N.D. 110065) is strategically located, spacious, and provides for a library-cum-conference room and a guest room. The ICAR-IRRI Collaborative Research Workplan for 1995-96 was finalized in February 1995. Research priorities include strategic and applied research on rainfed rice, with emphasis on eastern India; use of biotechnology and hybrid rice technology in crop improvement; germplasm conservation and improvement for yield, grain quality, and resistance to biotic and saline soil stresses; research on IPM, environment, and crop modeling; crop resource management and socioeconomic studies; and human resource development.

Two International Fund for Agricultural Development (IFAD) Workplan Meetings were held at New Delhi and at the Central Rice Research Institute (CRRRI), Cuttack, to finalize research plans for the 1995 rice season. A Simulation and Systems Analysis for Rice Production (SARP) Workshop was held at Hyderabad in June 1995 to review past research results on modeling of N management in lowland rice.

### Indonesia

Past collaboration between IRRI and Indonesia through INSURF proved the advantages, in terms of rice yield, of deep-placing modified urea, such as sulfur-coated urea (SCU) and urea supergranules (USG). It took more than 10 years to adopt

the technology on a large scale. Because of the difficulty of manufacturing uniform USG, urea tablets were conceived, tested, and proved to have the same efficacy as other modified urea formulations. A simple urea table applicator has also been developed from the idea of a farmer. Through appropriate government policy, this technology has been given a big push in Indonesia, and urea tablets will be used on 1.3 million hectares of rice in 1995.

### Lao PDR

The Lao-IRRI Project, financially assisted by the Swiss Development Cooperation (SDC), is in the middle of its second phase (1993-96) and produced the following significant outputs:

- establishment of a national rice research network involving 87 government officials in 14 out of 17 provinces
- release of one new glutinous rice variety, Phone Ngam 1, which with earlier released varieties of Niaw Thadokkham 1 and 2 are increasingly being adopted by Lao farmers in rainfed lowland areas;
- demonstration of the severe P and N deficiency of rice soils which give 50-220% increased rice yields with application of these nutrients;
- completion of a farmer survey that indicates that drought, insect pests, and diseases are the most important farmer-left constraints to rice production in rainfed lowland areas, and that research has to be intensified to alleviate these constraints;
- assessment of the potential heavy loss of organic matter (10 t/ha) and N (0.4 t/ha) due to erosion of 25 cm of topsoil in slash-and-burn cultivation of rice on sloping lands;

- completion of the National Agricultural Training Center (\$436,000) in Vientiane Municipality, office and laboratory facilities in Champassak Province (\$59,000), the National Upland Rice Research Center in Luang Prabang Province (\$111,000), and seed drying facilities at the National Agricultural Research Center (\$43,000), all of which considerably improved the research infrastructure. Additional funds have been committed, to construct a low temperature seed storage facility (\$100,000) at the Naphok National Research and Seed Multiplication Center, and to start the new *Lao journal of agriculture* (\$92,500 for the first five years).

### Madagascar

With the United States Agency for International Development (USAID) financial assistance the Madagascar-IRRI Project has been extended for 30 months from January 1995, with a two-member team to work on rice breeding (all ecosystems) and farming systems (northwest region), in collaboration with the National Center for Applied Research for Rural Development (FOFIFA). The just-ended Phase 3 accomplished

- identification of common insect vectors of the spreading RYMV disease: *Hispa gestroi* and *Trichispa servicea*;
- successful collaboration of FOFIFA-IRRI-German Agency for Technical Cooperation (GTZ) in the development of five RYMV-resistant lines (from imported Ciwini of Brazil and seven TOX lines of IITA) with grain yields of 4 t/ha, which will be field-tested in 1995;
- development of an efficient phosphorus root-dipping method for high P-fixing soils, and economic fertilizer recommendations for N

and P for different soils of the central highlands;

- strengthening of the decentralized regional research teams in the north west and middle west, and adoption of farmer participatory research for constraints analysis, technology development and evaluation in these regions.

### Myanmar

IRRI collaboration with Myanmar focuses on hybrid, rice development and rice plus forage/green manure systems. Two IRRI cytoplasmic male sterile lines (IR62829 A and IR58025 A) and two main-tainer lines (IR62329 B and IR58025 B) are being used in the Myanmar hybrid rice production program. Additional support is solicited from IRRI to improve nutrient management in summer rice, direct seeding, and mechanization.

### Papua New Guinea

Government funding of US\$520,000 has been allocated for a three-year period to support PNG-IRRI collaboration. The present level of local rice research capability is very low and considerable effort is needed to develop it. This project aims to develop a viable domestic rice industry in collaboration with the PNG Government and private sector. Research on crop establishment, nutrient management, mechanization, and development of human resources through appropriate training are the priorities for the project.

### Sri Lanka

With the reorganization of the Department of Agriculture in Sri Lanka (DOASL) and elevation of the Central Rice Breeding Station at Batalagoda to the Rice Research and Development Institute (RRDI), efficiency of IRRI collaboration with Sri Lanka has improved.

- DOASL joined the network organized by IRRI to collect and preserve wild rice species.
- The first high-yielding red rice variety BG304 (104 day duration) with resistance to major pests and diseases was released.
- Varietal development for direct seeding and breeding for resistance to thrips and other stresses were intensified., with the provision of seed samples of photo-period-sensitive varieties of Vietnam, improved varieties with BPH resistance genes, iron toxicity-tolerant HR lines, and new hybrid varieties by IRRI.
- Two Ph D scholars and five students with dissertation research completed their studies; DOASL scientists who participated in short-term courses include one in Hybrid Rice, one in Integrated Nutrient Management at IRRI, and two in Rice Production Research in Thailand..

### Vietnam

The continuing research collaboration between IRRI and Vietnam since 1968 provided the scientific base for the dramatic transformation of the country's rice economy, with consistent rice production increases of 5% per annum from 1988. The policy reform of 1988 and the provision of modern rice varieties and production technologies contributed greatly to Vietnam's rapid growth in rice production. Major accomplishments are

- release of 63 IRRI breeding lines as varieties which cover more than 70% of the rice-growing area;
- development of a strong network of national research institutions and agricultural universities for introduction, testing, and evaluation of modern rice varieties and related production technologies;
- training of 362 Vietnamese scientists at IRRI in degree and

### STRENGTHENING

#### INTERNATIONAL

#### PARTNERSHIPS PROGRAM

Expenditure 1994—\$ 1,018,000  
Approved budget 1995—\$904,000  
Budget planned 1996—\$940,000  
Internationally recruited staff—3  
Nationally recruited staff—4

#### Projects

- Southeast Asia
- South Asia, West Asia, and North Africa
- Eastern, Central, and Southern Africa

non degree programs since 1964;

- holding of a Vietnam-IRRI Rice Research Conference in Hanoi in May 1994, in which 82 Vietnamese, one ISNAR, and 22 IRRI scientists participated, reviewed, the past collaborative research, and identified the future strategic and development priorities for Vietnam-IRRI collaboration during 1994-2000. The proceedings of this conference have been published in *Vietnam and IRRI: a partnership in rice research*

In recognition of its contribution to rice production in Vietnam, IRRI was presented with the First Class Friendship Award in May 1994, with this citation:

“...an affirmation of the Government's and the people of Vietnam's appreciation of IRRI's assistance and (is also) a symbol of their wish to further develop the cooperation between Vietnam and IRRI in the future”

Future research collaboration in Vietnam will concentrate on development of rice varieties tolerant of BPH, blast, and ShB; hybrid rice for the Red River Delta; tissue culture; and rice grain quality. ■

# Networks

## Crop and Resource Management Network

The goal of CREMNET is to facilitate the free exchange, participatory evaluation, and dissemination of promising crop and resource management technologies for higher and sustainable productivity of rice-based systems, among and by national research and development organizations. This network offers a mechanism for exchange and rigorous testing of improved or emerging technologies, providing farmers' feedback to researchers, facilitating information sharing among various groups, and organizing periodic impact assessment of introduced technologies.

The research process will not be complete until the new knowledge or technology is applied by farmers to increase food production through improved resource use. CREMNET aims to help promote farmer evaluation and utilization of new crop and resource management technologies to improve the impact of research on food production and resource conservation.

### Highlights

#### Formation of IRRI CREMNET

##### Working Group

The IRRI CREMNET Working Group, an internal advisory body, was constituted on 10 Nov 1994 to foster collaboration between CREMNET and IRRI research programs and consortia. Members of ICWG include all

program leaders, selected division and center heads, and a social scientist on gender equity. The ICWG will review nominations of technologies from within IRRI for recommendation to the steering committee and encourage scientists to actively support technology evaluation by the network.

#### CREMNET organization meeting

The CREMNET organization meeting was held on 11 Feb 1995. Participants were 13 NARS representatives, one NGO representative, six IRRI country project leaders/representatives, and 11 IRRI headquarters staff. The goal, objectives, anticipated outputs, expected impact, and evaluation, thrusts/themes of the network were discussed and approved. Similarly, the proposed structure and guidelines of the network were discussed and adopted with minor changes. The participants emphasized the need for constraints analysis and identification of technical limitations in existing systems before choosing technologies for evaluation. They requested the addition of postharvest technologies, including processing of value-added rice products, for exchange and evaluation under CREMNET.

#### Proposed themes and technologies for CREMNET

CREMNET will focus on five themes:

- (1) enhancing and sustaining resource productivity,
- (2) minimizing environmental and health risks in rice farming,
- (3) systems diversification for higher income and food security,
- (4) increased labor productivity and mechanization, and
- (5) gender equity concerns

#### NETWORKS

Expenditure 1994—\$300,000

Approved budget 1995—\$251,000

Budget planned 1996—\$257,000

Internationally recruited staff—16

Nationally recruited staff—2

#### Projects

- Asian Rice Farming Systems Network
- Crop and Resources Management Network
- Women in Rice Farming Systems

Currently available technologies addressing the above themes will be selected for evaluation by CREMNET. Some examples of proposed technologies are chlorophyll meter-based N management, deep-point placement of N fertilizer, urea tablet placement and polymer-coated urea for rainfed rice, direct seeding methods, self-sustaining on-farm hybrid rice seed production, rice plus grain/fodder legume and rice plus fish systems, drum seeder, stripper-gatherer, micro rice mill, and rice hull stove.

#### Asian Rice Farming Systems Network

The ARFSN has been effective in promoting and coordinating collaborative research on cropping/farming systems in Asia, particularly in helping weaker national research programs to identify improved technologies. It has also helped strengthen participating national research programs' capabilities in farming systems research.

From 1992 to 1995, the network focused on refining on-farm research on rice plus fish production systems, food-forage production systems, and crop-livestock systems, and on knowledge-based and agricultural engineering technologies for women farmers. There was greater involvement of farmers, including women farmers, in problem identification, technology transfer verification, and the evaluation process.

To enhance the research capabilities of NARS scientists, 15 training programs were organized/sponsored by ARFSN in IRRI, Vietnam, and India. About 250 researchers were trained in methods of farming systems research and related topics. During this period, 13 workshops and meetings were organized and sponsored by ARFSN, which facilitated information exchange among the participating NARS scientists and stimulated other NARS to develop an in-country farming systems research network

In 1994-95, more emphasis was placed on social science issues in farming/agricultural research systems as a result of such changes in Southeast and South Asia as rapid industrialization, increasing population pressures, increasing agricultural labor wages, labor migration to the cities, implementation of General Agreement on Tariffs and Trade (GATT) policies, and the increasing participation of women.

A. socioeconomic assessment of the crop-animal systems project in Sta. Barbara, Pangasinan, Philippines, showed that farming families in this rainfed village benefited positively from technologies introduced since 1985.

The ARFSN will terminate in 1995 with the end of financial support from the IDRC of Canada. Network activities, however, will be continued



ARFSN activities in the Philippines, 1994-95. The photo shows a farmer operating a rice harrow in a field. The harrow is a large, yellow and blue machine used for tilling the soil. The farmer is wearing a yellow shirt and a hat. The background shows trees and a clear sky.

by the NARS, using their own resources. The Asian Farming Systems Association fills the need for linkages among key farming systems institutions and programs in many participating countries.

## Women in Rice Farming Systems

In 1994, this project accomplished the following:

- research on gender issues in seed management, crop protection, agricultural engineering, and socioeconomics. These are now incorporated into IRRI's disciplinary research and cross ecosystems research programs, and other collaborative research with the NARS, particularly in eastern India and Vietnam;
- development and commercialization of agricultural engineering technologies for women, now being continued by PhilRice;
- recognition of the outstanding achievements in rice science of five young female scientists from India, Indonesia, Vietnam, Burundi, and the People's Republic of China through awards presented at the International Rice Research Conference held at IRRI in Feb 1995;
- a training program in Gender Analysis in Farming Systems Research and Extension at IRRI in Nov 1994. Beginning in 1995, this program will be continued at the International Institute of Rural Reconstruction (IIRR), an International nongovernment

# Waste not, want not

**W**hile the seeds are the most valuable parts of the rice plant the rest of it need never go to waste

Rice straw and hulls are versatile commodities. The straw is used as animal feed compost mulch roofing thatch animal bedding rope woven items, and handmade paper.

The hulls are also used as a mulch or soil conditioner: And because of their high silica content, they can serve as a cement substitute or extender in building materials.

Ingenious farmers could find many other uses, too. Yet considering the quantities available, rice straw and hulls are underutilized. Large quantities of them are dumped into waterways or burned in fields.

One reason for this is that no suitable machinery has been available to permit both efficient threshing processes and multiple uses of straw. The straw that emerged from an efficient thresher was not in a suitable form.

That situation changed in 1994 with the development by IRRI of a low-cost rice straw chopper; powered by a 2.6-kW (3.5-HP) gasoline engine. Called the Flipper, it is easy and safe to use. Operators simply drop rice straw into the hopper. Blades are reversible and need not be resharpened until they have chopped 8-10 tons of material (which also can be farm byproducts other than rice straw).

The Flipper is sold in the Philippines for P8,000 (about US\$320) and will chop 1 ton of material on only half a liter of gasoline.

Besides their other applications, rice hulls can provide a household fuel that is free and environmentally benign. A Vietnamese stove, modified by IRRI and called the Ipa-Qalan, uses 1-1.5 kg of rice hulls for one hour's cooking. With a heat utilization efficiency of 15-25%, the stove will boil a liter of water in 5 minutes, compared to about 11 minutes for the Vietnam model.

By using rice hulls instead of wood as household fuel, a family of five or six people could save at least 2 tons of wood each year.

organization based in the Philippines, in collaboration with the IRRI Training Center.

These achievements indicate that the "goal of institutionalizing concerns for women's roles in agricultural research and extension

programs on rice farming systems" is now being realized within IRRI and in participating NARS. IRRI will continue its commitment and leadership in addressing women's concerns within IRRI's research activities and through CREMNET. ■

# Training

IRRI's training and professional advancement program has evolved over many years to address both its own global research objectives and the needs of the NARS. Its courses range from basic instruction in rice production and research methodology to those that teach new, advanced research techniques. The program also provides opportunities for doctoral and postdoctoral research and midcareer training of selected scientists in areas of mutual interest to IRRI and the NARS. And it develops and shares training materials readily adaptable to regional needs.

## TRAINING

Expenditure 1994—\$ 169,000

Approved budget 1995—\$1,336,000

Budget planned 1996—\$1,369,000

Internationally recruited staff—2

Nationally recruited staff—19

## Projects

n Degree and non-degree training

n Development of short-term courses

n Courseware development

n Collaborative in-country training

## Highlights

### Degree/nondegree training

Two hundred and thirty-eight MS/PhD degree scholars, research fellows, and on-the-job trainees from 31 countries in Asia, Africa, Europe, and North America participated in IRRI degree/nondegree and professional advancement programs in 1994. One hundred and seven completed their training during the year.

### Headquarters group training courses

One hundred and thirty-three trainees from 16 countries in Asia and Africa participated in nine group training courses.

### Regional collaboration in group training

- IRRI's eight-week Rice Production Research course was conducted for 19 trainees from six countries at Pathum Thani Rice Research Center, Thailand, by a team of Thai and IRRI trainers. This was the third consecutive year this regional collaborative course has been successfully implemented..
- Two additional regional, collaborative group training courses were conducted for the first time this year. A six-week Irrigation Water Management training course was offered for 18 scientists from 10 countries in Thailand. Training staff were from Thailand's Kasetsart University, the International Irrigation Management Institute (IIMI), and IRRI.

An Integrated Pest Management course was conducted in the Philippines for 19 scientists from 11 countries. Collaborating institutions in this eight-week course were the National Crop Protection Center (University of the Philippines Los Baños), PhilRice, SEARCA, and IRRI.

IRRI and scientists from the Indian Institute of Technology (IIT), Kharagpur, India, continued preparations to offer a version of IRRI's Engineering for Rice Agriculture course at IIT in late 1995.

### National collaboration in group training

- IRRI staff from various divisions/centers assisted NARS trainers in conducting thirty-one group courses for 644 national scientists. In-country courses were implemented in Bangladesh, Cambodia, China, India, Indonesia, Lao PDR, Myanmar, Philippines, Vietnam, Thailand, and the Ivory Coast (with WARDA).

### Training materials development

- Twenty new titles were produced in various formats: eight publications, nine instructional videos in two languages, and three learning tapes.
- Fifteen training materials were translated into Chinese as part of an ongoing China-IRRI collaboration in in-country training of provincial-level researchers in adaptive farming systems research methodologies. ■

# Information and knowledge exchange

IRRI disseminates its research results and exchanges knowledge globally through a comprehensive program that includes scientific and general publications, library and documentation services, conferences and workshops, and public awareness activities. It also serves as a convener, clearinghouse, and forum for dialogue with its partners in setting program strategies and priorities, planning rice research activities, and promoting discussion on institutional and policy issues.

## Highlights

### Scientific publication

Eighteen new books were published in English in 1994, and about 42,000 copies of major IRRI publications were distributed.

The *IRRI discussion paper series* was initiated to provide a vehicle for distributing preliminary reports, special project reports, and other material aimed at small, specialized, audiences. Five titles were produced.

Four issues of the International rice research notes and the annual index were distributed to more than 10,000 institutions and individuals in more than 145 countries.

### Library and documentation services

IRRI serves as the world's major repository of rice literature and this information available worldwide through electronic communication technology as well as conventional means. By the end of 1994, the on-line portion of the Rice bibliography, 1970 to date, numbered 149,197 entries, including 6,785 new references added during the year.

A project to catalog some 10,000 pre-1950 references neared completion. The earliest of these references were published in Europe in the mid-18th century. This file is a fully searchable database stored in a computer in the IRRI Library and Documentation service.

The Japan Library Office in Tsukuba, established in the early 1960s, continued to supply the IRRI Library with Japanese rice references.

These account for about 20% of the rice database.

### Public awareness

Contacts with national and international news outlets increased during 1994. About 135 international and Philippine journalists visited IRRI. Among them were broadcasters, writers, and information officers who attended four IRRI-sponsored events: Climate Changes and Rice Symposium, IRRI Small Farm Equipment Field Day, Training Program on Association of Southeast Asian Nations (ASEAN) News Exchange: A Comprehensive Approach, press conference on the

"Rice, the essential harvest," was featured in the May 1994 issue of National Geographic, whose circulation is about 9.4 million. Other prominent articles on rice and IRRI were featured in Asahi Shimbun, Bangkok Post, Far Eastern Economic Review, GEO, Hindi Daily, International Agricultural Development, Nikkei, Neue Zurcher Zeitung, Preferences, Samstag, The Arab World, The Australian, The Economic Times, International Herald Tribune, New Scientist, Riceworld, and The Washington Post. In its last edition of 1994, Time magazine named the announcement of IRRI's new rice plant type ("super rice") one of the five best environment stories of the year.

UK-IRRI Day was held on 1 Nov in London, England, sponsored by IRRI, the Biotechnology and Biological Sciences Research Council, and the Overseas Development Adminis-

tration. The theme was “Food security in Asia: contributions of IRRI and British science.” The scientific meeting was held at The Royal Society; a second event occurred in the British parliament building where IRRI’s director general addressed the All-Party Group on Overseas Development.

Japan-IRRI Days were held at two locations on consecutive days. On 24 Nov, the Japan-IRRI Day held in Tsukuba focused on recent rice research and challenges in the 21st century. It was organized by the Japan International Research Center for Agricultural Science (JIRCAS) in cooperation with IRRI, and more than 200 Japanese scientists attended. The following day, a Tokyo event, aimed at a broader audience, was sponsored by the and Saitama Prefecture Governments; Japan Macro-Engineers Society, and IRRI. Sponsors ??? Japan’s Ministries of Foreign Affairs and Agriculture, Forestry, and Fisheries, Japan’s Club of ??? Committee, Nihon Keizai Shimbun, Inc., and several agricultural societies. The theme was Japan’s role in Asian agricultural research and de-

velopment. More than 400 people attended: parliamentarians, media, government officials, the general public, and many from private sector organizations. Guest of honor at the Tokyo event was Crown Princess Maha Chakri Sirindhorn of Thailand.

**Communications materials**

IRRI Riceworld, a permanent exhibit of artifacts and implements from around the rice-growing world, opened in September, 1994. It is also a learning center about rice production, research, and the importance of rice in global food production. Some 18,000 visitors went through the exhibit before the end of the year.

News and information publications produced during the year included IRRI hotline, for decision-makers and donor representatives; IRRI reporter, a newsletter; IRRI 1993-1994; *filling the world’s rice-bowl* the Corporate Report; revised edition of *facts about IRRI, IRRI rice facts, and Facts about cooperation*. Two more booklets in the IRRI information series were also produced:

*Integrated pest management the IRRI Perspective, and Challenges and opportunities in a less favorable ecosystem: Flood-prone rice.*

IRRI issued 29 news releases, a Japanese version of the video *Creating rices for the 21st century*, and French and Khmer versions of *Rice: a tool for peace.* ■

**INFORMATION AND KNOWLEDGE EXCHANGE**

- Expenditure 1994—\$2,723,000
- Approved budget 1995—\$1,837,000
- Budget planned 1996—\$1,838,000
- Internationally recruited staff—3
- Nationally recruited staff—25

**Projects**

- Public awareness and general publication
- Scientific publication
- Library and documentation services
- Conferences and workshops



Figure 1. The IRRI Rice World exhibit in the IRRI building, Manila, Philippines. The exhibit is a permanent display of rice-related artifacts and implements from around the world.

# IVORY TOWERS AND FARMERS' FIELDS

**W**hen scientists and farmers meet, who earns from whom? Experience shows that the knowledge flow goes both ways.

Farmers are professional specialists in survival but their skills and knowledge have yet to be fully recognized, wrote R. Rhoades in *Farmer first*, one of Britain's intermediate technology publications. They have much of importance to say to scientists, and their methods of practical research are complementary

The view of farmers as ultraconservative, cautious people who stick to rigid traditional practices and never try anything new has been proved erroneous. Scientists themselves are realizing increasingly that farmers are, by nature, experimenters, continually trying out new methods.

In a special issue of the *Philippine journal of weed science* in 1994, IIRRI agronomist Keith Moody gave examples of how farmers' ideas and beliefs, gained from interviews. "led to more dynamic research programs which built on farmer-research interactions and supported farmer innovation." For example:

- Most farmers interviewed in South and Southeast Asia claimed, that they achieved effective weed control by applying herbicides at



Scientists are realizing increasingly that farmers are, by nature, experimenters, continually trying out new methods. Here an Indian scientist confers with a model farmer at Hazaribagh, India.

less than the recommended rate. A number of experiments conducted at IRRI and in Philippine farmers' fields confirmed this. They showed that rates of application of preemergence herbicides, such as butachlor and pretilachlor plus fenclorim, could be reduced by half that recommended without loss of efficacy or reduced crop yield.

- Farmers in a village in Nueva Ecija Province in the Philippines claimed they obtained better weed control in transplanted rice by spreading butachlor mixed

with urea than by the usual method of knapsack spraying. Scientists testing their method at experiment stations found they were right: mixing herbicides with urea—or sand—is not only as effective as spraying, but is simpler, more economical, and less toxic to the rice plants.

- Some Filipino farmers said they left weeds uncontrolled in their crops because they gathered them for animal feed. Research by scientists showed that if a farmer needs both grain and livestock fodder, not weeding and harvesting weeds plus grain was just as profitable as intensive weeding and harvesting the grain only. The research even produced a rule of thumb: for every kilogram of weeds that grow, one kilogram less of crop will be harvested.

“Most traditional methods of weed control were developed through trial-and-error, natural selection, and keen observation”, writes Moody. “A potential wealth of unexplored information on weed control awaits investigation, and documentation. We must learn from farmer practices.”

Government and extension officials, as well as policymakers and planners, often seem unaware of farmers' research, Moody says. This implies a regrettable waste of both a native resource and opportunity for dialogue.

He has the impression that the farmers' “research and extension network” operates independently and, even obviously of government programs, while it is often more practically oriented and therefore persuades more farmers to use its methods.

“The inevitable consequence of this neglect is a retarded rate of agricultural development.” ■

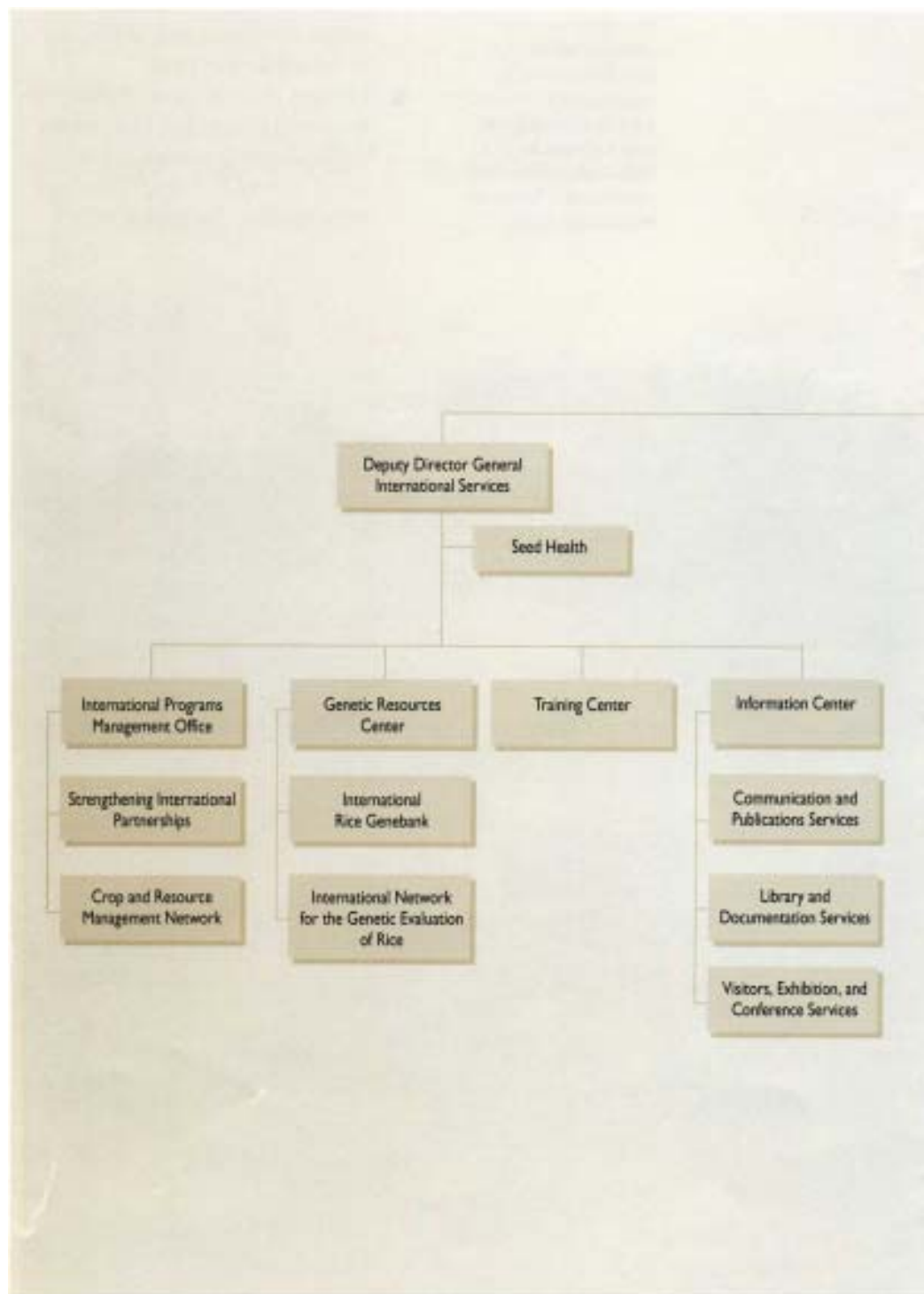


# FINANCE AND ADMINISTRATION

## IRRI Multilateral Executive Agreement

**O**n 19 May 1995, a Multilateral Executive Agreement recognizing the international legal personality of IRRI beyond the territorial boundaries of the Philippines was signed at Malacañang Palace by 10 countries: the Philippines, Bangladesh, Bhutan, Cuba, Denmark, Indonesia, Lao PDR, Russia, Vietnam, and Papua New Guinea. The signing was witnessed by the President of the Philippines, Fidel V. Ramos. On 14 Jun 1995, Iran and Switzerland signed the Agreement at the headquarters of the Department of Foreign Affairs and on 12 Jul and 14 Sep respectively. Myanmar and India through their Ambassadors signed the Agreement at IRRI. With the Agreement in effect, IRRI as an international organization does not come under the jurisdiction of the Philippine Securities and Exchange Commission governing private institutions within the Philippines. The new IRRI Charter, which is appended to the Agreement as signed, now governs IRRI's operations.

In the past five years, IRRI has implemented strategies to ensure optimum research outputs despite the continuing decrease in funding levels. These included cutting down the number of NRS by al





most 50% over a period of four years. Travel economies were instituted, especially for travel within the Asian continent. Arrangements were made with two airlines for substantial discounts on international travel to Europe and the United States. Efforts to reduce fuel consumption and overtime costs have also produced cost savings for the Institute.

The Institute has introduced a yearly maintenance program for its physical facilities, equipment, vehicles, and appliances up to the year 2010. This program ensures that aging facilities are upgraded and other capital items are replaced when necessary. It complements the recent program for upgrading research facilities and buildings within the research center.

The containment facility for transgenic materials and experiments is now fully operational. Scientists from IRRI and from nearby University of the Philippines Los Baños and PhilRice will benefit equally from this facility.

The upgrading of IRRI computer services continues. IRRI is now connected to the INTERNET and its systemwide integrated voice and data network (IVDN). Initial tests have been started to expand the local area network to a client-server configuration, in which various groups within the Institute can organize themselves around distributed servers.

Using information provided by the research programs, the first 10,000 rice crosses made at IRRI were successfully converted to the International Crop Information System (ICIS) data base format, allowing structured analytical access to the pedigree information. Software development in this area is proceeding in collaboration with a sister center, International Maize and Wheat Improvement Center.

The enhanced performance of the retirement fund for NRS has been encouraging. Due to its good performance, and upon approval of the Board of Trustees, it can now provide a bridging fund for

the housing scheme of the NRS. The NRS formed among themselves a housing association and developed a plan to provide a facility to buy houses and lots, or lots only, through certain financing schemes.

Due to the two staff reduction programs, the job responsibilities and duties of the remaining staff have changed. A job evaluation exercise was undertaken internally. Consequently, new position titles to reflect job specifications and qualifications were developed and implemented, simultaneous with new minimum position requirements.

The financial systems continue to provide information on a timely basis. There is ongoing work to shift from a mainframe-based computer system to a user-friendly, personal computer-based system which will continue to support the General Ledger, Purchase Order, Accounts Payable, Fixed Assets, Inventory Control, and Human Resources modules. ■

# Support from donors in 1994

Summary of financial support to IRRI core and complementary (special) projects committed for 1994.

SOURCE	Amount (US\$)			TOTAL
	CORE		Complementary (Special) Projects	
	Unrestricted	Restricted		
Japan	8,540,013	634,866	978,412	10,153,291
United States Agency for International Development	3,400,000		1,074,896	4,474,896
World Bank	3,516,000		412,340	3,928,340
United Nations Development Programme		1,774,022	949,979	2,724,001
Australia			1,947,022	2,585,752
European Union	638,730			2,146,954
Switzerland	2,146,954		2,716,191	2,716,191
Overseas Development Administration-United Kingdom			157,943	1,475,693
Environmental Protection Agency (EPA), USA	1,317,750		1,355,178	1,355,178
Denmark			505,030	1,306,031
Canadian International Development Agency	747,916	53,085		1,014,000
The Netherlands	1,014,000		536,099	822,961
BMZ, Germany	286,862			783,868
BMZ/GTZ, Germany	783,868		707,386	707,386
Swedish Agency for Research Cooperation				609,691
The Rockefeller Foundation	609,691	193,888	467,272	661,160
Asian Development Bank			450,000	450,000
International Development Research Centre, Canada		30,000	400,773	400,773
Republic of Korea	200,000	242,953	33,833	263,833
France <sup>a</sup>				242,953
Belgium	113,282		21,564	134,846
Norway	132,585			132,585
Philippines	117,194			117,194
The Ford Foundation			100,000	100,000
India	100,000			100,000
People's Republic of China	90,000			90,000
Islamic Republic of Iran			84,672	84,672
Spain	40,000			40,000
Indonesia	12,500		33,271	12,500
Others				33,271
Total	23,807,345	2,928,814	12,931,861	39,668,020

<sup>a</sup> The Government of France (through the research organizations ORSTOM and IRAT) also provided IRRI the services of four resident scientists. The value of their services cannot be quantified.



# Report Of Independent Accountants

## FINANCIAL STATEMENTS DECEMBER 31, 1994 AND 1993

To the Board of Trustees of  
**The International Rice Research Institute**  
(A nonstock, nonprofit organization)

We have audited the accompanying statements of financial position of The International Rice Research Institute (a nonstock, nonprofit organization) as at December 31, 1994 and 1993 and the related statements of activities and of cash flows for the years then ended. These financial statements are the responsibility of the Institutes management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with generally accepted auditing standards in conformity with international audit guidelines as issued by the International Federation of Accountants. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall, financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

As explained fully in Note 2, the Institute's financial statements are prepared on the basis of accounting practices prescribed for international agricultural research centers seeking assistance from the Consultative Group on International Agricultural Research. Such practices conform with generally accepted accounting principles.

In our opinion, the financial statements referred to above present fairly the financial position of The International Rice Research Institute as at December 31, 1994 and 1993 and its activities and its cash flows for the years then ended, in conformity with generally accepted accounting principles.

Our audits were made for the purpose of forming an opinion on the basic financial statements taken as a whole. The supplementary schedules of grant revenue, fixed assets, capital expenditures, capital fund movement, funds in trust and details of operating expenses for the years ended December 31, 1994 and 1993 are presented for purposes of additional analysis and are not a required part of the basic financial statements. The information in such supplementary schedules has been subjected to the auditing procedures applied in the audit of the basic financial, statements and, in our opinion, is fairly stated in all material respects when considered in relation to the basic financial statements taken as a whole.

Price Waterhouse  
Makati, Metro Manila, Philippines  
February 28, 1995

STATEMENTS OF FINANCIAL POSITION  
DECEMBER 31, 1994 AND 1993  
(US DOLLAR '000)

	Note	1994	1993
<b>ASSETS</b>			
<b>CURRENT ASSETS</b>			
Cash and cash equivalents	2, 3	42,497	40,821
Accounts receivable			
Donors	4	5,557	2,908
Employees		99	198
Others	5	1,079	1,036
Inventories, net of allowance for Inventory obsolescence of \$50 in 1994	2	1,556	1,332
Prepaid expenses		374	179
<b>Total current assets</b>		<b>51,162</b>	<b>46,474</b>
<b>FIXED ASSETS</b>			
Property and equipment		60,522	59,352
Less: Accumulated depreciation		(26,338)	(25,472)
<b>Total fixed assets - net</b>	2, 6	<b>34,184</b>	<b>33,880</b>
<b>Total assets</b>		<b>85,346</b>	<b>80,354</b>
<b>LIABILITIES AND FUND BALANCES</b>			
<b>CURRENT LIABILITIES</b>			
Loan payable		-	2,500
Accounts payable			
Donors	7	8,730	6,466
Employees	8	9	5
Others	9	1,448	1,643
Funds in trust	10	353	27
Accruals and provisions	11	14,617	14,794
<b>Total current liabilities</b>		<b>25,157</b>	<b>25,435</b>
<b>LONG-TERM LIABILITIES</b>			
Accounts payable			
Employees	8	4,667	3,744
Others	9	1,326	1,385
<b>Total long-term liabilities</b>		<b>5,993</b>	<b>5,129</b>
<b>Total liabilities</b>		<b>31,150</b>	<b>30,564</b>
<b>NET ASSETS</b>			
Capital invested in fixed assets			
Center owned	13	31,692	32,408
In custody	13	2,492	1,472
Capital fund	13	14,479	10,666
Operating fund	13	4,827	4,489
Self-sustaining funds	13	666	876
<b>Total net assets</b>	2	<b>54,156</b>	<b>49,911</b>
Cumulative translation adjustments		40	(121)
<b>Total liabilities and net assets</b>		<b>85,346</b>	<b>80,354</b>

(See accompanying notes to financial statements)

STATEMENTS OF ACTIVITIES  
FOR THE YEAR ENDED DECEMBER 31, 1994 AND 1993  
(US DOLLAR '000)

	Note	Core			Complementary	Self-sustaining Activities	Total	
		Unrestricted	Restricted	Total			1994	1993
Revenues								
Total grants	2	23,808	3,310	27,118	12,067	-	39,185	44,489
Other revenues		1,647	-	1,647	-	1,296	2,943	2,504
<b>Total revenues</b>		<b>25,455</b>	<b>3,310</b>	<b>28,765</b>	<b>12,067</b>	<b>1,296</b>	<b>42,128</b>	<b>46,993</b>
Operating expenses								
Research programs		9,475	1,970	11,445	5,905	-	17,350	15,149
International programs		5,172	709	5,881	6,162	-	12,043	14,070
Research support		2,417	-	2,417	-	-	2,417	1,445
General administration		3,807	469	4,276	-	-	4,276	3,796
General operations		5,092	162	5,254	-	1,398	6,652	11,413
Depreciation	2	1,606	-	1,606	-	108	1,714	1,261
Staff adjustment program		-	-	-	-	-	-	2,517
<b>Total operating expenses</b>		<b>27,569</b>	<b>3,310</b>	<b>30,879</b>	<b>12,067</b>	<b>1,506</b>	<b>44,452</b>	<b>49,651</b>
Recovery of indirect costs		(2,452)	-	(2,452)	-	-	(2,452)	(2,491)
<b>Total expenses</b>		<b>25,117</b>	<b>3,310</b>	<b>28,427</b>	<b>12,067</b>	<b>1,506</b>	<b>42,000</b>	<b>47,160</b>
Excess (deficit) of revenue over expenses	13	338	-	338	-	(210)	128	(167)
Allocated as follows:								
Operating fund	13	338	-	338	-	-	338	(207)
Other funds (self-sustaining)	13	-	-	-	-	(210)	(210)	40
		338	-	338	-	(210)	128	(167)
<b>MEMO ITEM</b>								
Operating expenses - By natural classification								
Personnel costs		14,727	772	15,499	2,284	342	18,125	19,240
Supplies and services		10,117	2,171	12,288	8,389	1,050	21,727	26,379
Operational travel		1,119	367	1,486	1,394	6	2,886	2,771
Depreciation		1,606	-	1,606	-	108	1,714	1,261
Recovery of indirect cost		(2,452)	-	(2,452)	-	-	(2,452)	(2,491)
<b>Total operating expenses</b>		<b>25,117</b>	<b>3,310</b>	<b>28,427</b>	<b>12,067</b>	<b>1,506</b>	<b>42,000</b>	<b>47,160</b>

(See accompanying notes to financial statements)

STATEMENTS OF FINANCIAL POSITION  
DECEMBER 31, 1994 AND 1993  
(US DOLLAR '000)

	1994	1993
<b>CASH FLOWS FROM OPERATING ACTIVITIES</b>		
Excess (deficit) of revenues over expenses –	128	-167
Core operations and self-sustaining activities		
Adjustments to reconcile net cash provided		
By operating activities:	1,714	1,261
Depreciation		
Disposals and write – off of property and equipment	310	45
Decrease (increase) in assets:		
Accounts receivable	-2,649	3,069
Donors		
Employees	99	39
Others	-43	259
Inventories	-224	224
Prepaid expenses	-195	2
Increase (decrease) in liabilities:		
Accounts payable		
Donors	2,264	-5,796
Employees	4	-802
Others	-195	503
Funds in trust	326	-
Accruals and provisions	-177	-3,147
<b>NET CASH PROVIDED BY (USED IN) OPERATING ACTIVITIES</b>	<b>1,362</b>	<b>-4,510</b>
<b>CASH FLOWS FROM INVESTING ACTIVITIES</b>		
Acquisition of property and equipment	-1,873	-8,508
Center owned		
In custody	-455	-896
Funds invested in property and equipment	304	8,098
Increase in capital fund	3,813	5,674
Increase in operating fund due to adoption of accrual method of accounting in 1993	-	1,957
Cumulative translation adjustments	161	144
<b>NET CASH PROVIDED BY INVESTING ACTIVITIES</b>	<b>1,950</b>	<b>6,469</b>
<b>CASH FLOWS FROM FINANCE ACTIVITIES</b>		
Increase (decrease) in long-term liabilities:		
Accounts payable	923	-
Employees		
Others	(59)	-
Proceeds from (payments for) loan World Bank	(2,500)	2,500
<b>NET CASH PROVIDED BY (USED IN) FINANCING ACTIVITIES</b>	<b>-1,636</b>	<b>2,500</b>
<b>NET INCREASE IN CASH AND CASH EQUIVALENTS</b>	<b>1,676</b>	<b>4,459</b>
<b>CASH AND CASH EQUIVALENTS</b>	<b>40,821</b>	<b>36,362</b>
Beginning		
End	42,497	40,821

(See accompanying notes to financial statements)

Note 1 - General

The International Rice Research Institute (Institute) was established in 1960 to undertake basic research on the rice plant and applied research on all phases of rice production, management, distribution and utilization with the objective of attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas.

As a nonstock, nonprofit organization under Republic Act No. 2707 and an international organization under Presidential Decree No. 1620, the Institute was conferred the status of an international organization in the Philippines and was granted, among other privileges and prerogatives, the following tax exemptions:

- a) exemption from the payment of gift, franchise, specific, percentage, real property, exchange, import, export, documentary stamp, value-added and all other taxes provided under existing laws or ordinances. This exemption extends to goods imported and owned by the Institute to be leased or used by its staff;
- b) exemption from payment of gift tax; all gifts, contributions and donations to the Institute are considered allowable deductions for purposes of determining the income tax of the donor; and
- c) exemption from payment of income tax of non-Filipino citizens serving on the Institute's technical and scientific staff on salaries and stipends in United States dollars (US\$) received solely from, and by reason of, service rendered to the Institute.

The Institute receives support from various donor agencies and entities primarily through the Consultative Group on International Agricultural Research (CGIAR). CGIAR is a group of donors composed of governments of various nations and international organizations and foundations.

Note 2 -Basis of financial statements presentation and significant accounting policies

The accompanying financial statements, expressed in US\$, are prepared on the basis of accounting practices prescribed for international agricultural research centers seeking assistance from the CGIAR. The CGJAR - prescribed accounting practices conform with generally accepted accounting principles.

A summary of the Institute's significant accounting practices is set forth to facilitate the understanding of data presented in the financial statements.

*Cash equivalents* - Cash equivalents are short-term, highly liquid investments that are readily convertible to known amount of cash with original maturities of three months or less.

*Foreign currency transactions* - Philippine peso and other foreign currency-denominated transactions are translated to US\$ for reporting purposes at standard bookkeeping rates which approximate the exchange rates prevailing at the dates of the transaction. Exchange differences resulting from (a) the collection of foreign currency-denominated receivables and, (b) the settlement of foreign currency-denominated obligations at rates which are different from which they were originally booked are credited/charged to operations. Exchange differences resulting from the translation of balances of foreign-currency denominated accounts are carried in the "Cumulative Translation Adjustments" account.

*Revenue* - Revenue from unrestricted core grants 5e pledged on an annual basis and are recognized in the accounts when there is probability of collection in the year the grant is pledged. If the pledge is later judged to be uncollectible, it is written off against revenue of the year in which it is determined to be uncollectible. These grants are utilized to fund core programs and the regular operating requirements of the Institute.

Restricted core grants and grants for complementary projects are recognized as income when funds are committed or received from the donors to the extent of expenses actually incurred. Disbursements from these sources are limited by conditions embodied in agreements with donor organizations. Excess of grants received over expenses, representing grants applicable to succeeding years, is classified as Accounts Payable - Donors in the Statement of Financial Position.

*Inventory of materials and supplies* - Inventory of materials and supplies is stated at cost using the moving average method. Materials in transit are stated at invoice cost.

*Property and equipment* - Property and equipment acquired prior to 1991 are carried at cost or estimated value; acquisitions starting 1991 are stated at cost. Replacement and renovation of assets and property are financed through reserves funded primarily by depreciation. Depreciation of all assets which are owned by the Institute is computed on the straight-line method over the following estimated useful lives of the related assets:

Category description	Estimated life in years
Physical facilities	60
Building and improvements	12
Electrical equipment	
Infrastructure and leasehold	60
Site improvements	
Furniture and equipment	
Farming	
Farm machinery and equipment	15
Shop machinery and equipment	12-15
Laboratory	10
Office	5-12
Auxiliary units	10
Computers	5-8
Vehicles	6-10

Assets in custody are financed by restricted and complementary funding and remain the property of respective donors until the expiration of the agreement/contract after which decisions on disposition are made by donors. Such assets are shown as a separate item in the statement of financial position.

Effective January 1, 1993, assets in custody are no longer depreciated.

### **Note 3 - Cash and cash equivalents**

Cash and cash equivalents at December 31 consist of:

	1994	1993
Unrestricted	4,827	4,489
Restricted	37,670	36,332
	42,497	40,821

The restricted cash balance includes \$14,479 thousand. as of December 31, 1994 (1993 - \$10,666 thousand), which represents funds set aside for replacements of or improvements on property and equipment.

**Note 4 -Accounts receivable - donors**

Accounts receivable from donors consist of unreleased balances of approved grants and expenses advanced at December 31 and are classified as follows:

	1994	1993
Unrestricted core grants	2,433	216
Complementary projects grants	3,124	2,692
	5,557	2,908

The Secretariat of CGIAR assists the Institute in following up the release of core grants by donors.

**Note 5 -Accounts receivable - others**

Other receivables at December 31 consist of:

	1994	1993
Advances to projects	16	143
Advances to suppliers	632	550
Others	431	343
	1,079	1,036

**Note 6 -Property and equipment; leases**

Property and equipment at December 31 are classified under the following accounts:

	1994	1993
<i>Owned</i>		
Cost		
Physical facilities	32,995	28,026
Infrastructure and leasehold, Furnishing and equipment	1,320	6,379
	23,715	22,969
	58,030	57,374
Accumulated depreciation		
Physical facilities	11,296	10,803
Infrastructure and leasehold Furnishing and equipment	105	101
	14,431	14,062
	25,832	24,966
Net book value	32,198	32,408
<i>In Custody</i>		
Cost		
Physical facilities	313	247
Furnishing and equipment	2,162	1,731
Infrastructure and leasehold	17	-
	2,492	1,978
Accumulated depreciation (Note 2)	506	506
Net book value	1,986	1,472
	34,184	33,880

The land used as site for research activities is leased for a period of 25 years up to year 2000 from the University of the Philippines for a nominal rent and is renewable upon mutual agreement of the parties. Pursuant to the Memorandum of Understanding between the Government of the Republic of the Philippines and the Institute, all the physical plant, equipment and other assets belonging to the Institute shall become the property of the University when the institute's operations are terminated.

In support of any expansion of the agricultural research program of the Institute and the University, the Philippine Government authorized the University to acquire by negotiated sale or by expropriation certain private agricultural property under Presidential Decree No. 457

The Institute leases land and other property from third parties for project experimental sites for periods ranging from one to five years.

The institute also owns an administrative office in Makati.

**Note 7 -Accounts payable - donors**

Accounts payable to donors at December 31 consist of grants received, in advance and applicable to succeeding periods as follows:

	1994	1993
Unrestricted core	2,805	1,100
Restricted projects	1,785	2,200
Complementary projects	4,140	3,266
	8,730	6,466

**Note 8 -Accounts payable - employees**

The current and long-term accounts payable to employees consist of accumulated leave earned by and payable to Internationally and Nationally Recruited. Staff upon termination of services in addition to repatriation costs of Internationally Recruited Staff.

**Note 9 -Accounts payable - others**

The current and long-term accounts payable-others represent accrual of training charges of post-doctoral scholars, research fellows and trainees such as stipend, board and lodging and other direct expenses to be incurred by the Institute.

**Note 10 - Funds in trust**

Funds in trust pertain to funds provided by donors and managed by the Institute with an ultimate beneficiary other than CGIAR centers.

**Note 11 - Accruals and provisions**

Accruals and provisions at December 31 consist of:

	1994	1993
Trade payables	3,902	1,058
Capital projects	1,660	4,828
Staff benefits	3,042	2,282
Others	6,013	6,626
	14,617	14,794

**Note 12 - Staff benefit plan**

The institute maintains a non-contributory provident fund for the benefit of its Nationally Recruited Staff. Monthly contribution to the fund is computed at 10.5% of the employees' basic salary. The plan provides for lump-sum payment to qualified employees/members, upon their separation from the Institute, under certain conditions.

Contributions to the fund amounted to \$506,894 in 1994 (1993 - \$414,281)

**Note 13 - Changes in fund balances**

	Fund Balances					
	Capital invested in Fixed Assets		Capital	Operating Fund	Self- sustaining	Total
	Center owned	In Custody				
Balance, December 31, 1993	32,408	1,472	10,666	4,489	876	49,911
Additions (deductions) net	-716	1,020	3,813	-		4,117
Excess (deficit) of revenues over expenses	-	-	-	338	-210	128
Balance, December 31, 1994	31,692	2,492	14,479 (a)	4,827	666	54,156

(a) \$1,092 of equipment and fixed assets purchase orders were placed in 1994 and not received. This amount was not deducted from capital fund in 1994.

# IRRI TRUSTEES

## AT APRIL 1995

DR. EMIL Q. JAVIER (EX-OFFICIO)  
President  
University of the Philippines  
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DR. VO-TONG XUAN  
Vice Rector and Center Director  
Mekong Delta Farming Systems  
Research and Development  
Center  
University of Cantho  
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DR. KLAUS J. LAMPE (EX-OFFICIO)  
UNTIL 31 MAR 95)  
Director General  
Kari-Bieber Hoehe 29  
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# IRRI INTERNATIONAL STAFF 1994

KLAUS J. LAMPE PH D, *director general*  
FERNANADO A. BERNARDO, PH D, *deputy  
director general for international  
services*  
KENNETH S. FISHER PH D, *DEPUTY  
director general for research  
programs*  
MICHEL F. L., GOON MBA, *deputy  
director general for finance and  
administration*

## ADMINISTRATIVE PERSONNEL

ERNEST W. NUNN, PH D, *director,  
operations*  
EDWARD N. SYAEGH, BBA, *director  
finance*  
BENITO S. VERGARA, PH D, *director  
administration, and part-time  
liaison scientist for China*  
KWANCHAI A. GOMEZ, PH D, *statistician  
and head, liaison, coordination  
and planning*  
MARINUS CORNELIS VAN DEN BERG, BS,  
*head, computer services*  
REBECCA C. PASCUAL, MS, *manages food  
and housing services*  
VOLKER HELL, *senior advisor consultant*  
HERMAN JOSEF BREUER, *consultant*  
MITSUAKI TANABE, *sculptor*<sup>3</sup>  
YOSHIKO YAMAMOTO, PH D, *consultant*<sup>3</sup>  
GELIA T. CASTILLO, PH D, *consultant*<sup>4</sup>  
BERND JOPP, *consultant*<sup>4</sup>

## STAFF POSTED TO NATIONAL AGRICULTURAL RESEARCH SYSTEMS

### Bangladesh

SADIQUL I. BHUIYAN, PH D, *interim  
liaison scientist*

### Cambodia

HARRY J. NESBITT, PH D, *agronomist and  
team leader*  
PETER WHITE, PH D), *soil scientist*  
EDWIN L. JAVIER, PH D, *plant breeder*  
RAVINDRA C. JOSHI, PH D, *crop  
protection specialist*<sup>7</sup>

### Egypt

RICHARD L. TINSLEY, PH D, *agronomist  
and team leader*<sup>1</sup>, *consultant*<sup>3\*</sup>  
ADUSUMILLIN NARAYANA RAO, PH D),  
*agronomist (weed scientist)*<sup>1,6\*\*</sup>

### India

BRIJNANDAN P. GHILDYAL, PH D, *liaison  
scientist*

### Indonesia/Malaysia/Brunel

CEZAR P. MAMARIL, PH D, *agronomist  
and liaison scientist*  
GENARO O. SAN VALENTIN, PH D,  
*agronomist*

### Japan

TADASHI MORINAKA, PH D, *liaison  
scientist*

### Lao PDR

JOHN M. SCHILLER, PH D, *agronomist  
and team leader*  
WALTER RODER, PH D, *agronomist*  
TAWEE KUPKANCHAN, PH D,  
*Agronomist*<sup>4</sup>

### Madagascar

SUSAN W. ALMY, PH D, *agroeconomist*<sup>1</sup>  
MARTHA M. GAUDREAU, PH D, *cropping  
systems agronomist and team  
leader*  
TOMAS M. MASAJO, PH D, *plant breeder*

### Myanmar

ARNULFO G. GARCIA, PH D, *cropping  
systems agronomist and IRRI  
representative*

### Thailand

DONALD W. PUCKRIDGE, PH D,  
*agronomist and IRRI  
representative, and program  
leader deepwater and tidal  
wetlands rice ecosystem research*

### Africa

KRISHNA ALLURI, PH D, *liaison scientist  
and INGER regional coordinator*

### Latin America

FEDERICO E. CUEVAS-PEREZ, PH D, *liaison  
scientist and INGER regional  
coordinator*<sup>1</sup>

## STAFF AT HEADQUARTERS

### Agricultural Engineering

GRAEME R. QUICK, PH D), *agronomist and head*<sup>2</sup>

REYNALDO M. LANTIN, PH D), *visiting scientist and acting head*<sup>1</sup>

MARK BORU DOUTHWAITE, MS, *consultant*

MARTIN GUMMERT, MS, *consultant*

### Agronomy, Plant Physiology, and Agroecology

KENNETH G. CASSMAN, PH D, *agronomist and head*

MARTIN J. KROPFF, PH D, *agronomist/crop modeler*<sup>1</sup>

KEITH MOODY, PH D, *agronomist*

LEONARD J. WADE, PH D, *agronomist*

VIRENDEA PAL SINGH, PH D, *agronomist*

ADUSUMILLI NARAYANA RAO, PH D, *agronomist (weed scientist)*<sup>1,6</sup>

MOTOHIKO KONDO, M AGR *Agronomist*<sup>4</sup>

MINORU YAMAUCHI, PH D, *plant Physiologist*<sup>1</sup>

TIMOTHY L. SETTER, PH D, *plant physiologist*

SHAOBING PENG, PH D, *associate crop physiologist*

UPENDRA SIN GH, PH D, *visiting scientist*

ROBIN B. MATTHEWS, PH D, *visiting Scientist*<sup>1</sup>

THOMAS GEORGE, PH D, *visiting scientist*

GUY TREBUIL, PH D, *visiting scientist*

DANIEL OLK, PH D, *visiting scientist*

MARIA OLOFSDOTTER-GUNNARSEN, PH D, *visiting scientist*<sup>1</sup>

Felino Lanfelino Lansigan, PH D, *visiting Scientist*<sup>4</sup>

P.K. AGGARWAL, PH D, *visiting Scientist*<sup>4</sup>

T.M. THIYAGARAJAN, PH D, *visiting scientist*<sup>4</sup>

ELSA RUBIA, MS, *consultant*<sup>4</sup>

TOLENTINO MOYA, PH D, *consultant*

A.N. Singh, PH D, *consultant*<sup>3</sup>

MARCO WOPEREIS, MS, *consultant*<sup>1</sup>

H.H. VAN LAAR BS, *consultant*<sup>3</sup>

CURTIS WELDON, BS, *consultant*<sup>3</sup>

Rico Pamplona, BS, *consultant*<sup>3</sup>

QIDE ZHANG, PH D, *consultant*<sup>3</sup>

QUIJIE DAI, PH D, *consultant*<sup>3</sup>

### Entomology and Plant Pathology

TWING W. MEW, PH D, *plant pathologist and head*

KONG LUEN HEONG, PH D, *entomologist*

ROBERT S. ZEIGLER, PH D, *plant pathologist and program leader, rainfed lowland rice ecosystem research*

PAULS S. TENG, PH D, *plant pathologist and program leader, cross-ecosystems research*

HIROKI KAGANEZAWA, PH D, *plant Pathologist*<sup>1</sup>

REBECCA J. NELSON PH D, *plant pathologist*

MICHAEL COHEN, PH D, *insect host plant resistance specialist*

JEAN-CLAUDE PROT, PH D, *visiting scientist and interim program leader upland rice ecosystem*

SERGE SAVARY, PH D, *visiting scientist*<sup>3</sup>

ALAN WATSON, PH D, *visiting scientist*

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MA. LUZ C. GEORGE, PH D, *consultant*<sup>4</sup>

BART COTTYN, PH D, *consultant*<sup>4</sup>

HEI LEUNG, PH D, *consultant*<sup>3</sup>

### Plant Breeding, Genetics, and Biochemistry

GURDEV S. KHUSH, PH D, *principal plant breeder and head*

JOHN BENNETT, PH D, *senior molecular biologist*

DARSHAN S. BRAR, PH D, *plant breeder*

NING HUANG, PH D, *plant molecular geneticist*

TOKIO IMBE, PH D, *plant breeder*

SURAPONG SARKARUNG, PH D, *plant breeder*

DHARMAWANSA SENADHIRA, PH D, *plant breeder*

SANT SINGH VIRMANI, PH D, *plant breeder*

SWAPAN K. DATTA, PH D, *tissue culture specialist*

SUSAN R. MCCOUCH, PH D, *associate geneticist*<sup>1</sup>

NAM KYU PARK, PH D, *visiting scientist*

MICHEL A. ARRAGDEAU, PH D, *visiting scientist and program leader, upland rice ecosystem research*<sup>1</sup>

BRIGITTE COURTOIS PH D, *visiting scientist*

ZJONGZHUAN LING, PH D, *visiting scientist*<sup>3</sup>

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VIVIAN P.S. TOLENTINO, PH D, *Consultant*<sup>4</sup>

JIZHANG HUANG. PH D, *consultant*<sup>4</sup>

### Social Sciences

MAHAHUB HOSSAIN, PH D, *agricultural economist and head*

JAMES S. FUJISAKA, PH D, *social Scientist*<sup>1</sup>

SUAN PHENG KAM, PH D, *geographic information systems (GIS) specialist*<sup>4</sup>

PRABHUL L. PINGALI, PH D, *agricultural economist and program leader, irrigated rice ecosystem research*<sup>2</sup>

SUSHIL PANDEY, PH D, *agricultural economist*

SARAH J. TISCH, PH D, *visiting scientist*<sup>1</sup>

ROBERT EVENSON, PH D, *visiting scientist*<sup>5</sup>

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*Consultant*<sup>3</sup>

SAMJHANA SHRESTHA, MS, *Consultant*<sup>3</sup>  
DIBYA TIMSINA, MS, *Consultant*<sup>3</sup>

### **Soil And Water Sciences**

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JAGDISH K. LADHA, PH D, *soil  
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*Microbiologist*<sup>4</sup>

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### **Biometrics**

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### **Genetic Resources Center**

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SANG-WON AHN, PH D, *plant  
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RAM CHET CHAUDHARY, PH D, *global  
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N. BRIAN LEE, BA, *visiting scientist*<sup>3</sup>

L. REGINALD MCINTYRE, *visiting  
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L4N WALLACE, MLS, *consultant*

ALAN FLETCHER, *consultant*<sup>3</sup>

JOHN MADELY, *consultant*<sup>3</sup>

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international collaboration  
and head*

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and coordinator, asian rice  
farming systems network  
(ARFSN)*<sup>1</sup>

VETHAIYA BAIASUBRAHMANLAN, PH D,  
*agronomist/CREMNET  
coordinator*<sup>7\*\*\*\*</sup>

### **Training Center**

ELLIS L. MATHENY, JR., PH D, *head*

ROBERT I RAAB, PH D, *training and  
courseware specialist*

JANICE PUCKRIDGE, *consultant*<sup>4</sup>

<sup>1</sup>left During The Year.

<sup>2</sup>On Study Leave/Training.

Joined And Left During The Year.

<sup>4</sup>joined During The Year

<sup>5</sup>cooperative Research Staff

<sup>6</sup>Transferred From Egypt-Irr[ Office  
From July 1994.

<sup>7</sup>formerly From Madagascar-Irr[ Project.

\*Returned To Iraj[ Leadquarters After The  
termination of the project for consultancy  
assignment up to October 1994.

\*\*Returned To IRRI Headquarter after The  
termination of the project on the same status.

\*\*\*Retired and then appointed as consultant  
effective 15 Dec 1994.

\*\*\*\*Formerly soil scientist and team leader  
Madagascar-IRRI Project

# CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH (CGIAR)

THE CGIAR IS A WORLDWIDE NETWORK OF RESEARCH CENTERS SUPPORTED BY AN INTERNATIONAL DONOR GROUP. IRRI IS PART OF THIS GLOBAL SYSTEM. THROUGH RESEARCH AND EDUCATION,—THE CGIAR HELPS MAKE FARMING IN DEVELOPING COUNTRIES MORE PRODUCTIVE—THE FIRST STEPPING STONE OUT OF POVERTY. FOR FARMERS AND THE RURAL POOR, INCREASED AGRICULTURAL PRODUCTION LEADS TO BETTER NUTRITION, HIGHER INCOMES AND IMPROVED STANDARDS OF LIVING. INCREASED AND MORE STABLE PRODUCTION OF FOOD STAPLES ALSO LEADS TO LOWER PRICES, WHICH ALLOW POOR PEOPLE IN THE CITIES TO SATISFY MORE OF THEIR FOOD NEEDS.

SOME 1,000 INTERNATIONALLY RECRUITED SCIENTISTS REPRESENTING 60 DIFFERENT NATIONALITIES CONDUCT RESEARCH AT CGIAR CENTERS AND IN COLLABORATION WITH NATIONAL PROGRAM SCIENTISTS IN SOME 40 DEVELOPING COUNTRIES.

## MISSION of the CGIAR

Through international research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture, forestry and fisheries in developing countries in ways that enhance nutrition and well-being, especially of low-income people.

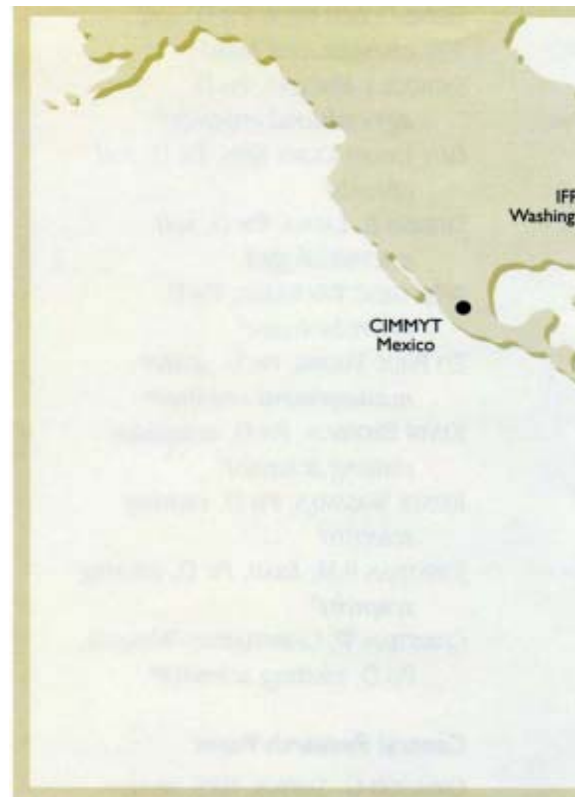
**CIAT**—Centro Internacional de Agricultura Tropical, with headquarters in Colombia. Focus on germplasm development in beans, cassava, tropical forages and rice for Latin America, and on resource management in humid ecosystems in tropical America (hillsides, forest margins and savannas).

**CIFOR**—Center for International Forestry Research, with headquarters in Indonesia. Focus on conserving and improving the productivity of tropical forest ecosystems.

**CIMMYT**—Centro Internacional de Mejoramiento de Maíz y Trigo, with headquarters in Mexico. Focus on increasing the productivity of resources committed to maize, wheat and triticale in developing countries.

**CIP**—Centro Internacional de la Papa, with headquarters in Peru. Focus on potato and sweet potato improvement and on natural resource conservation in the Andean region.

**ICARDA**—International Center for Agricultural Research in the Dry Areas, with headquarters in Syria. Focus on increasing the productivity of farming systems involving wheat, barley, chickpea, lentils, pasture legumes and small ruminants in North Africa and West Asia.



**ICLARM**—International Center for Living Aquatic Resources Management, with headquarters in the Philippines. Focus on improving production and management of aquatic resources in developing countries.

**ICRAF**—International Centre for Research in Agroforestry, with headquarters in Kenya. Focus on mitigating tropical deforestation, land depletion and rural poverty through improved agroforestry systems.

**ICRISAT**—International Crops Research Institute for the Semi-Arid Tropics, with headquarters in India. Focus on contributing to more sustainable agricultural production systems through improved productivity of sorghum, millet, chickpea, pigeonpea and groundnut



**IFPRI**—International Food Policy Research Institute, with headquarters in the United States. Focus on identifying and analyzing policies for meeting the food needs of developing countries, in particular the poorer countries.

**IIMI**—International Irrigation Management Institute, with headquarters in Sri Lanka. Focus on strengthening the development, dissemination and adoption of lasting improvements in the performance of irrigated agriculture in developing countries.

**IITA**—International Institute of Tropical Agriculture, with headquarters in Nigeria. Focus on contributing to sustainable and increasing food production in the humid and subhumid tropics, in particular in maize, cassava, cowpea, plantain, soybean and yam, and in partnership with African national agricultural research systems.

**ILRI**—International Livestock Research Institute, with headquarters in Nairobi, Kenya. Focus on improving livestock production and the contribution of livestock to sustainable agricultural production systems and in controlling major animal diseases (trypanosomiasis and tick-borne diseases) that seriously limit livestock industries in Africa and many other parts of the world.

**IPGRI**—International Plant Genetic Resources Institute, with headquarters in Italy. Focus on conserving gene pools of current and potential crops and forages. The International Network for the Improvement of Banana and Plantain (INIBAP) is an IPGRI program aimed at increasing the productivity and stability of banana and plantain grown on small farms in developing countries. INIBAP's major operational base is in France

**IRRI**—International Rice Research Institute, with headquarters in the Philippines. Focus on generating and disseminating rice-related knowledge and technology of long-term environmental, social and economic benefit

**ISNAR**—International Service for National Agricultural Research, with headquarters in the Netherlands. Focus on institutional development and strengthening of national agricultural research systems.

**WARDA**—West Africa Rice Development Association, with headquarters in Côte d'Ivoire. Focus on improving rice varieties and production methods among smallholder farm families in the upland/inland-swamp continuum, the Sahel and mangrove swamp environments.

## Appendix I. Institutions collaborating with IRRI.

### Australia

Australian Agency for International Development (AusAID)  
Australian Centre for International Agricultural Research (ACIAR)  
Commonwealth Scientific and Industrial Research Organization (CSIRO)  
University of Melbourne  
Yanco Agricultural Institute

### Bangladesh

Bangladesh Agricultural University (BAU)  
Bangladesh Rice Research Institute (BRRI)  
Bangladesh Agricultural Research Institute (BARI)

### Belgium

Belgian Administration for Development Cooperation (BADC)  
Universite Catholique de Louvain  
Rijkuniversiteit Gent

### Bhutan

Ministry of Agriculture

### Brunei

Department of Agriculture, Ministry of Industry and Primary Resources

### Cambodia

Ministry of Agriculture

### Canada

Canadian International Development Agency (CIDA)  
International Development Research Centre (IDRC)  
McGill University  
Universite Laval

### China

Ministry of Agriculture: Agricultural Support Services Project (ASSP)  
Chinese Academy of Agricultural Mechanization Sciences (CAAMS)  
Chinese Academy of Agricultural Sciences (CAAS)  
Chinese Academy of Sciences (CAS)  
China National Rice Research Institute (CNRI)  
Provincial Academy of Agricultural Sciences (e.g., Guangdong, Hunan, Fujian AM)  
University of Beijing  
Zhejiang Agricultural University  
South China Agricultural University

### Cuba

Cuban Rice Research Institute  
State Committee for Economic Cooperation of the Republic of Cuba

### Denmark

Danish International Development Agency (DANIDA)

### Egypt

Ministry of Agriculture and Land Reclamation

### France

Centre de cooperation internationale en recherche agronomique pour le developpement, departement des cultures annueles (CIRAD.CA)  
Institut national de la recherche agronomique (INRA)  
Institut francais de recherche scientifique pour le developpement en cooperation (ORSTOM)  
Centre national de la recherche scientifique (CNRS)

### Germany

Deutsche Welthungerhilfe (DW)  
Entwicklungspolitische Informationen  
Federal Ministry for Economic Cooperation (BMZ)  
German Agency for Technical Cooperation (GTZ)  
Fraunhofer-Gesellschaft Zur Forderung Der Angewandten, Forschung E.V. (FhG)  
Max. Planck Institute (MPI)  
University of Hohenheim  
University of Leipzig  
University of Goettingen  
Justus Liebig-University of Giessen

### India

The Government of India, Department of Agriculture and Cooperation, Directorate of Plant Protection, Quarantine and Storage  
Indian Council for Agricultural Research (ICAR)  
Uttar Pradesh Council of Agricultural Research (UPCAR)  
Indian Institute of Technology  
Central Rice Research Institute  
Tamil Nadu Agricultural University  
Indian Agricultural Research Institute (IARI) of the Indian Council of Agricultural Research (ICAR)  
Directorate of Rice Research  
Andhra Pradesh Agricultural University  
Assam Agricultural University  
Indira Gandhi Agricultural University  
Punjab Agricultural University  
University of Agricultural Sciences  
Narendra Dew University of Agriculture Technology

### Indonesia

Agency for Agricultural Research and Development (AARD)  
Central Research Institute for Food Crops (CRIFC)  
Ministry of Agriculture  
Institut Pertanian Bogor  
Universitas Gadjah Mada

### Iran

Agricultural and Natural Resources Research Organization of the Ministry of Agriculture and Rural Development  
University of Guilan

### Israel

Hebrew University of Jerusalem

### Japan

National Agriculture Research Center (NARC)  
Plantech Research Institute  
Japan International Research Center for Agricultural Sciences (JIRCAS)  
Mie University

### Kenya

Kenya Agricultural Research Institute (KARI)

### Korea, Republic of

Academy of Agricultural Sciences (AAS)  
Rural Development Administration (RDA)

### Korea, Democratic People's Republic of

Rice Research Institute of the Academy of Agricultural Sciences (AAS)

### Lao PDR

Ministry of Agriculture and Forestry (MAF)

### Madagascar

Ministry of Research Applied to Development National

Center for Research Applied to Rural Development (FOFIFA)

University of Antananarivo

### Malaysia

Malaysian Agricultural Research and Development Institute (MARDI)  
Universiti Pertanian Malaysia

**Myanmar (formerly Burma)**

Ministry of Agriculture: Myanma Agricultural Service (MAS)

**Nepal**

Department of Agriculture: National Agricultural Research Centre (NARC)

**Netherlands**

C.T. de Wit Graduate School of Production Ecology (PE)

Institute for Agrobiological and Soil Fertility Research (AB-DLO)

Centre for Agrobiological Research (CABO) and Theoretical Production Ecology (TPE), Wageningen Agricultural University

**Pakistan**

Pakistan Agricultural Research Council (PARC)  
National Agricultural Research Center (NARC)

**Papua New Guinea**

Department of Agriculture and Livestock  
Trukai Industries Pty. Ltd.

**Philippines**

Central Luzon State University (CLSU)

Los Baños Science Community

Department of Agriculture

Department of Science and Technology

National Irrigation Administration (NIA)

Philippine Council for Agriculture, Forestry and Natural

Resources Research and Development (PCARRD)

Philippine Rice Research Institute (PhilRice)

National Post-Harvest Institute for Research and Extension (NAPHIRE)

University of the Philippines Los Baños (UPLB)

Bureau of Plant Industry (BPI)

International Institute for Rural Reconstruction (IIRR)

Bureau of Plant Industry

Visayas State College of Agriculture (VISCA)

Western Mindanao State University (WMSU)

**Sri Lanka**

Department of Agriculture (DOASL)

**Switzerland**

CIBA-GEIGY Ltd.

Swiss Development Cooperation (SDC)

**Taiwan (P.R. China)**

Ministry of Agriculture, Project Management Office

**Tanzania**

Ministry of Agriculture: Department of Research and Training

**Thailand**

Asian Institute of Technology

Department of Agriculture

Ministry of Agriculture and Cooperatives

Kasetsart University

Chiang Mai University

Rice Research Institute

**United Kingdom**

Imperial college, University of London

Natural Resources Institute (NRI)

Overseas Development Administration (ODA)

University of Nottingham

University of Birmingham

University of Reading

**USA**

Environmental Protection Agency (EPA)

United States Agency for International Development (USAID)

Ford Foundation (FE)

Rockefeller Foundation (RE)

IBSNAT Project University of Hawaii

Research Corporation of the University of Hawaii (RCUH)

NifTal Project. University of Hawaii

Oregon State University

Soil Management Collaborative Research Support Program

University of California, Davis Campus

University of Maryland. College Park (UMCP)

United States Department of Agriculture Agricultural Research Service (ARS) and National Seed Storage Laboratory

Washington State University

Winrock International Institute for Agricultural Development

Michigan State University

University of Arkansas

University of Florida

Virginia Polytechnic Institute and State University

**Vietnam**

Ministry of Agriculture and Food Industries (MAFI)

Ministry of Higher Education (MHE)

Cuu Long Delta Rice Research Institute (CLRRI)

Institute of Food Crops Research

Institute of Plant Protection

Cantho University

University of Agriculture and Forestry

**International Organizations**

Asian Development Bank (ADB)

Asian Vegetable Research and Development Center (AVRDC)

Centro Internacional de Agricultura Tropical (CIAT)

Centro Internacional de la Papa (CIP)

Food and Agriculture Organization (FAO)

International Board for Plant Genetic Resources (IBPGR)

International Centre for Agricultural Research in the Dry Areas (ICARDA)

International Centre of Insect Physiology and Ecology

(ICIPE)

International Center for Living Aquatic Resources Management. Inc. (ICLARM)

International Center for Research in Agroforestry (ICRAF)

International Fund for Agricultural Development (IFAD)

International Fertilizer Development Center (IFDC)

International Food Policy and Research Institute (IFPRI)

International Irrigation Management Institute (IIMI)

International Institute of Rural Reconstruction (IIRR)

International Institute of Tropical Agriculture (IITA)

Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA)

United Nations Development Programme (UNDP)

United Nations Environment Programme, Global Resources Information Database Component (UNEP-GRID)

West Africa Rice Development Association (WARDA)

World Bank

## Appendix 2. Ongoing IRRI complementary projects, 1994.

No	Project title	Donor	Budget (US\$)	Project start	Project end
1	Assessment of the Active Barrier System for Rodent Control at IRRI	ACIAR	5,540	1993	1994
2	Analysis of Nitrogen and Starch in Tropical Crops Using NIR Spectroscopy	ACIAR	29,938	1994	1995
3	Decentralized Participatory Research for Less Favorable Rice Ecosystems and Rice-Wheat Systems of Asia	ADB	3,000,000	1991	1994
4	Asian Rice Biotechnology Network. Part I	ADB	900,000	1993	1995
5	IRRI-UCL Project on Azolla	AGCD	234,466	1987	1994
6	Managing Rice Diseases through Seed Health and Rice Seed Associated Bacteria -A Key Component of 1PM	AGCD	1,653,700	1994	1999
7	Cambodia-IRRI-Australia Project (Phase III)	AIDAB	7,833,617	1991	1996
8	Disease Management in RLR w/ Special Reference to Characterization of Microenvironment for Extrapolating Technology	BMZIGTZ	228,518	1991	1996
9	Nitrogen Dynamics in Lowland Rice as Affected by Organic Farming Practices	BMZIGTZ	106,800	1993	1996
10	Strengthening INGER in Africa (ECSA Portion)	BMZ/GTZ	800,000	1992	1995
11	Asian Rice Biotechnology Network (ARBN) - Part 2	BMZIGTZ	1,380,000	1993	1995
12	Upland Rice Consortium in South and Southeast Asia (Phase II)	BMZJGTZ	470,588	1994	1996
13	Postharvest Technologies for Rice in the Humid Tropics (Phase II)	BMZIGTZ	112,500	1993	1996
14	Field Variabilities of Soil and Plant: Impact on Rice Productivity and Use in Modeling of Soil Kinetic and Rice Yield	GTZ	187,275	1992	1995
15	The Economics of Integrating Fish into Rice-based Farming Systems in Asia	GTZ	19,600	1992	1995
16	Permanent Rice Exhibition at IRRI	GTZ	73,350	1994	1994
17	Women in Rice Farming Systems	DANIDA	94,100	1993	1995
18	Assessing Opportunities for Biological Nitrogen Fixation in Rice	DANIDA	610,000	1994	1996
19	Managing Weeds With Less Herbicides: Allelopathic Activity of Rice Germplasm	DANIDA	625,000	1994	1996
20	Systems Analysis and Simulation for Rice Production (SARP3)	DGIS	1,272,712	1992	1995
21	Rainfed Lowland Rice Research Consortium	DGIS	128,800	1994	1995
22	Cambodian Refugee Training Support Project	DW	54,250	1991	1995
23	Improving Farming Systems Productivity and Sustainability in the Hilly Regions of Myanmar	DW	65,000	1994	1995
24	Effects of UV-B and Global Climate Change on Rice	EPA	6,655,738	1990	1995
25	FAD-IRRI Collaboration and Participatory Research in Pest Management	FAQ	15,000	1992	1995
26	Development of Ecosystems Analysis and Farming Systems Research in Eastern India (Phase II)	FF	650,000	1989	1995
27	Women in Rice Farming Systems (Phase II)	FF	200,000	1991	1995
28	IRRI-ORSTOM Project on Nematology	France	59,061	1988	1994
29	Data Management for On-farm Trials	IDRC	179,340	1989	1994
30	Asian Rice Farming Systems	IDRC	458,720	1992	1995
31	Bhutan - IRRI Rice Farming Systems (Phase II)	IDRO	330,055	1990	1995
32	IRRI-Myanmar Low-Cost Sustainable Rice-Based Farming Systems Project for Hilly Regions of Myanmar	IDRC	305,302	1992	1995
33	Agricultural Economics Capacity (Vietnam-IRRI)- (Phase II)	IDRC	191,312	1994	1996
34	Development of Rainfed Rice Production in Bangladesh	FAD	387,700	1989	1994
35	Collaborative Research and Development of Sustainable Rice Farming Systems in Southern Asia (Phase II)	IFAD	1,379,300	1994	1996

**Appendix 2 continued**

No	Project title	Donor	Budget (US\$)	Project start	Project end
36	IRRI-IFPRI Collaborative Projects on Rice Policy in Southeast Asia	IFPRI	303,822	1989	1994
37	Iran-IRRI Collaborative Project	IRAN	500,000	1994	
38	Projections and Policy Implications of Medium- and Long-term Rice Supply and Demand	JAPAN	1,618,400	1990	1995
39	Training and Professional Advancement of Rice Farming Systems Scientists in Africa	JAPAN	574,400	1986	1994
40	Development of Stabilization of Technology for Rice Double Cropping in the Tropics	JAPAN	1,949,100	1989	1994
41	IRRI-Japan Shuttle Research Program	JAPAN	650,000	1990	1995
42	Improving Sustainability through Increasing Rice Productivity in the South and Southeast Asian Upland	JAPAN	400,000	1994	1997
43	Assessing Opportunities for Nitrogen Fixation in Rice	JAPAN	300,000	1994	1995
44	Stabilization of Rice Culture under Water Stress in the Tropics Utilizing a Broader Spectrum of Genetic Resources	JAPAN	434,866	1994	1995
45	IRRI-NRI Collaborative Research on Rice Tungro Disease: Epidemiology and Vector Ecology	NRI	140,525	1993	1995
46	Rice Genetic Manipulation for Improved Yield Stress Tolerance and Disease Resistance Using Protoplasts	ODA	240,570	1991	1994
47	Methane Generation and Consumption in Rice Fields	ODA	23,135	1993	1996
48	Characterization and Evaluation of Key Seedborne Fungal Pathogens of Rice	ODA	306,303	1994	1997
49	Molecular Markers and their Use in Organizing Plant Germplasm Collections	ODA	26,600	1993	1996
50	Germplasm Utilization for Value Added	RDA	30,000	1991	1994
51	Differential Impact Study on Modern Rice - Tamil Nadu, India	RF	90,000	1988	1994
52	Postdoctoral Fellowship (Dr. Michael Champoux)	RF	5,000	1990	1994
53	Environmental Research Fellowship in International Agriculture	RF	24,000	1991	1994
54	Application of Molecular Techniques to Problems in Rice Pathology (Phase III)	RF	130,000	1993	1994
55	Genome Mapping and Molecular Marker-Assisted Plant Breeding	RF	154,000	1992	1994
56	Transgenic Rice for Control of Yellow Stem Borer	RF	148,500	1994	1994
57	Administrative Support for the Biotechnology Program in India	RF	112,000	1990	1994
SB	Fellowship in Rice Biotechnology	RF	88,000	1993	1995
59	Terminal Sequencing of Mapped Rice Genomic Probes	RF	118,000	1994	1995
60	Rice Research Prioritization	RF	125,000	1993	1995
61	Training and Technology Transfer Fellowships in Rice Biotechnology	RF	270,480	1993	1996
62	Establishment of an International Rice Drought Screening Facility at Ubon Rice Research Center	RF	78,900	1993	1996
63	Developing Marker-aided Selection Techniques for Identifying Flood-Tolerant Rice Genotypes	RF	74,300	1994	1998
64	Rice Biotechnology Research Project	RF	700,000	1994	1995
65	Molecular Mapping of Genes Controlling Cytoplasmic Sterility and Fertility Restoration in Rice	RF	34,000	1995	1997
66	Developing Research for Increasing Yield in a Sustainable Rice Production System - Phase II	SAREC	744,486	1992	1995
67	Safeguarding and Preservation of the Biodiversity of the Rice Gene Pool - Phase I	SDC	3,286,000	1993	1995
68	Lao-IRRI Rice Research and Training Project - Phase II	SDC	3,540,000	1993	1996
69	Integrated Pest Management Research Network - Phase II	SDC	967,869	1994	1996

**Appendix 2** continued

No	Project title	Donor	Budget (US\$)	Project start	Project end
70	Reversing Trends of Declining Productivity in Intensive Irrigated Rice Systems A Mega Project	SDC	763,000	1994	1996
71	INGER 2000	SDC	631,440	1994	1995
72	Strengthening the Cuu Long Delta Rice Research Institute	UNDP	481,125	1992	1995
73	An Interregional Programme on Methane Emission from Ricefields	UNDP	4,403,400	1993	1997
74	A Global Research Programme to Develop Sustainable Rice Production Systems	UNDP	8,000,000	1991	1996
75	Effects of Continuous, Irrigated Rice Croppings on the Chemical Composition of Soil Organic Matter	USAID	50,000	1992	1994
76	Induction of Nodules on Rice Roots by Rhizobium	USAID	53,700	1993	1995
77	IRRI-Madagascar Rice Research Project - Phase III	USAID	5,600,000	1990	1994
78	Crop Residue Decomposition and Trichoderma for Disease Management in Rice-based Cropping Systems	USAID	110,000	1993	1997
79	China - IRRI Agricultura] Support Services Project	WB	784,186	1993	1996
80	Vietnam/IRRI Rice Research and Training	AIDAB	593,594	1991	1994
81	Research on Rice Seedborne Disease	AGCD	120,315 -	1991	1994
82	Farm Tools and Equipment in Laos and Myanmar	DW	8,000	1994	1994

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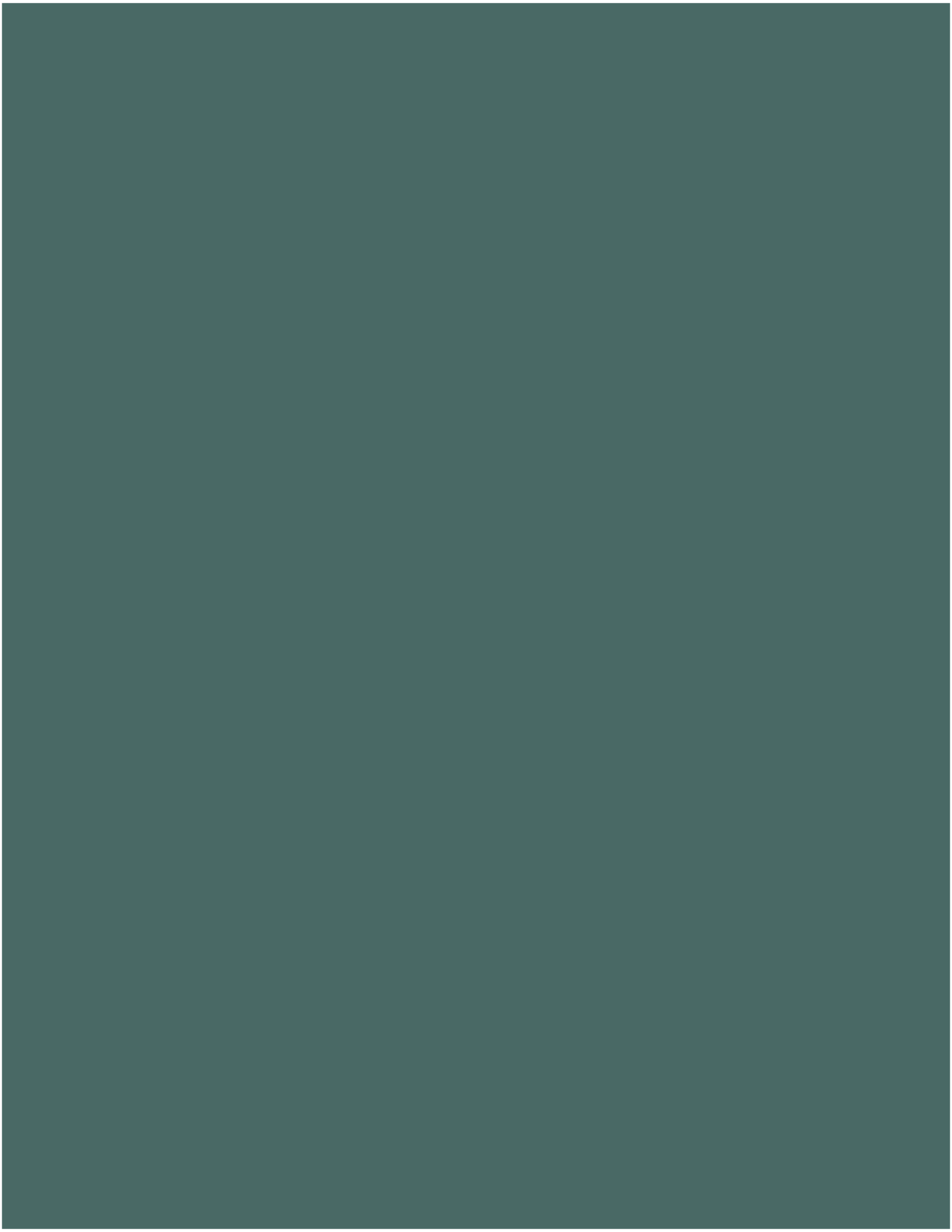
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## **IRRI's Mission Statement**

### **Our goal**

To improve the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes.

### **Our objectives**

To generate and disseminate rice-related knowledge and technology of short- and long-term environmental, social, and economic benefit and to help enhance national rice research systems.

### **Our strategy**

We pursue our goal and objectives through

- interdisciplinary ecosystem-based programs in major rice environments
- scientific strength from discipline-based divisions
- anticipatory research initiatives exploring new scientific opportunities
- conservation and responsible use of natural resources
- sharing of germplasm, technologies, and knowledge
- participation of women in research and development
- partnership with farming communities, research institutions, and other organizations that share our goal

### **Our values**

Our actions are guided by a commitment to

- excellence
- scientific integrity and accountability
- innovation and creativity
- diversity of opinion and approach
- teamwork and partnership
- service to clients
- cultural diversity
- gender consciousness
- indigenous knowledge
- environmental protection



