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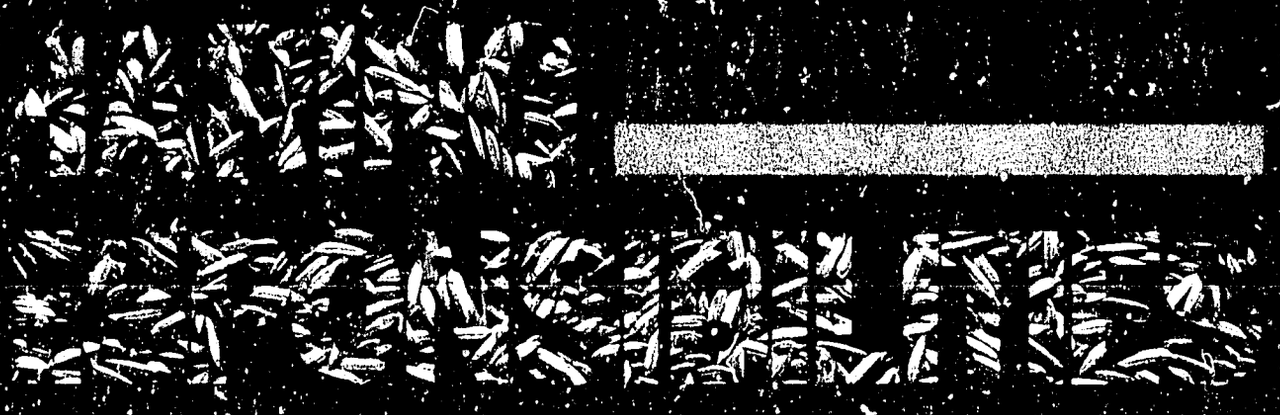

MERCI RESEARCH INSTITUTE

IRRI toward 2000 and beyond

The goal
Improved well-being of present and future generations of rice farmers and consumers, particularly those with low incomes.

The 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.

The strategy
To increase rice production efficiency and sustainability in all rice-growing environments through interdisciplinary research and to ensure the relevance of IRRI research and the complementarity of international and national research efforts through close collaboration with national programs.

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INTERNATIONAL RICE RESEARCH INSTITUTE
P.O. Box 933, 1099 Manila, Philippines

Sharing responsibilities

Alleviating today's pressing global concerns about agriculture—availability of food, conservation of resources, sustainability of the environment—calls for solving complex, interactive problems. Finding the knowledge and developing the technology to address these problems demands creative thinking and extensive research.

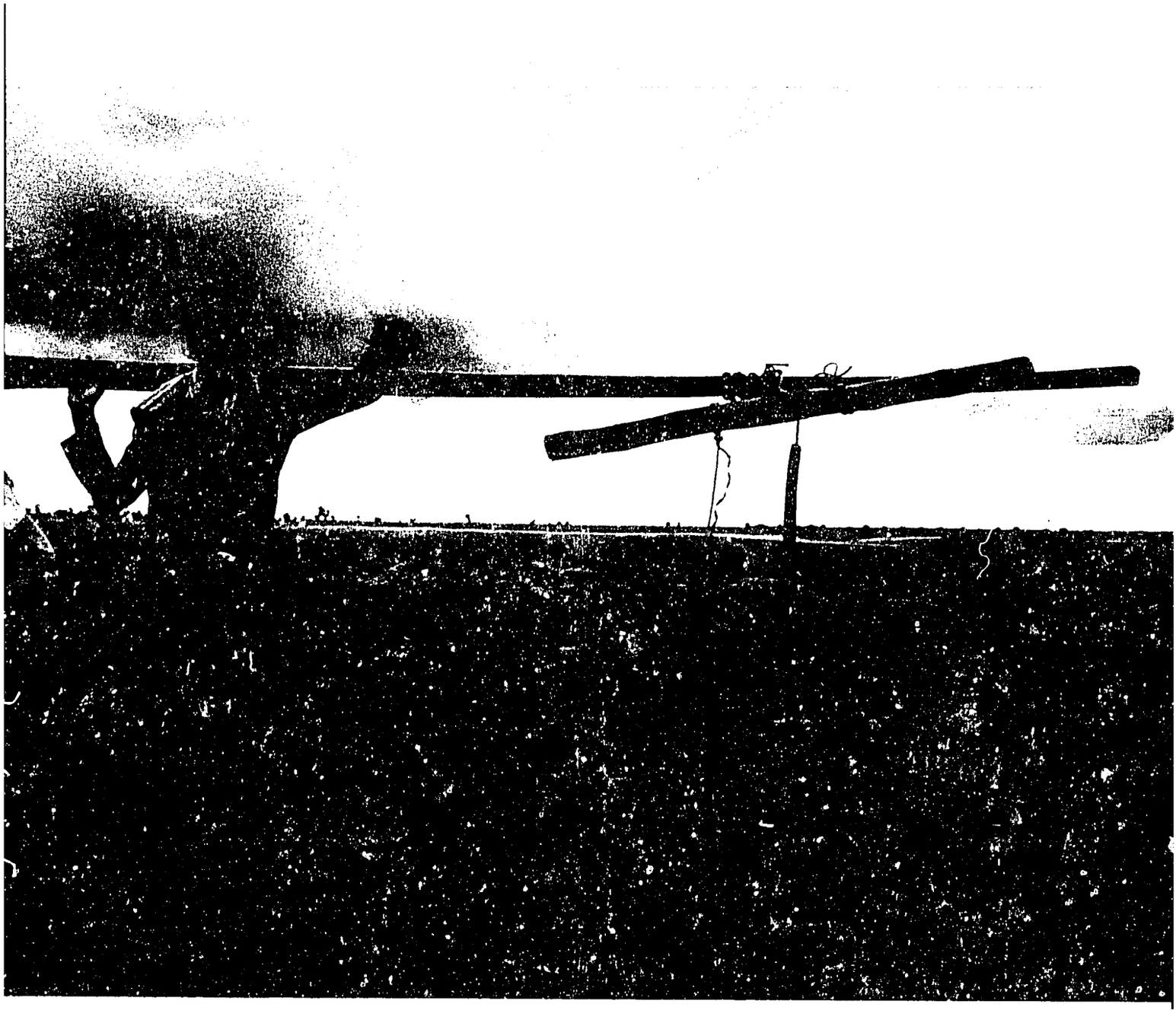
This is particularly true in the rice world. Rice is the basic food of nearly half the people on earth, most of them concentrated in Asia. Expanding populations and intensifying rice production are highlighting the extent and complexity of the food–resources–environment conundrum. This is a puzzle no single institution working alone can possibly solve.

IRRI's objectives are to seek the knowledge and develop the tools and technology that will increase and sustain rice production while decreasing costs, in the context of environmental sustainability and secure human well-being. Achieving these objectives depends on close collaboration.

Each IRRI scientist works with colleagues in other disciplines—inside IRRI, in national rice research programs, in other advanced institutions and laboratories, in sister international agricultural research centers, in nongovernmental organizations, in the private sector.

Problems can be resolved more easily and in relatively less time through such collaboration. Scientists and research institutions in many countries of the world are developing exciting new methodologies and expanding knowledge applicable to resolving important issues in sustainable rice production.

Collaboration has many synergistic benefits—speeding the transfer of information and advanced research methodologies, shortening the time needed to solve problems, enabling scientific collaboration across political borders and economic barriers. ■



Attaining sustainable, environmentally-safe rice production demands creative research.

Since its inception, IRRI has reached out to share knowledge and new technologies developed from that knowledge with those who can benefit most. The 7,000 alumni of the IRRI training program and the thousands of publications the Institute distributes are only two indications of the ways IRRI has met its responsibility.

Very early, we also accepted the responsibility of strengthening cooperation within and among national systems dealing directly or indirectly with rice research. As well as being a research center in its own right, IRRI serves as a scientific clearinghouse for knowledge generated in both industrialized and agriculture-dominated economies, as a promoter of across-national-boundaries cooperation in rice research, and as a facilitator in bridging the gaps between scientific disciplines, rice ecosystems and agricultural research institutions.

Over the years we have learned more about how to use knowledge developed elsewhere—even outside agricultural research institutions—to strengthen our own activities and those of our partners in rice-growing countries. Historical divisions of labor and strict differentiation among scientific disciplines can hinder mutual learning, at IRRI and within and among national agricultural research systems. The growing complexity of the problems and the necessity of seeking environmentally friendly solutions challenge us to seek innovative opportunities.

Sharing knowledge includes sharing the responsibility for its acquisition and use, by highly sophisticated institutions solving very specific problems and by national agricultural research systems across a wide spectrum of scientific capacity.

IRRI also has successfully experimented with alternative approaches to sharing responsibilities in rice research. The latest and most promising—the research consortia—are linking several national agricultural research systems with IRRI to conduct jointly planned research agenda.

Similar developments can be reported in other areas. IRRI is shifting its training program from providing most activities at IRRI headquarters to collaborative

training in-country, cooperating closely with national scientists and using local facilities. This devolution will make better use of national program resources and reflect the growing independence and expanding international responsibilities of many strong national agricultural research systems.

The strength of evolving national systems, however, must not be over-estimated. Knowledge base, physical facilities and the financial resources to undertake research are different aspects of strength. Many national agricultural research systems with extremely limited budgets are being forced to allocate most of their financial resources just for salaries. This makes funding the needed research virtually impossible.

IRRI obviously cannot fill the shortfalls in national rice research resources. Our prime responsibility is to enhance the effectiveness of rice research in general. As an international center, however, we have an obligation to increase awareness and understanding among donors, national policymakers and the concerned public of the need for increased and more sharply focused investment in agricultural research in general and food research in particular.

In evolving a more equitable division of labor with national systems, IRRI's role will more and more be defined by strong involvement of the Institute's scientists in strategic research. This move demands close interaction with advanced centers and national agricultural institutions in industrialized countries doing basic research relevant to IRRI's strategic agenda, particularly that related to the application of biotechnology. The work will involve many scientific disciplines.

An example of such interaction is IRRI's cooperation with basic research centers that are studying fundamental processes relating to climate change. This collaboration is applied in IRRI's work on methane emissions from ricefields.

IRRI has a broad research agenda—from developing small-scale agricultural equipment suitable for use by resource-poor farmers to simulating the stress on rice plants of elevated ultraviolet band radiation. As traditional resources shrink, the Institute is being forced to focus on fewer projects and to mobilize new resources. Sharing responsibilities with others expands the effectiveness of the work done by IRRI scientists and by rice researchers everywhere.

Enhancing public and political attention on the need for strengthened research to enable the production of adequate staple food supplies into the 21st century is another responsibility IRRI must share with others. Even stronger research efforts are needed to help protect the world's agroecosystems and environments from overuse and destruction.

Rice production has a history of at least 7,000 years. Our contribution into the 21st century must be to safeguard the ability to produce even more rice, to feed the growing number of rice-dependent people. To achieve this objective without negative effects on the environment of which we are all a part is a task not comparable to any other in the world. ■

Klaus Lampe
Director General

Advancing rice science through collaboration

IRRI's collaboration with other institutions takes many forms, depending on the knowledge sought and the resources available. The research needed to resolve a particular problem or to acquire specific new knowledge may draw on several approaches simultaneously or may start with a relatively modest project and add elements over time. Approaches include:

- Interdisciplinary research. Appropriate disciplinary scientists work together on a project. IRRI's approach is ecosystem focused.
- Joint venture. IRRI and a collaborating institution together carry out a specific research project.
- Visiting scientist. An IRRI scientist is posted temporarily to another institution or a scientist from another institution spends time at IRRI, to work on a mutual project.
- Joint work plan. IRRI and a rice-producing country or another institution develop an agreement to together carry out specified projects.
- Consortium. A group of selected institutions mutually agree to accept different responsibilities to contribute to achieving a common objective. IRRI initiated two consortia this year.
- Shuttle research. IRRI and a national program or another institution carry out different phases of a project.
- Network. IRRI and a relatively large group of national programs set up a system for evaluating research methodologies and findings across varying conditions.

• Country and regional projects. IRRI responds to specific requests by a rice-growing country or region. Long-term assignments of IRRI scientists are supported by special grants.

The brief reports of collaborative work that follow highlight only some of IRRI's wide-ranging work. They are selected to illustrate modes of collaboration and advances in rice science. Additional highlights of IRRI's program activities in 1991 can be found farther along in the book. ■

Rice price decline reflects increased productivity at lower cost

Remarkable progress in Asia's rice sector has been achieved within the last three decades as a result of work in the global rice research system. Even as populations increased and growth in total rice area slowed, rice production kept up with demand, and more.

At the same time, the real price of rice declined.

A number of factors contributed to the downward trend of prices in rice-producing and rice-consuming countries:

• Research achievements enabled greatly increased productivity of ricelands at lower production costs.

• This led to self-sufficiency in rice production in major importing countries.

• Population growth slowed, particularly in the East Asia and Pacific countries that account for nearly 60 percent of Asian rice consumption.

• This resulted in increased urbanization and higher incomes, particularly in East Asia.

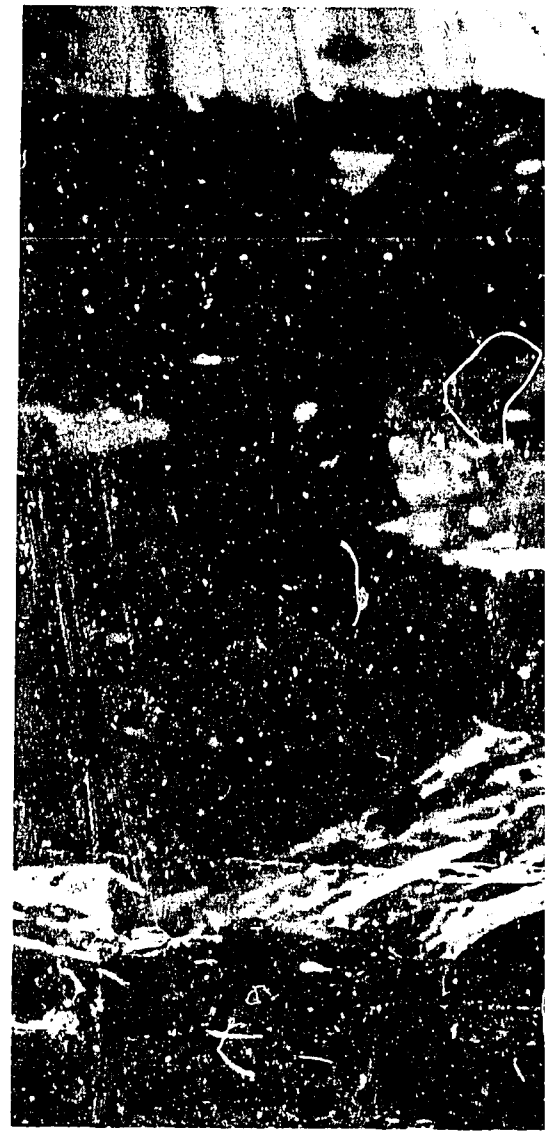
While rice production increased at almost the same rate across 1960-1990, the sources of growth changed substantially. During the first 15 years, one third of the growth resulted from an increase in rice area. During the second 15 years, almost all the growth came from increases in yield brought about by the spread of the modern rice technology.

With sustained growth in rice production, many traditional rice-importing countries achieved self-sufficiency. Once that occurs, production that increases faster than population-driven demand forces domestic rice prices down, unless surplus rice can be exported without dampening the world market.

The unit cost of production is lower for modern rice varieties than for traditional varieties. The reduction in production costs associated with the adoption of modern varieties allowed farmers to accept lower unit prices for bigger rice harvests.

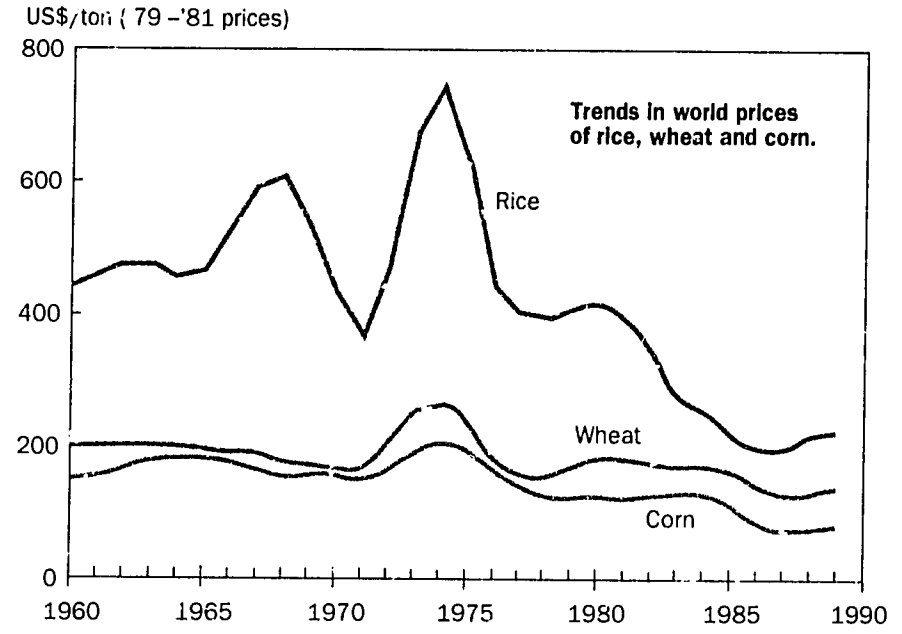
Lower prices transfer some of the gains realized through modern technology from rice producers to rice consumers. This is an important contribution to alleviating the poverty of rural landless and urban poor, who spend a much larger proportion of their incomes for rice than do those with higher incomes. As net consumers of rice, small and marginal farmers—the largest population group in most Asian rice-growing countries—also benefit.

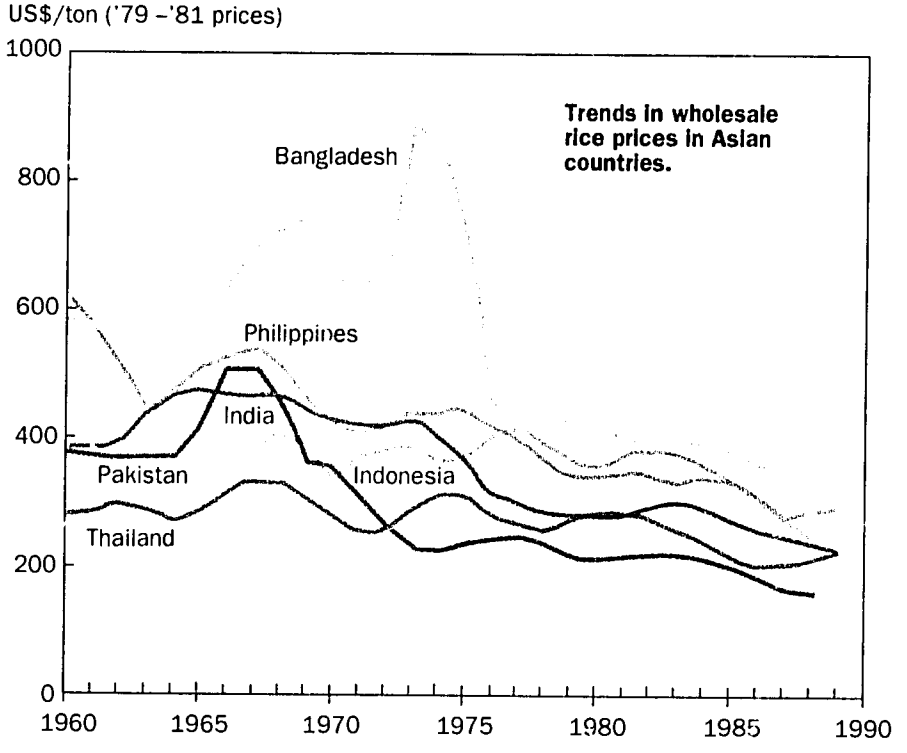
Urbanization also affects rice consumption. When income levels are low, urbanization increases the consumption of grain. But as incomes increase, rice consumption reaches a relatively high level. Beyond that income level, food habits change, and the demand for grains, particularly rice, ceases to grow.



The urban poor spend a large part of their incomes just for rice.

Modern rice production technology resulted in lower rice prices, benefiting both rural and urban poor.





Across 1960-1989, real rice prices declined by 3.1 percent a year, compared to 2.5 percent for corn and 1.2 percent for wheat.

Although price changes have differed in different countries, the trend toward ever-lower rice prices has been strong throughout Asia.

Rapid urbanization and income increases in East and Southeast Asia slowed growth in demand for rice. Per capita rice consumption in Japan, the Republic of Korea, Taiwan-China and the Philippines has either stayed level or declined.

A recent study at IRRI shows that a positive elasticity of demand for rice in relation to urbanization during the 1960s turned negative during the 1970s, with the negative elasticity becoming more pronounced during the 1980s. A 10 percent increase in urban population meant a 0.7 percent decline in demand for rice. The proportion of urban to rural population in Asia increased 1965-1990, from 19 to 50 percent in East Asia and the Pacific and from 18 to 26 percent in South Asia.

Now indications are the favorable rice situation of the last few decades may have started to change. The easy gains from modern rice technology have already been achieved, particularly in irrigated rice. Costs of expanding irrigation have increased sharply. Structural adjustment policies and heavy debt burdens of many countries are squeezing public expenditures, for irrigation and chemical fertilizer subsidies and for research to develop new technology.

Increasing labor costs and the changing patterns of food demand associated with rapid economic growth also have altered the comparative advantage of highly labor-intensive rice production against other economic activities. Growth in rice yields has already started to slow in China, Indonesia and the Philippines and has leveled off in Japan and the Republic of Korea.

All this means it is time to ask whether Asian countries will be able to meet the future demand for rice of their still rapidly-growing populations, given present prices and current technology. Faced with a

choice between accepting higher relative prices of rice and developing even more-efficient technology to provide production incentives to farmers, policymakers concerned about poverty and the well-being of landless labor, marginal farmers and the urban poor should prefer production incentives.

The persistent need to extend the technology frontier will be difficult to achieve without increases in the funding of rice research. ■

Support for Rice Research

Many Asian countries cannot afford the investments and subsidies that would enable rice farmers to apply water, nutrients and optimal management to increase yields. Concerns about impacts on the environment also are raising new questions about agricultural practices that involve large applications of fertilizers and pesticides.

Technology that will alleviate economic and environmental problems and, at the same time, increase productivity is urgently needed. Yet public investments in agriculture and in rice research are decreasing, and that jeopardizes future production potential.

The slowdown in public investment seems to have been caused primarily by short-term factors—depressed world rice prices, macroeconomic adjustments to reduce budget deficits, foreign debt—not by long-term considerations of social profitability. But minimal and short-term funding encourages recurrent food shortages and oversupply, which in turn pressure world and domestic price fluctuations. Unstable prices lead farmers to continue practices that deplete the resource base. ■

National programs and international centers examine trends in rice supply and demand

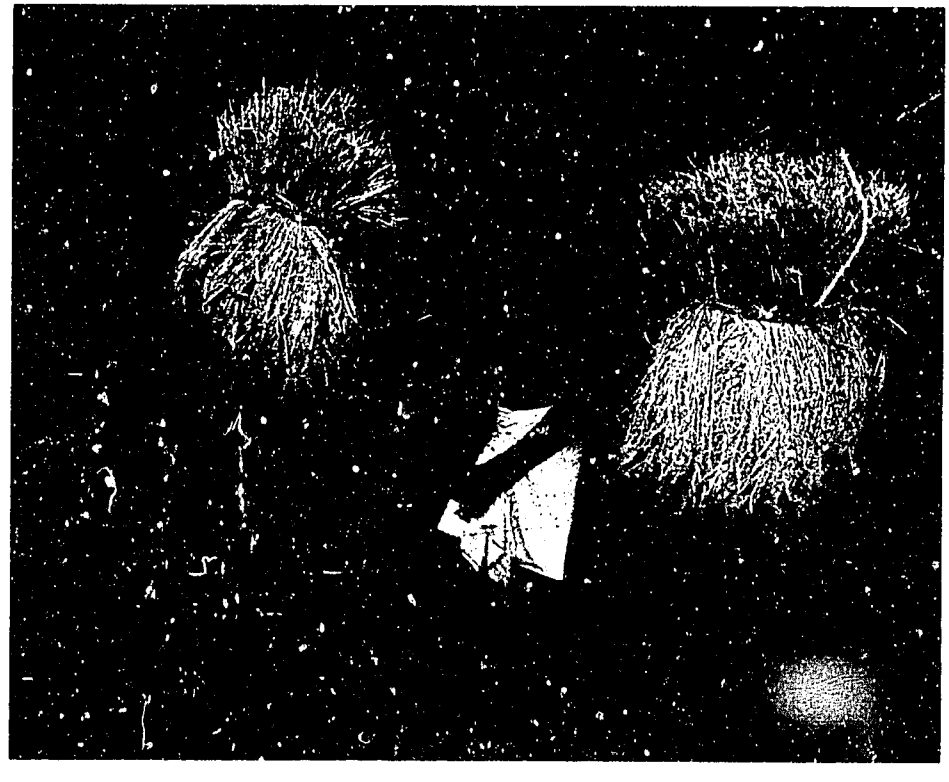
Developing policies that will enable rice production to keep up with increasing demand is challenging low income, land scarce countries whose populations continue to grow at an alarming rate. Where rice is the primary basis of rural livelihood and rice self-sufficiency a national objective, the issue is much more complex than just higher yields. It involves

- How to produce affordable rice for rural landless and poor urban consumers.
- How to maintain a comparative advantage for resource-poor rice farmers.
- How to reduce the costs, including impacts on the environment.

More information about constraints that impede efficient growth of the rice sector would help policymakers design strategies to overcome the barriers. Developing such an information base requires assessing medium- and long-term trends in world rice prices, social opportunity costs of domestic rice production and potential for technological change in rice production, as well as possibilities of expanding irrigation.

The International Food Policy Research Institute (IFPRI), IRRI and a group of national program scientists initiated such an assessment this year, in a project supported by the

Rice technology must both ease economic and environmental problems and increase productivity.



Government of Japan. It involves collaborative research on medium- and long-term projections and policy implications of rice supply and demand in Bangladesh, China, India, Indonesia, Pakistan, the Philippines and Thailand.

Country participants are using a common methodology to

- Model the dynamics of rice and related crop supplies.
- Analyze the structure and dynamics of demand for rice and other foods.
- Evaluate policies related to rice pricing and public investment.
- Project the impacts of policy alternatives on production, prices and equity.

Special studies in Myanmar and Vietnam will focus on the rapid growth in rice production in those countries and on policy and institutional constrains in their rice sectors. Regional studies in East Asia, Africa and Latin America will determine the impact of increasing demands for rice and of related national policies in those regions. A global rice supply–demand–trade model will be designed to analyze the world market.

IFPRI and IRRI are organizing the collaborative activities, developing prototype country studies, building the global trade model and conducting the intercountry analyses. The data generated will expand the world rice statistics database maintained at IRRI that is available to rice researchers throughout the world. The collaborative approach itself will facilitate information exchange and dialogue among analysts of important policy issues. ■

Consortia: a new initiative for sharing resources and expertise

The problems of increasing production and protecting the environment in the less favorable, more heterogeneous and more variable rice ecosystems—rainfed lowlands, uplands and deepwater and tidal wetlands—are complex. Research agenda for the less-favorable ecosystems must take into account

- Variability and uncertainty of the environment.
- Need to increase productivity in the short term and to promote sustainability of the system in the long term.
- Integration of new components and enhanced biological productivity of a whole system.

Sophisticated techniques for sampling and extrapolation, long-term research into biological processes and farmer knowledge-based design of new technology are needed. The research must be conducted in sites that represent the heterogeneity of rice production systems, to account for variability and to identify and address relevant problems.

This year, a new approach to collaborative research got underway: International Rice Research Consortia. Forming a consortium of complementary strengths to resolve complex problems is common in the private sector. IRRI initiated research consortia to capture the benefits of sharply-focused collaboration for the Asian rice sector.

New tools in biotechnology, geographical information systems and

computer-assisted modelling are opening opportunities for answering complex questions. Many national programs have large, well-trained scientific staffs who already contribute substantially to increasing knowledge about rice in the different ecosystems.

Consortia are a way to harness these resources and apply them to broad strategic issues.

A consortium is a research organization without walls. Membership is limited to particular institutions that can contribute resources to carry out sharply focused, strategic research projects. Each member is committed to making a specific contribution to achieving the group's objectives.

Two consortia have been established with initial funding by the Asian Development Bank: the Rainfed Lowland Rice Research Consortium and the Upland Rice Research Consortium. While each has its own agenda and work plan, they have similar structures.

A consortium steering committee involves researchers representing each member institution. The steering committee develops the consortium work plan, harmonizes resource allocations, guides research activities, sets priorities, develops strategies to accomplish objectives, and identifies new members and key research sites. Periodic planning meetings review overall activities and evaluate accomplishments against objectives.

At each research site, a key site coordinating committee involves scientists from the participating institution and a participating IRRI scientist. The coordinating committee sets priorities and plans and administers the research being carried out at the key research site.

IRRI, as a member of each consortium, contributes to the strategic research needed. In early stages of consortia development, IRRI is also providing coordination. ■

Dividing strategic tasks in rice research consortia

Of 132 million hectares planted to rice in Asia in 1990, 37 million hectares was rainfed lowland, 11 million hectares upland, and 9 million hectares deepwater and tidal wetlands. These less favorable rice ecosystems account for nearly half of the total rice area but produce only about a fourth of the rice harvest. Their marginal lands are highly degradable and, given current knowledge and technology, cropping is risky.

Opportunities do exist to enhance the productivity of these systems. Much of the work is being undertaken by national programs and IRRI.

Rainfed lowland rice research consortium members have committed resources to research key ecosystem problems.

Member	Key site	Ecosystem problems (research focus)
Bangladesh	Rajsahl	Drought prone (moderate drought, photoperiod sensitivity)
India	Faizabad, Mosodha	Drought prone, submergence prone (salinity, shallow flash flooding)
	Polba-Chinsurah, West Bengal	Submergence prone, medium deep water (stagnant flooding)
Indonesia	Jakenan, Central Java	Drought and submergence prone (dry direct seeding, K deficiency)
IRRI	Tarlac-Pangasinan, Philippines	Drought prone (rainwater conservation, nutrient management, tillage)
Philippines	Batac, Ilocos Norte	Favorable (long-term sustainability)
Thailand	Ubon	Drought (severe drought, soil physical problems, low soil fertility, P deficiency, blast disease, weeds)

Upland rice research consortium members have committed resources to research key ecosystem problems.

Member	Key site	Ecosystem problem (research focus)
India	Hazaribagh, Bihar	Moderately acidic soils, short rainy season, tropical savannahs, old cultivated land (drought)
Indonesia	Sitiung, Sumatra	Acidic soils, long rainy season, equatorial forests, slash-and-burn cropping (soil problems)
IRRI	Cavinti, Luzon, Philippines	Very acidic soils, long rainy season, highly deforested (blast disease)
Philippines	Matalom, Leyte	Acidic soils, medium length rainy season, old cultivated lands (weeds)
Thailand	Samoeng, North	Moderately acidic soils, short-medium rainy season, deforested, slash-and-burn cropping (land management)

Transferring international responsibilities to a national rice research system

Deepwater rice technology must be adapted to many diverse and difficult conditions. Most of IRRI's deepwater rice work has been carried out in cooperation with national programs where significant areas of deepwater rice are planted. The Ministry of Agriculture and Cooperatives of the Government of Thailand and IRRI have collaborated in this research for many years.

Thailand has staff experienced in deepwater rice and excellent research facilities. Work there has expanded from primarily plant selection to a broad spectrum of research in plant breeding, agronomy, physiology, pest management and cropping systems. Many Thai scientists and technicians were trained at IRRI.

This significant capacity has led Thailand to accept a larger role in international rice research. On 29 August 1991, during the visit of Crown Princess Maha Chakri Sirindhorn to IRRI headquarters, Thailand and IRRI signed a new memorandum of understanding to establish a joint research and training program in deepwater rice.

Thailand and IRRI will jointly develop new and improved rice varieties and cultural practices and conduct research to better understand the deepwater rice environments of Southeast Asia (Thailand, Myanmar, Laos, Cambodia, Vietnam and parts of Indonesia) and South Asia (India and Bangladesh).

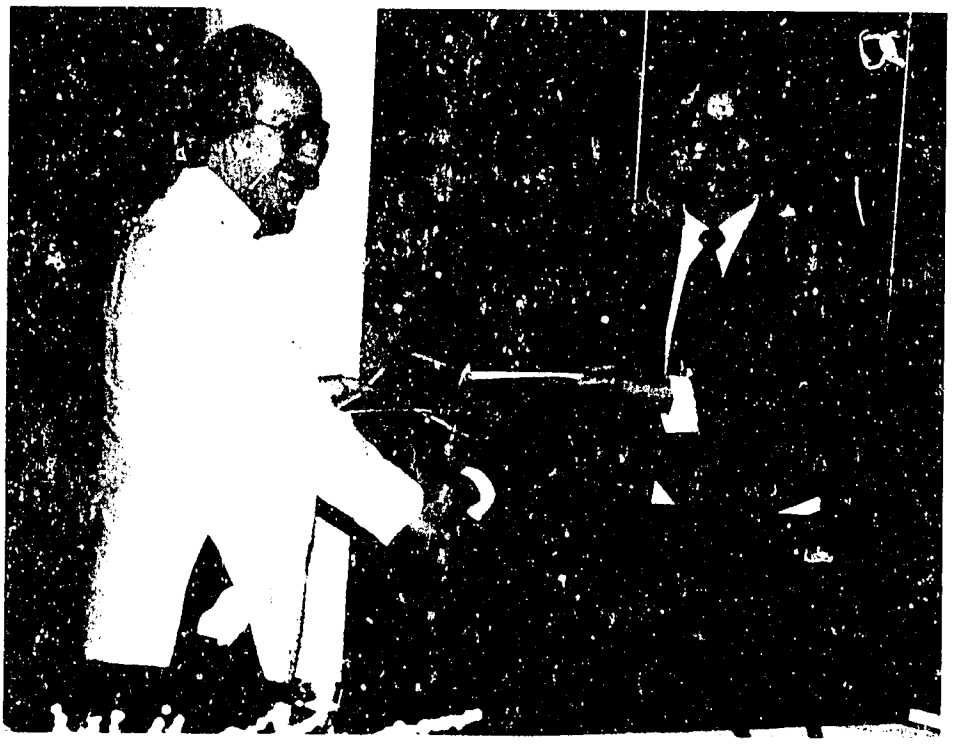
The Thailand deepwater rice breeding program is expanding to cover the interests of those countries. Scientists at Prachinburi Research Center and Huntra Experiment Station will lead in selecting, testing, evaluating and distributing breeding materials. Facilities at Pathum Thani Rice Research Center and Suphanburi Rice Experiment Station will be used for early selection for plant type and pest resistance and for seed increase in a safe environment.

Rice scientists from national programs will visit Thailand to observe breeding materials growing in the field and Thai scientists will visit the deepwater areas of other countries to coordinate research.

IRRI's role within the joint program is focused on strategic and basic research, particularly the application of biotechnology to characterizing unexploited traditional deepwater rice varieties of the highly photoperiod sensitive types found in southeast Asia and the early flowering types found in India. IRRI will generate first generation crosses that are difficult to make at Prachinburi and Huntra and provide facilities to carry out rapid generation advance.

To ensure the safe movement of germplasm to other collaborators, IRRI will distribute advanced breeding materials and elite lines in coordination with INGER (International Network for Genetic Evaluation of Rice). ■

Dr. Klaus Lampe, IRRI director general, and Dr. Yookti Sarikaputhi, permanent secretary of Thailand's Ministry of Agriculture and Cooperatives, signed a Memorandum of Understanding outlining new modes of collaboration on 29 August 1991.



A global approach to genome manipulation

Collaboration with advanced laboratories through the Rockefeller Foundation program on rice biotechnology is accelerating IRRI's application of expertise at the frontier of biological science. The program focuses on discovery, on expanding basic knowledge about rice at the molecular and cellular level.

Rockefeller Foundation is supporting research involving genome manipulation in a number of laboratories in industrialized countries and is helping build research capacity in developing countries. IRRI is a member of the advisory committee that helps identify laboratories and projects to be funded. IRRI also supplies the germplasm for research underway and collaborates directly with several laboratories.

Wide hybridization

IRRI researchers systematically evaluating the germplasm of wild *Oryza* species conserved in the International Rice Germplasm Center (IRGC) have identified several accessions highly resistant to important insects and diseases. Transfer of useful genes from wild species to *O. sativa* through interspecific hybridization broadens the gene pool for rice improvement.

The University of Georgia, USA, collaborates in characterizing the introgressed lines. So far, resistance to brown planthopper and white-backed planthopper insects and to blast and bacterial blight diseases are captured in modern breeding lines.

Genome mapping and gene tagging

A number of morphological and isozyme markers have been located on the chromosome map of rice and linkage groups have been associated with their chromosomes. Now work is underway to locate the centromere positions on the chromosome map. Emphasis in the Cornell University, USA and IRRI collaboration is on tagging genes for disease and insect resistance and quantitative trait loci (QTL).

Mapping the rice genome involves peering deep into plant tissues to identify genes adapted to environments.

Genes for resistance to white-backed planthopper and bacterial blight have been tagged with random fragment length polymorphism (RFLP) markers and efforts are underway to tag QTL's for drought and salinity tolerance and for partial resistance to blast. Linked molecular markers will improve efficiency in selecting germplasm with desirable traits for new rice varieties.

Identifying pathogen races

RFLP data has helped identify new races of the bacterial blight disease pathogen *Xanthomonas oryzae* pv. *oryzae*. In this work, IRRI is collaborating with the University of the Philippines and Washington State and Kansas State Universities, USA.

Data from repetitive DNA probes revealed that races 1 and 5 each consist of two distinct lineages. When pathogen strains representing the different lineages were tested on rice cultivars containing known genes for resistance, statistically significant differences in bacterial blight lesion lengths occurred. This confirmed that the different lineages are distinct races. Several genes giving differential reactions to the new races have been identified. The new races can be used to characterize donors of resistance to bacterial blight.

Developing transgenic plants

Most transformation work has been carried out with japonica rices. Yet much of the rice area in tropical Asia is planted to indica rice. Indica rices had not been transformed because their protoplasts could not be regenerated. Protocols for regenerating improved indicas IR43 and IR58 have been developed and experiments to introduce novel genes into indicas are underway, in collaboration with the University of Tokyo, Japan, and Washington State University, USA.

Engineering resistance to insects

Evaluation of the pathogenicity of more than 4,000 *Bacillus thuringiensis* strains collected from various locations in the Philippines identified several strains that are toxic to stemborer and leaffolder. Now IRRI is developing collaborations with advanced laboratories to clone the *Bt* genes identified. When the gene constructs become available, transformation will be used to introduce them into elite rice lines.

Engineering resistance to diseases

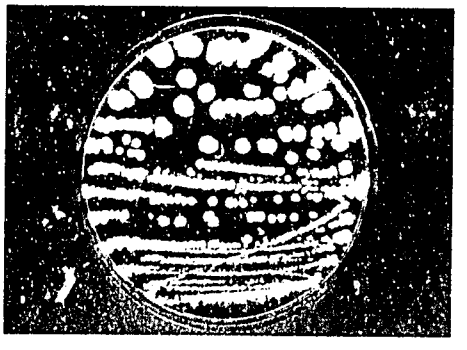
Engineered rice plants that express coat protein genes of the viruses that cause tungro are likely to be resistant to the disease. Coat protein genes of the rice tungro viruses have been cloned in collaboration with John Innes Research Institute in Norwich, UK, and Washington University in St. Louis, USA. These genes are being introduced into japonica rices in collaboration with the University of Nottingham, England, UK, and into indica rices in collaboration with Purdue University, USA.

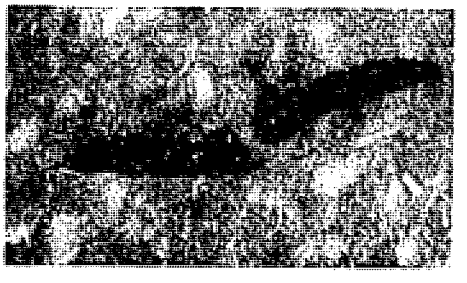
A course at IRRI to train national program scientists in the advanced biotechnology methods was taught by resource scientists from IRRI and other advanced institutions. ■

IRRI and the private sector work to develop insect resistance in rice

IRRI's increasing use of biotechnology to speed improvement of rice has created a pressing need for input from advanced laboratories. Although cooperation is mostly with public institutions, work in collaboration with the private sector is beginning.

One example is PGS (Plant Genetic Systems) in Belgium. PGS has special skills and equipment to handle work in protein chemistry, gene isolation, DNA sequencing and gene construction.





IRRI and PGS are collaborating to develop a system for deploying *Bacillus thuringiensis* to control rice insect pests. One possibility involves inserting *Bt* genes into engineered rice plants, to control yellow stemborer.

A transgenic system for controlling yellow stemborer is especially appealing because no current rice variety has resistance to this pest. Farmers try to control yellow stemborer with insecticides, but the sprays are rarely effective and the chemicals used could be a hazard to human health and the environment.

The first step involved identifying *Bt* toxins that can be used in transgenic systems. IRRI collected samples of *Bt* populations in the Philippines and extracted nearly 4,000 strains that show activity against rice insect pests.

PGS used gel electrophoresis and enzyme-linked immunosolvent assay (ELISA) with antibiotics specific for different crystal proteins to characterize the strains. This yielded 40 specific toxins and combinations. At least two toxins are new identifications and several of the combinations are unusual.

IRRI's agreement with PGS protects the interests of low income rice farmers in the tropics. PGS will not market in the less developed countries any materials or technology that result from the collaboration. IRRI will make materials and technology available through its normal collaborations with those countries.■

The crystal proteins produced by Bt bacteria kill the rice pest insects that eat them, but can't harm humans.

Bacillus thuringiensis

Bt is a spore-forming bacterium that occurs naturally in the environment. It produces crystal proteins that, when ingested by an insect, break down into toxins. Those toxins cause the cells of the insect's gut to rupture.

Ingestion of sufficient amounts of the crystal, and hence of the toxin, will kill the insect. Bt toxins affect only insects; no adverse impact on humans or nontarget organisms has been found.

Commercial formulations of Bt sprays have been used for 20 years to control many insect pests in the USA and other countries. Bt has been exploited for decades in China, using bacterium generated in small-scale fermenters or from pulverized insect larvae infected with the pathogen.

Now there is considerable interest in putting Bt genes into transgenic plants. Such plants would mimic the insecticidal action of Bt sprays, but without the need to treat the crop. Several activities at IRRI are interacting in work to achieve that objective.

Rice impacts global warming, climate change impacts rice

IRRI is the first international agricultural research center to initiate a comprehensive program on the interaction between agriculture and climate change. Rice production turns out to play a dual role.

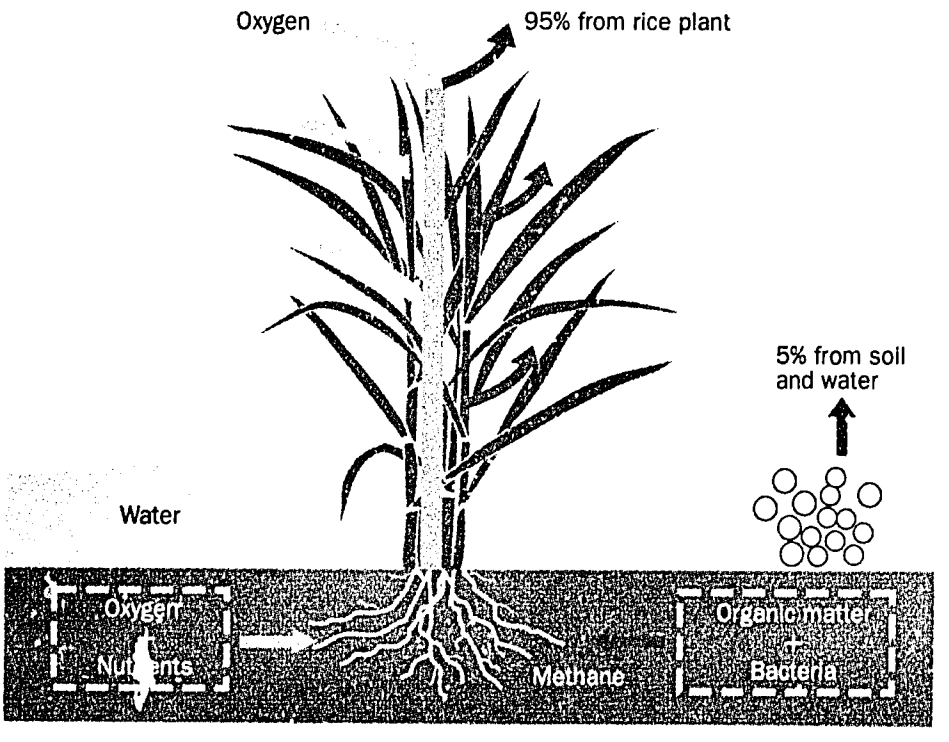
- Intensifying rice cultivation appears to increase concentrations of the greenhouse gas methane in the atmosphere.
- Increasing concentrations of carbon dioxide, higher temperature and elevated ultraviolet band irradiation affect rice growth and yield.

Applying the expertise of a number of scientific disciplines is essential for acquiring the needed knowledge, methodologies, and technology in time to avert unknown consequences. Equally important is bridging the interstice between advanced research institutions and national rice research systems.

The United States Environmental Protection Agency and IRRI have initiated a comprehensive project to work on both issues, in cooperation with the Fraunhofer Institute for Environmental Atmospheric Research, Germany, and the Biogeochemistry Institute of Louisiana State University, USA.

Studies on methane emission by rice aim to elucidate the mechanisms governing methane fluxes and identify mitigation approaches. Fraunhofer Institute provides expertise on gas flux measurements from soil and plant systems. LSU has expertise on the chemistry of wetland soils. IRRI has integrated experience with rice.

How methane is formed and emitted from flooded ricefields.



Ricefields emit greenhouse gases, increased UV-B stunts rice plants

Rice cultivation annually releases an estimated 60 million tons of methane into the atmosphere. Methane has a global warming efficiency some 30 times greater than that of carbon dioxide and is an important sink for OH-radicals, the only cleaning agent for the atmosphere.

Intensified rice production could further increase methane levels and that could contribute significantly to a negative feedback system, with unpredictable consequences for atmospheric chemistry.

Up to 90 percent of the methane flux is mediated through the plant, the rest is diffused through the soil-water interface. The rice plant itself acts as a gas vent: a special tissue, the aerenchyma, supplies atmospheric oxygen to submerged rice roots and vents methane.

The complexity of the interaction between methane formation and oxidation, rice cultivation and methane emission requires integrated, interdisciplinary research to understand the variables, to discriminate more reliably the strength of different rice ecologies as sources of methane and to develop and adapt technologies to lessen methane emission.

Finding a way to reduce methane emissions is only feasible if the technology also increases rice productivity.

The other side of the rice production equation is the thinning of the ozone layer by chlorofluorocarbons—gaseous emissions from industrial chemicals—that is increasing ultraviolet band irradiation. Higher UV-B stunts the growth of rice plants.

The tropics, which are located near the equater where the ozone layer already is naturally the thinnest, receive the highest UV-B irradiation. Much of the world's rice is produced in the tropics. ■

Additional collaboration with the Agricultural University of Wageningen, The Netherlands, is seeking to discover the methane production potential of different soil types. The University of California, USA, is conducting isotopic studies of methane emitted. US-EPA is developing a global geographical information system on methane emission from ricefields.

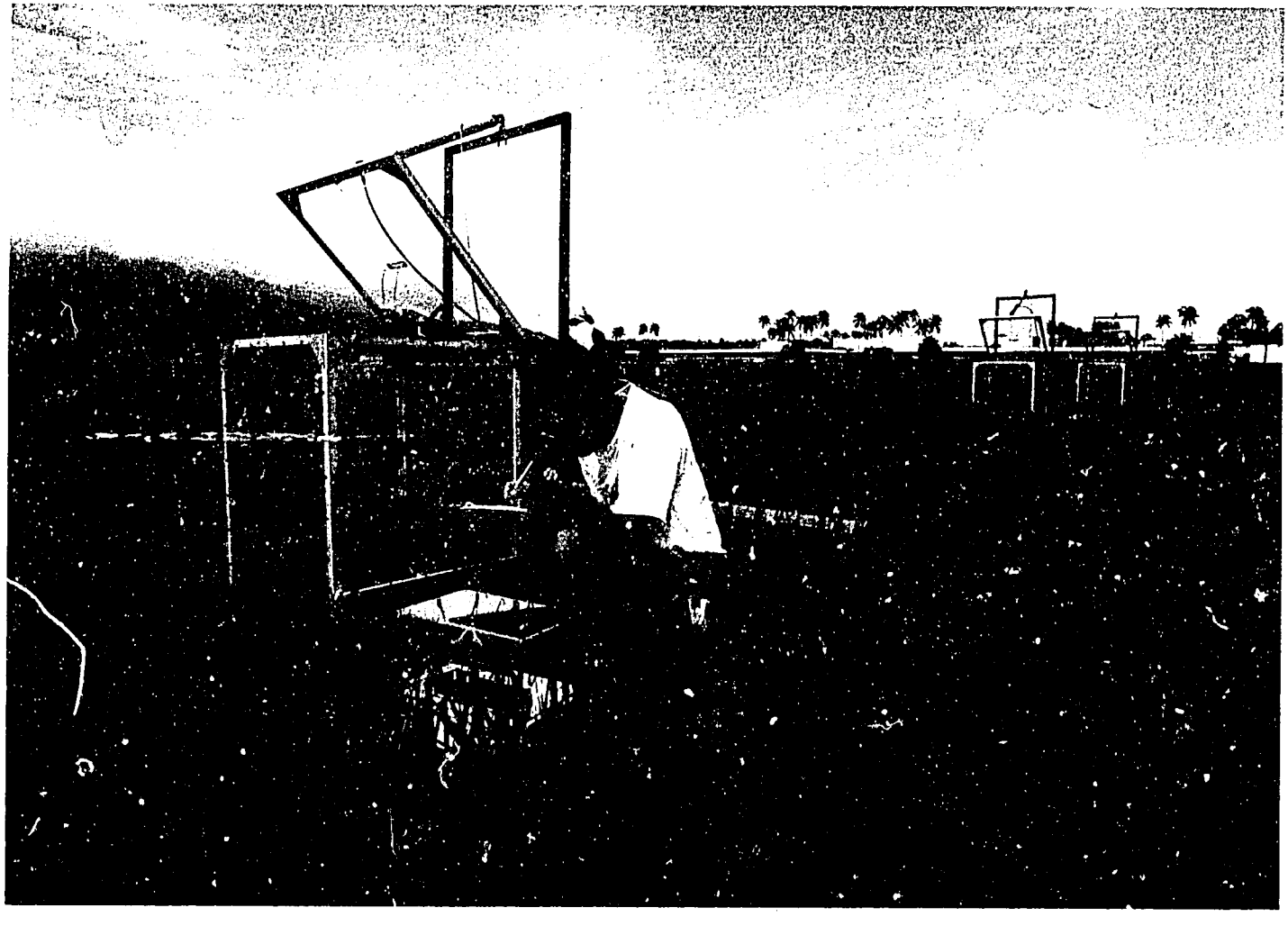
IRRI also is leading an interregional program funded by UNDP (United Nations Development Program) to strengthen methane research in China, India, Indonesia, the Philippines and Thailand. This work will more reliably discriminate among the major rice-growing ecosystems according to the strength of methane source and will develop and adapt methane mitigation technology to regional and local conditions.

Studies on the effects of climate change on production focus on how higher temperatures and increases in UV-B irradiation impact rice growth and yield. IRRI and collaborating scientists are studying how different levels of UV-B affect the structure and functions of rice plants.

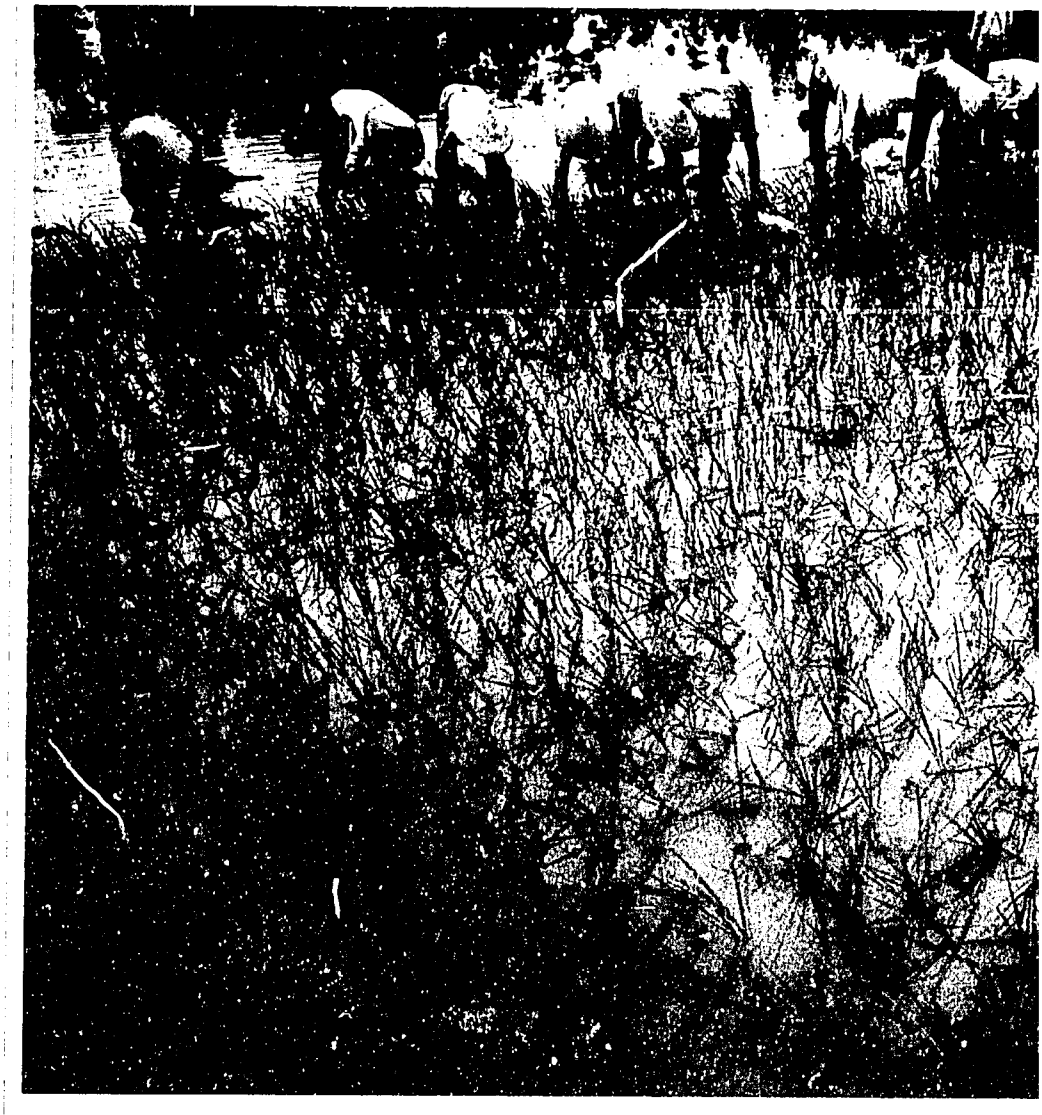
Responses vary. Rice is most sensitive to UV-B during early growth, but some rice varieties are less sensitive than others. Content of the plant pigments that filter UV-B increases at higher levels but root activity, protein content and nutrient uptake decrease.

All this could alter the competitive balance between rice plants, diseases and weeds. Experiments in specially-designed greenhouses and specially-equipped field plots at IRRI, plus laboratory work at advanced institutions in Europe and the USA, are amassing a wide range of data. Computer simulations will help trace the interactions. ■

Measuring the methane released by rice is a first step toward lessening the release of this greenhouse gas.



Australia and IRRI join forces to help rehabilitate national programs



The three countries in Indochina—Lao PDR, Cambodia, Vietnam—faced a morass of problems following devastation of their agricultural bases during the war-wracked 1970s. Collaboration to alleviate some of the problems started in 1986, with a memorandum of understanding signed by the Government of Australia and IRRI.

The objective is to train scientists and technicians. Training helps upgrade the research undertaken and accelerate transfer of improved rice technology to farmers. Australia also is assisting in the development of research and training infrastructure.

An IRRI scientist initiated activities in Cambodia and established continuing cooperation with all three countries.

Cambodia–IRRI rice project

An early achievement in Cambodia was the reintroduction of traditional rice varieties lost during the Pol Pot period. The varieties collected in earlier years had been conserved in the IRRI genebank. Promising breeding materials introduced from IRRI also matched plant characteristics with the mosaic of rice production environments in Cambodia.

More than 50 Cambodian scientists and technicians have been trained in the last four years. An in-country training program is extending their new knowledge and skills to more agricultural technicians.

An IRRI farming system agronomist works with Cambodian scientists and agricultural officers to design, implement and analyze on-station and on-farm experiments. A plant breeder assists in developing a systematic program to evaluate traditional and modern rice varieties. A technology transfer specialist collaborated with Cambodian scientists for two years, to develop appropriate rice management recommendations and farmer's field demonstrations. The next phase will involve a soil scientist, a crop protection specialist and an agricultural engineer.

The project supports establishing and developing the Cambodian Rice Research and Development Institute (CARRDI). A joint Ministry of Agriculture-IRRI design team identified a suitable site and developed a blueprint for CARRDI organization, program thrusts and infrastructure.

Lao–IRRI project

The Lao–IRRI collaborative project focuses on development of low-cost technologies for the country's main rice growing environments, with complementary training of rice scientists and technicians. Additional support comes from the Swiss Development Cooperation.

Vietnam–IRRI project

Vietnam and IRRI have been collaborating since 1963. Early activity primarily involved exchanging germplasm and training staff. So far, 251

Rice farmers need production technologies that are environmentally sound and economically viable.

Vietnamese scientists have been trained at IRRI, 18 earned master of science degrees, 6 earned PhDs.

Priority in a new project begun in 1991 is to develop rice production technologies that are sustainable—environmentally sound and economically viable. Major scientific themes are integrated pest management, integrated nutrient management and improved water management. Projects are carried out by Vietnamese scientists and visiting IRRI scientists. ■

NGOs accelerate research and technology transfer in the Cambodia–IRRI project

The Cambodia–IRRI rice project supported by the government of Australia is helping Cambodia improve its rice research and development capacity. Major assistance is tapped from a number of nongovernmental organizations:

PADEK (Partnership for Development in Kampuchea)
CIDSE (Cooperation International pour le Developpement et la Solidarite)
ACR (Australian Catholic Relief)
RB (Redd-Barna)
WVI (World Vision International)
GRET (Groupe de Recherche ed d'Echanges Technologiques)

Regular meetings of all organizations involved in agriculture research and development—government agencies, NGOs, IRRI—are making it possible to pool resources and avoid duplication.

NGO centers use trials designed by the Cambodia–IRRI project for farmer training (NGO volunteers assist with in-country training courses). The uniform experimental design enables trial results to be collated as a basis for government agency recommendations for improved rice production practices.

The collaboration also speeds delivery of good quality rice seed to Cambodian farmers. The Cambodia–IRRI rice project provides the breeder seed, NGO-sponsored centers supervise its multiplication and distribution to farmers.

The benefits are large: multiplier effects from training, improved supervision of experiments and field trials, extra resources, considerable synergism derived from close interaction. ■

Research on integrated nutrient management involves IFDC and IRRI

Intensively cropped irrigated and favorable rainfed lowland areas produce more than 70 percent of Asia's rice. On fields planted to two or even three rice crops a year, commercial fertilizer will continue to be the main source of nitrogen to sustain yields—at least for the foreseeable future.

Translating that fertilizer nitrogen into more rice or growing rice using less applied nitrogen means the nitrogen uptake efficiency and nitrogen productivity of the crop must be increased. Simultaneously, the capacity of soils to support intensive cropping must be improved and adverse environmental impacts from nitrogen loss must be reduced.

This requires integrated research expertise. IRRI and the International Fertilizer Development Center have been working on the problems for 14 years. Early research focused on transformation processes that govern nitrogen loss. Volatilization was identified as the major loss mechanism. The interactive effects of fertilizer placement and timing and water control on nitrogen loss were quantified, and that knowledge used to devise strategies to increase nitrogen use efficiency.

Now work that emphasizes integrated nutrient management is exploring opportunities to improve the utilization of nitrogen from three sources—indigenous soil resources, incorporated plant residues, biological nitrogen fixation—to supplement or reduce commercial fertilizer inputs. The research emphasizes learning

more about utilization of soil nutrients and biologically-fixed nitrogen. It seeks to increase efficient use of fertilizer inputs by matching timing and placement of fertilizer with seasonal crop demand and rice root activity. ■

Year-round management of nitrogen from soil–green manure–fertilizer

The fallow period between rice crops has a large influence on the efficient use of nutrients by a cropping system, particularly in rainfed lowland systems with long fallows between annual crops and in upland systems with even longer time between rice crops, across years.

Incorporating the weeds that grow during fallow can supply the equivalent of 40 kg nitrogen per hectare to the following rice crop. The weeds capture soil nitrate that would have been lost when the soil is flooded for rice. That nitrogen is recycled when the incorporated weed mass rapidly decomposes.

Aquatic legume green manure crops can accomplish the same thing, but labor and the cost of legume seeds are a constraint to adoption by resource-poor farmers.

In the more adverse rainfed lowland environments where soils may be deficient in both nitrogen and phosphorus, fertilizer needs of the rice crop depend on planting method. Rice wet seeded in puddled soil utilizes more indigenous soil nutrients than a crop dry seeded before the soil is flooded. Wet seeded rice yields are twice as high as dry seeded yields, even without additional fertilizer.

A bountiful rice crop depends on year-round management, of the soil and of fertilizer inputs.

France and IRRI work on sustainability and biodiversity in rice

French agencies ORSTOM (Institut Francais de Recherche Scientifique pour le developpment en Cooperation) and IRAT (Institut de Recherche Agronomiques Tropicales et des Cultures Vivrieres), a department of CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement), have collaborated with IRRI for many years.

Major focuses are the genetic diversity of rice and the sustainability of the marginal and fragile upland rice ecosystem. Some French researchers are assigned as long-term visiting scientists at IRRI, others are involved in shorter-term collaborations. Research plans are developed during biennial France–IRRI planning meetings.

Four French scientists are currently assigned at IRRI: three from ORSTOM are working on genetic evolution, nematodes, and characterization of rice pest systems; one from IRAT is working on upland rice breeding. The IRAT scientist is also leader of the IRRI upland rice research program and coordinator of the Upland Rice Research Consortium. Until recently, another scientist worked on nitrogen fixation and soil fertility maintenance.

Important outcomes of the France-IRRI collaboration include

- A new methodology for classifying rice using enzymes to differentiate among rice sub-species, with emphasis on the role of one of these species in the uplands and in temperate areas.
- Initial studies on genetic markers and development of specific rice populations that are useful in biotechnology work at IRRI and in advanced laboratories.
- Innovative concepts to improve knowledge about rice blast disease and identification of new sources of more durable resistance.
- Identification of new sources of drought resistance.
- A comprehensive understanding of the role of blue-green algae and other nitrogen-fixing biological organisms in the nitrogen dynamics of flooded ricefields. ■

Scientists in seven countries study biological control of sheath blight

In Asia, chronic diseases can cause loss of up to 20 percent of a rice crop, even without an epidemic. Pathogens that infect rice seeds affect grain quality and the value of the crop.

Many rice diseases are not yet effectively controlled; sources of genetic resistance have not been found and resource-poor farmers cannot afford pesticides. When pesticides are used, inappropriate application can threaten the environment and human health.

Sheath blight caused by *Rhizoctonia solani* is an example of the problem. Chronic infection is a major concern for rice production in Korea, China and Vietnam and affects production in other Asian countries. It is found most often where rice is grown in intensive production systems.

A working group on biological control of rice diseases is investigating the uses of plant-associated microorganisms, such as antagonistic bacteria from flooded ricefields, to control fungal diseases of rice, with special funding from the Asian Development Bank. An initial study at IRRI demonstrated that large populations of such organisms are highly antagonistic to many fungal pathogens that attack rice.

Scientists in China, Korea, India, Indonesia, Malaysia, Thailand, the Philippines and IRRI agreed to focus on sheath blight as an important disease in irrigated rice. IRRI developed standard methods for isolating and screening the bacteria. The collaborating scientists collected and screened thousands of bacterial isolates for antagonism to *R. solani*. Promising isolates were identified in all countries; some significantly inhibit development of sheath blight and enhance rice plant growth.

Seed treatments and plant sprays are being tested in all the countries, to evaluate biological control against chemical control.

Now scientists from Bangladesh and Vietnam have joined the working group. In a second on-the-job training workshop at IRRI, participants agreed to carry out standard experiments and to add marker-facilitated studies on population dynamics. Mass production of bacteria, improvement of effective strains, development of application techniques, and examination of farmer acceptance of biological control will be addressed. ■

The interactions of scientists from IRRI and other advanced research institutions speed results.

Belgian university tests identify bacteria associated with rice seed

The rice sheath discoloration at booting and seed discoloration from heading to ripening found widely in tropical ricefields apparently are caused by complex interactions of stresses. One causal factor is bacteria.

Although many bacteria are associated with rice seed, their roles—as phytopathogenic pests or as favorable biological agents—are not fully understood. Nor is their diversity classified. Identifying the diversity is a first step in understanding the problem.

Rijksuniversiteit Gent (RUG) in Belgium is the world center for classification of pathogenic organisms. RUG and IRRI are collaborating to identify the bacterial pathogens associated with rice sheath and grain discoloration.

Of more than 4,000 bacteria isolated from sheath and seed samples collected in the Philippines, 185 were found to be pathogenic, to cause losses in grain quality or production. Of three types of symptoms that appeared on rice seedlings inoculated with the pathogenic bacteria, none was distinctly associated with a particular isolate nor were any similar to those caused by *Pseudomonas* pathogens.

Similar bacterial strains do vary biochemically. This means their biology and pathogenicity on japonica and indica rices in temperate and tropical environments could be different. RUG used biochemical tests to compare its reference strains of pathogenic *Pseudomonas* with the Philippine isolates. Eight species in nine clusters were identified.

This wide array indicates broad diversity in the bacteria associated with rice grain. ■

Rice researchers take advantage of special climates and special skills

Many rice-growing countries have only one cropping season a year. This slows work to develop the new varieties important to sustaining and increasing rice productivity to meet growing supply and demand pressures. Rapid generation advance through shuttle breeding accelerates the process.

The Egypt–IRRI collaboration includes growing a winter nursery of Egyptian breeding materials at IRRI. The China–IRRI collaborative breeding project involves crossing Chinese varieties with elite IR lines and growing two generations a year alternately at IRRI and at the China National Rice Research Institute in Zhejiang province.

The shuttle of breeding materials enables growing and evaluating six generations in three years. With local adaptive testing, a new variety can be released to farmers only 8 years after the first cross, instead of the normal 11 or 12 years.

A similar shuttle in the Korea–IRRI collaboration is developing rices tolerant of low temperature and cold irrigation water. Collaborative Thailand–IRRI shuttle breeding is developing germplasm suitable for adverse rainfed lowland rice environments. Evaluation of the progeny of crosses made at IRRI is done at sites in Thailand that have different soil fertility, water regime and disease pressure. ■

Scientist shuttle taps special skills and resources

Some collaboration involves an organized exchange of rice scientists, to take advantage of skills and equipment at other advanced institutions and experience with rice and experimental facilities at IRRI. Collaboration is accelerating research in genetic engineering, plant pathology, plant physiology, microbiology and social sciences.

A number of activities are underway, with five institutions in Japan, Cornell University in the USA and McGill University in Canada. Much of the work is scientist-to-scientist interaction. PhD candidates also work on their research at IRRI.

In Japan, IRRI and Hokkaido University are working to enable transformation of indica rice. IRRI and Kyushu University are tagging genes for resistance to bacterial blight and using gene markers to analyze the use and efficiency of gene combinations. IRRI and the Tropical Agriculture Research Center are indexing the rice yellow dwarf pathogen by nucleic acid hybridization-based assay and are developing thermosensitive genic male sterility for breeding hybrid rices. IRRI and Tohoku University are analyzing elongation ability and degree of elongation in deepwater rices using cellular and biochemical analyses. IRRI and Chiba University are studying allelic relationships of wide compatibility genes.

The Cornell University and IRRI project links IRRI's biotechnology work with Cornell's work on genome mapping (including the human genome). An IRRI scientist assigned at Cornell gives IRRI immediate access to the latest technology in molecular markers. Probes have been brought to IRRI and the rice genome map is assisting breeders in making selections for desired traits.

The McGill University and IRRI project relates to the development of integrated weed management through the application of environmentally-friendly biological pathogens. In many ecosystems, weeds have evolved that are very similar to the rice plants themselves. McGill has identified bacterial and fungal organisms that reduce a weed's viability. Studies of variability in the effect of these naturally occuring friendly bacteria on weeds and ways to use them to control weeds are done at IRRI. ■

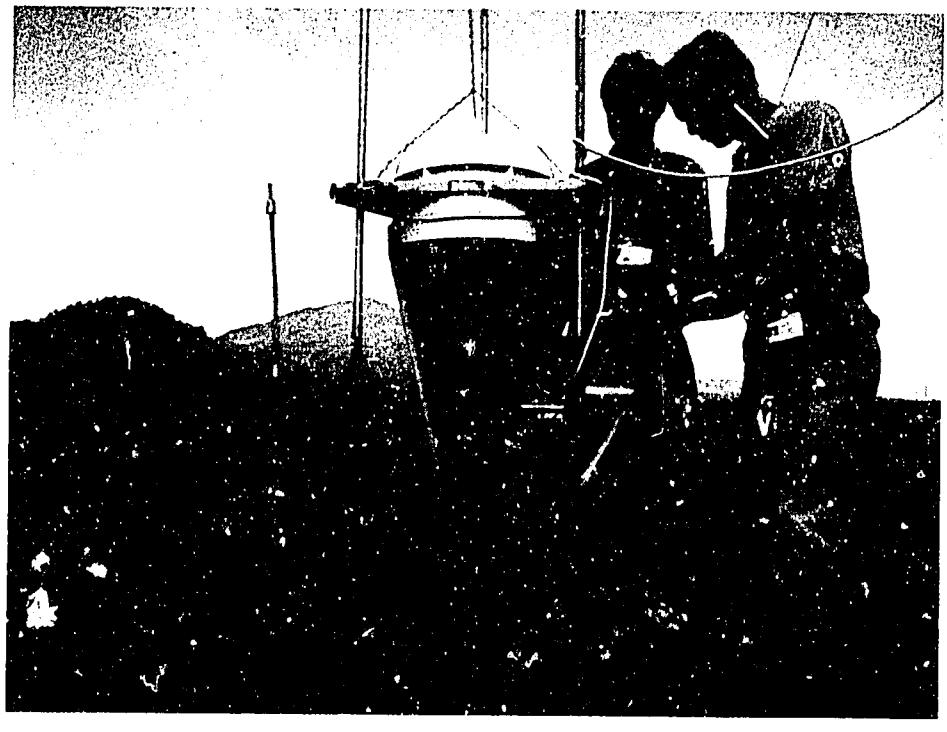
UK and IRRI collaborate on tungro: vector ecology and disease epidemiology

Tungro, a rice disease widely distributed throughout South and Southeast Asia, can cause significant yield loss or even crop failure. One estimate put annual rice crop losses at $1.5 billion. Intensified cropping technologies complicate disease management.

The disease is caused by rice tungro spherical virus (RTSV) and rice tungro bacilliform virus (RTBV). It is transmitted by the green leafhopper *Nephotettix virescens*.

Early research focused primarily on the etiology and transmission of tungro, with relatively little attention

Better understanding of the way green leafhoppers transmit rice tungro-causing viruses will help in disease control.



to its epidemiology in relation to the population ecology and dispersal of the vector green leafhopper.

The Natural Resources Institute, a scientific unit of the UK Overseas Development Administration, and IRRI are systematically addressing research gaps, to establish a basis for integrated disease management. Research is focusing on

- Spatial and temporal nature of green leafhopper behavior, dynamics and dispersal in relation to tungro disease, as influenced by weather, crop culture and the rice plant.
- Spatial and temporal dynamics of tungro viruses in epidemics, as influenced by the type and strength of the virus and by characteristics of the rice ecosystem.
- Strategies for tungro management based on knowledge of green leafhopper ecology and dynamics, epidemiology of the disease, rice crop management and characteristics of farmers.

Two NRI scientists are studying green leafhopper ecology and tungro epidemiology at IRRI. Another is studying the flight behavior of the green leafhopper vectors.

IRRI scientists are studying the relative importance of weeds and other natural vegetation and rice stubble as sources of tungro-causing viruses and of green leafhoppers. A scientist at the NRI has developed a prototype computer model that simulates the dynamics of tungro viruses in the field across time. ■

Long-term conservation preserves the world's rice genetic heritage

Conservation of rice genetic resources is always a collaborative venture. IRRI began actively participating in germplasm collecting in 1972. More than 70 collecting missions have netted some 12,000 samples of cultivars and wild rices in 15 countries of Asia, Africa and the Pacific region. Many more countries have participated in helping make rice one of the best conserved of all the world's crops.

Early collections of rice germplasm in China, India, Japan and the United States, among other countries, laid the foundation for the International Rice Germplasm Center (IRGC) at IRRI.

Collecting missions are often multidisciplinary and multinational. Germplasm collected during a mission is shared among institutions, to ensure safe duplicate storage.

Recently, the IRGC has returned entire conserved national germplasm collections to Cambodia, Nepal, Pakistan, the Philippines, Senegal and Sri Lanka—more than 9,000 accessions of rice.

Safeguarding the world's invaluable germplasm resources for use by future generations relies on such duplication. Samples of the germplasm conserved in the IRGC are sent annually to the National Seed Storage Laboratory in Colorado, USA, where

45,000 accessions are held in duplicate storage.

Supplying conserved germplasm to advanced laboratories worldwide is helping fuel rapid advances in rice biotechnology. Evaluation by other users of germplasm has laid the foundation for new improvements in modern rice varieties.

Only recently, the wild rice *Oryza minuta* from the Philippines was found to be a source of resistance to blast. *O. brachyantha* from Africa is a source of resistance to the two viruses that make up the tungro disease complex. ■

The germplasm of rice and related species collected in different countries is shared among institutions, to ensure safe duplication of the genetic resources.

Conservation of rice germplasm improved

Within just the last few years, eight major rice-producing countries have established modern genebank facilities that greatly improve their ability to conserve rice germplasm. Concurrent developments in biosafety, biodiversity and biotechnology are opening new opportunities in genetic conservation.

Increased interaction among rice genetic resources workers should enhance the safety, documentation and utilization of the germplasm conserved and accelerate the application of new tools to facilitate that work. IRRI joined IBPGR (International Board for Plant Genetic Resources) to sponsor a workshop aimed at fostering closer linkages among rice genetic resources workers in the genebanks that house major rice germplasm collections.

The participants proposed forming a working group to improve overall coordination of rice genetic resources conservation. Representatives from nine countries agreed to work toward standardization of genebank documentation systems, increased exchange of information about holdings and joint exploration for additional germplasm. IRRI is providing logistical support. ■

National programs–CIMMYT–IRRI collaborate to improve rice-wheat systems in Asia

In tropical rice-wheat cropping systems, rice is grown in puddled soil during the hot, rainy months and wheat is grown in drained soil during the cooler, drier months. Rice-wheat is grown on some 25 million hectares and is one of the most intensive and productive cereal systems in the world.

But productivity and sustainability of the system are under threat. Yield increases realized from planting modern high-yielding rice and wheat varieties using improved management practices are leveling off. More and more inputs are needed to achieve the same yields. Production is not keeping up with costs.

The natural resource base for the system is also in decline. Irrigation systems are not being maintained, large areas are becoming saline and the capacity of the soil to provide nutrients is degrading.

IRRI and CIMMYT developed a collaborative project with Bangladesh, India, Nepal and Pakistan that is a model for ecoregional research. IRRI and CIMMYT are together studying strategic issues associated with the sustainability of the system and examining the processes that influence the water–soil–nutrient interface. A geographical information system has been developed for the agroecosystem, linked to models that can extrapolate the productivity of rice and wheat under different conditions in different environments. The

national programs are undertaking the applied and socioeconomic research, to base the development of technologies that will ensure the sustainability of the system and increase its productivity.

The integrated research collaboration is supported by the Asian Development Bank (ADB) and the U.S. Agency for International Development (USAID). ■

Systems analysis and simulation for rice production

Sixteen national agricultural research centers, IRRI and Wageningen Agricultural University, the Netherlands, are collaborating in an informal network on systems analysis and simulation modelling for rice production (SARP).

The project started in 1984. By then, crop models, dynamic simulation and other techniques of systems analysis that use sophisticated computer technology had developed into practical tools to improve the efficiency of agricultural research. The techniques enable integrating large amounts of data from a number of disciplines.

The goal is to build and support research capacity with the help of modern systems research techniques. Multidisciplinary teams, each including four researchers from the same institution, participate. Each team has at least one plant physiologist or agronomist.

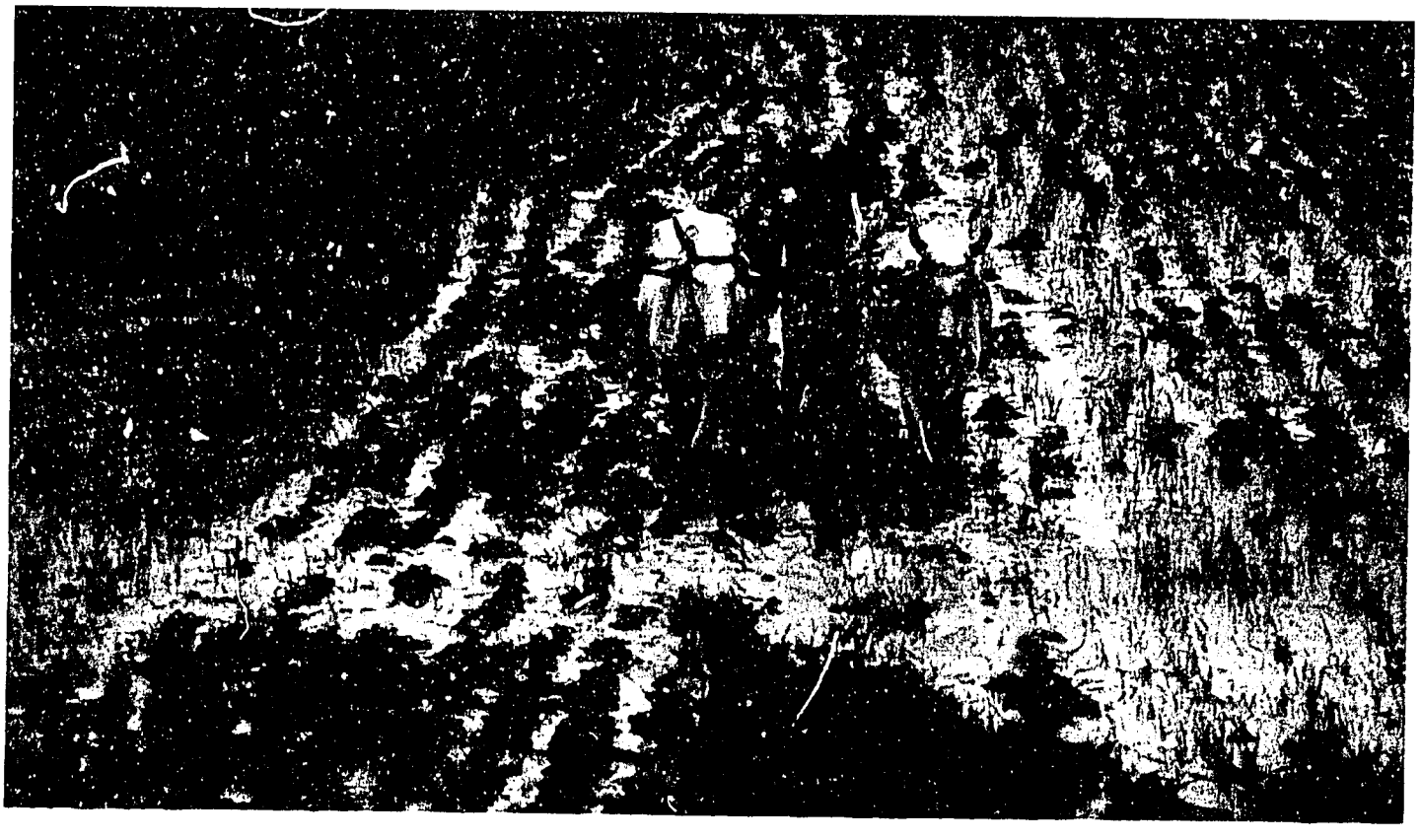
Modelling as an approach to studying real problems is the central focus. Simulation models are a transparent starting point to research and can be adapted to many objectives.

The first phases of the SARP project—now in its ninth year—involved a basic 8-week training course, one-year case studies conducted at each team's home institution and workshops during which teams presented the results of their case studies. A natural follow-up was for teams to continue their simulation and modelling work and to continue to collaborate.

During the workshops, research supervisors participated with team leaders in drafting network activities centered on practical outputs. Four research themes emerged:

- Agroecosystems. Agroecological zoning helps prioritize research and determine the extrapolation domain of new technologies. Simulation models are a key tool because they can integrate the effects of weather and soil on crop performance.

Simulation models are a transparent starting point to research, linking to systems analysis to illuminate problems and potentials in crop improvement.



• Potential production. Model-assisted research on processes helps improve crop management. Models also help define breeding objectives.
• Crop and soil management. Models enable simulating water and nitrogen dynamics in the soil and crop.
• Crop protection. Models of the damage mechanisms of insects and diseases can be used to quantify the impact of rice pests on rice yields.

The collaborating scientists have found modeling an excellent tool to integrate knowledge from relevant disciplines for application to their studies of practical problems. Even though most teams are working on problems specific to their home country agroecological environments, the growth processes are the same across environments and using the same models is appropriate. The countries involved are China, Bangladesh, India, Indonesia, Korea, Malaysia, Sri Lanka, the Philippines and Thailand. Groups specializing in modeling of Wageningen are from the Centre for Agrobiological Research and the Department of Theoretical Production Ecology. ■

Decentralized training taps skills of IRRI alumni

More than 7,000 scientists have participated in the training courses and professional advancement programs traditionally offered by IRRI. Those IRRI alumni, who now comprise much of the scientific staff and faculties of major rice research institutions and universities in Asia, are contributing significantly to advancing rice research in their countries.

Since its founding, IRRI has offered degree and nondegree scholarships/fellowships for training in rice science. Group training courses were traditionally taught at IRRI headquarters. Degree candidate scholars most often attended the University of the Philippines at Los Baños (UPLB).

Now training is moving out, to collaborating national programs and institutions in rice-growing countries of Asia. Many of the larger national programs conduct their own group training courses using IRRI-developed materials. IRRI has formal memoranda of agreement with approximately 30 universities worldwide, under which MS and PhD students take course work elsewhere and come to IRRI to carry out their thesis research.

IRRI is also assisting national programs with special needs to improve their in-country training capacities. A long-term collaborative program in Cambodia is implemented by IRRI-trained instructors using IRRI course materials translated into Khmer.

Collaborative training will expand over the next several years. Many of IRRI's traditional group courses will be offered elsewhere, by national programs with adequate resources and facilities and a commitment to regional participation.

At the same time IRRI will be developing new courses at headquarters that will make available to national program participants the sophisticated research techniques needed in strategic research. ■

In-country training extends new knowledge and new skills to more agricultural researchers and research technicians.

Emerging collaboration in Africa

About 2.4 million hectares of ricelands in the east, central and southern regions of Africa are cultivated. Another 1 million hectares have the potential for rice. While the countries in the region—Burundi, Kenya, Swaziland, Tanzania, Zambia and Zimbabwe—all have the problem of low rice productivity, limited rice area constrains allocation of national resources to rice research.

A 1990 regional workshop on rice research and production in Southern African Development Coordination Conference (SADCC) and neighboring countries recognized the rapidly increasing demand for rice in the region and the potential of utilizing its wetlands for rice production. Participants recommended increased efforts to strengthen the scientific and technical capabilities for rice research of national program scientists and technicians.

In 1991, officials of the Southern Africa Coordinating Centre for Agricultural Research (SACCAR) invited a team of IRRI scientists to assess the potential for increasing rice production in that part of the region. That led to a proposal for a SACCAR–IRRI regional rice research and training project.

These initiatives are being developed in the context of IRRI–IITA–WARDA agreements to share responsibilities for developing rice production in Africa: West Africa regional responsibilities belong to WARDA, with IITA and IRRI providing assistance. IRRI will focus on the Eastern, Central and Southern Africa region, with support from IITA. ■

Increasing demand for rice in the east, central and southern regions of Africa is leading countries with relatively little riceland to seek to increase production.

New stripper harvester for small ricefields

Agricultural engineering at IRRI designs equipment suitable for small rice farms. The objective is to reduce drudgery and increase labor productivity. If rice production in Asia is to be sustained, rice farming must be attractive to future farmers.

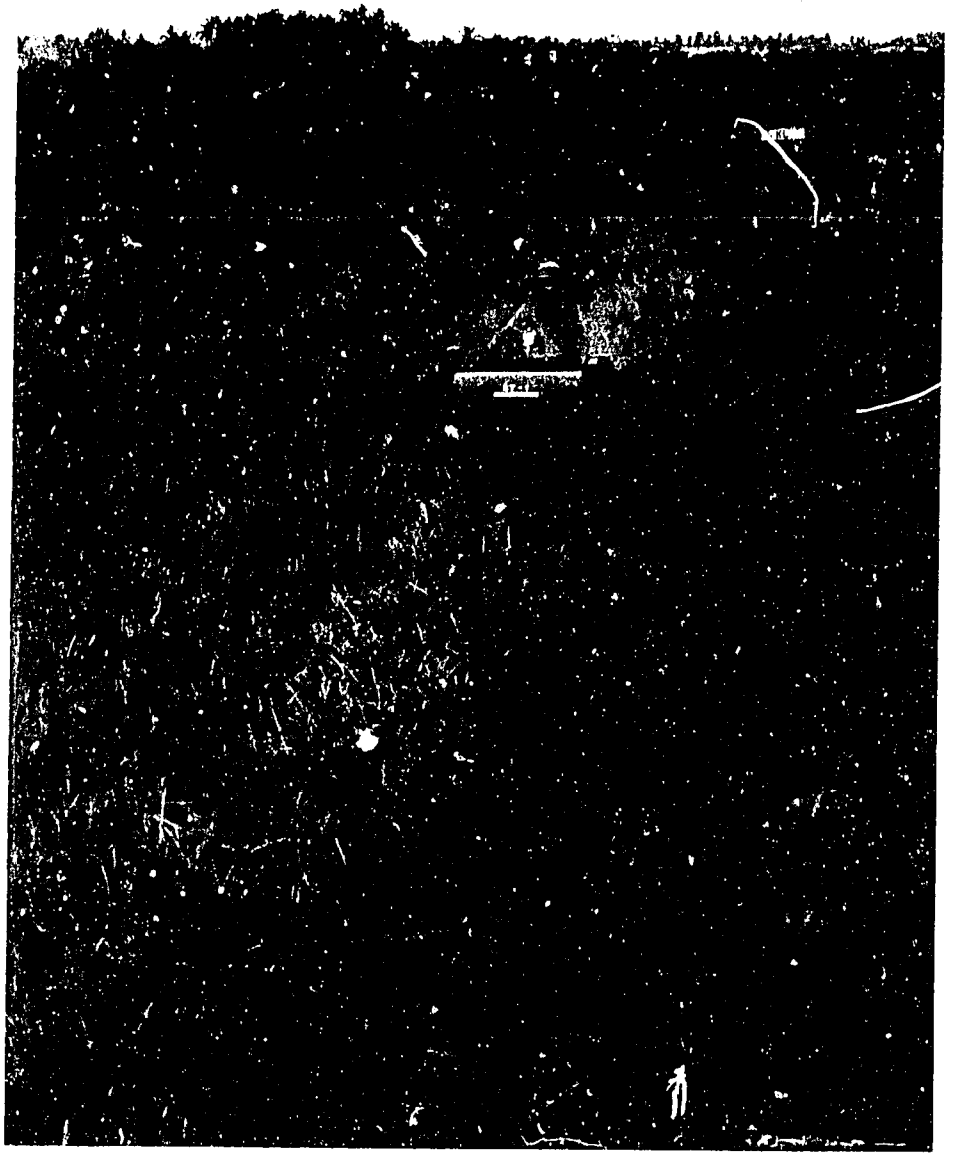
An example is harvest delays because of labor scarcity. Small farmers risk losing part of their crop, grain quality deteriorates and planting the next crop is delayed. The Overseas Development Administration and Sisoe Research Institute, UK, and IRRI are working to apply on a small scale the upward-combing stripper rotor principle originated by Sisoe Institute .

Results so far indicate lower grain losses than with hand harvesting, with less straw gathered. Harvest time is shortened, too. The process involves

- A walk-behind, highly maneuverable stripper-gatherer that can be carried over bunds and into small fields.
- A removable container which collects harvested panicles and straw.
- A rethresher to clean and sack the grain right in the field.

The system requires only 6 labor days per hectare. Although more straw is left in the field than with hand harvesting, pilot experiments indicate twice as much residue could be incorporated without significantly lengthening turnaround time for the next crop.

Two agricultural engineers from Thailand Department of Agriculture and Khon Kaen University familiarized themselves with the new machine at IRRI. They see potential for



A new, highly maneuverable stripper-gatherer will reduce hand harvesting drudgery and increase productivity.

its use in North and Northeast Thailand, where harvest labor is in short supply and ricefields too small for larger harvesting equipment.

Specifications of IRRI-designed equipment are made available free to qualified small-scale manufacturers in collaborating countries. All the equipment is designed to use local materials and labor. ■

Monitoring crop flow in the axial flow thresher

Crop flow measurements were needed to evaluate performance of the IRRI-designed axial flow thresher. Hohenheim University in Germany and IRRI collaborated to apply an inductive grain flow measuring system to solve the problem.

The effects of feed rate, threshing drum speed and louver adjustments on grain flow and threshing performance were tracked and analyzed using a computer program package. Flow was strongly influenced by louver angle (that determines the number of revolutions the panicles make around the threshing drum).

A modified louver angle improved flow and reduced backfeed. ■

Developing a low temperature, rice storage/dryer

In the humid tropics, a rice storage bin in which the grain could also be dried would reduce handling and lessen loss of quality. The IRRI–Hohenheim University collaboration assessed the feasiblity of such a system.

The prototype involves a rectangular rice bin, a sweep floor for air distribution and unloading, an electric heater and a centrifugal fan. In tests across two wet seasons, a rice layer up to 2 meters thick could be dried from 28 percent moisture to a safe storage level in one pass. Rice dried this way graded premium quality in the Philippines. ■

Research programs

This annual report of IRRI's continuing response to the challenges of the 1990's and beyond documents the evolution of rice science. Research done at IRRI and in collaboration with research partners all over the world reflects broad concerns for the rice farmers and consumers of today and for those of the generations to come.

IRRI's research focuses on

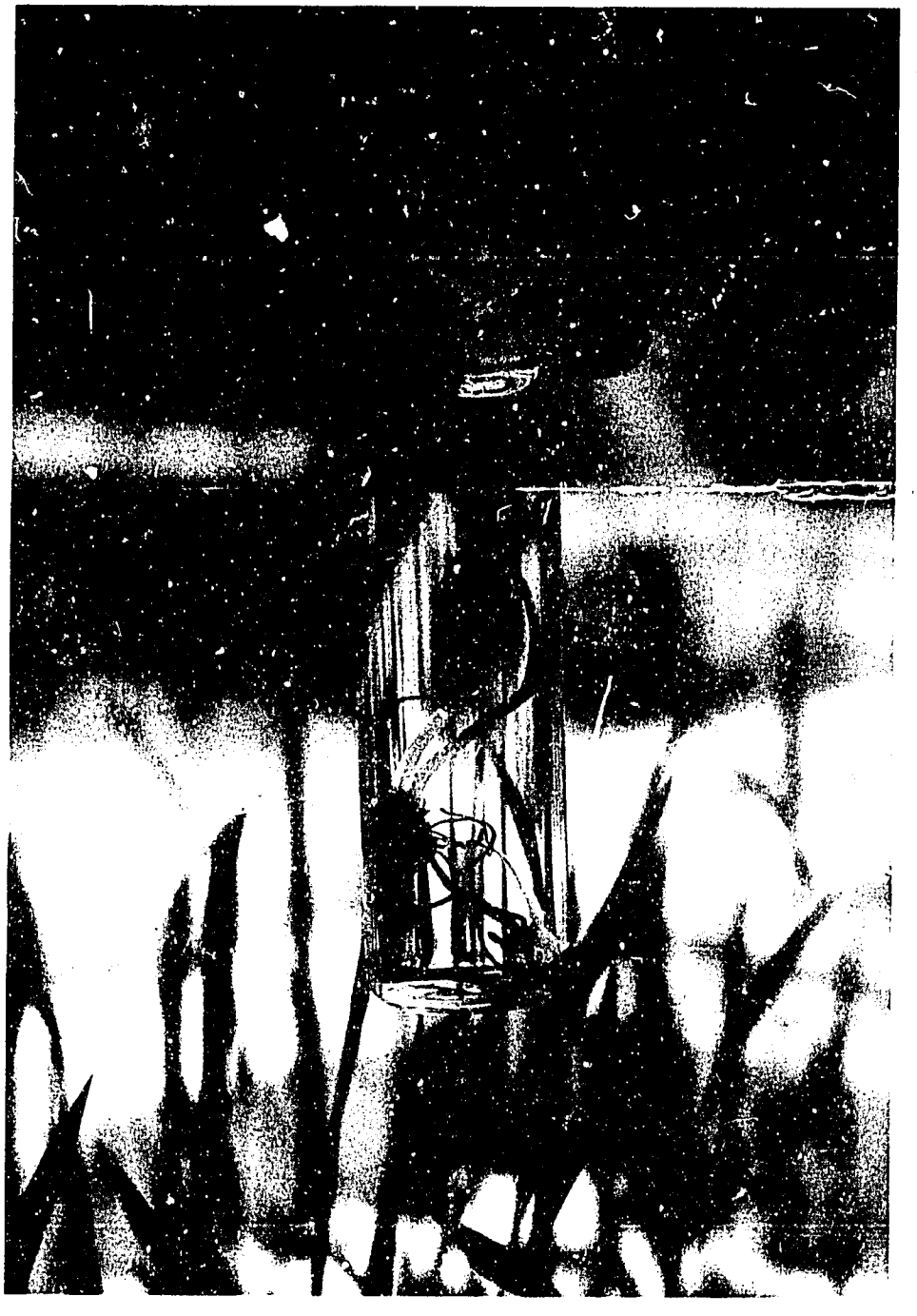
- Increasing rice yields and breaking the yield ceiling. This involves basic and strategic research to better understand and utilize fundamental yield-determining processes.
- Developing and deploying more durable, environmentally friendly pest management systems. This involves learning to manage the diversity of resistance genes in rice, of the rice pests themselves and of their natural enemies in ricefield environments.
- Managing and carefully exploiting the natural resource base to ensure its sustainability. This means directing more attention to biological and socioeconomic processes that influence resource use.
- Increasing the productive return to the use of limited resources, particularly those available to resource-poor farmers. This means conducting research at representative sites to amplify favorable crop and varietal diversity with practices that provide an integrated nutrient and pest management environment.

We carry out our research within a framework of concern for

- The resources available for research.
- The drudgery of rice production, particularly for women.
- The global environment.
- The poor urban rice consumers.

Meeting the challenge demands deploying research resources across a wide range of approaches, from applying new tools for transferring novel genes into rice to studying how farmers use their knowledge of biodiversity and other practices to optimize the productivity of their limited resources in variable, risky environments. It involves inventing technologies that will reduce the emission of greenhouse gases from rice systems and developing new rice

Wetland rice cropping involves intense hand labor operations, including exceptionally drudgerous tasks traditionally done by women.



An experimental plant into which a marker gene has been inserted via protoplast fusion shows the characteristic blue color that indicates successful transformation.

breeding lines that can respond positively to a changing environment.

This report gives many examples of our progress toward meeting the goals. We cite only a few.

IRRI has identified and marked 12 economically-important genes on the rice genome. Using this biotechnology tool will increase the efficiency of conventional breeding to develop rices with improved tolerance for biotic and abiotic stresses. We also will test rice plants that have been transformed genetically for novel resistance to major pests.

At the same time, we are identifying farmer knowledge of naturally-occurring biological agents. This will help in designing integrated pest management systems that minimize the need to use chemicals with the potential to harm human and environmental health.

Five years ago, we used our understanding of the processes that determine maximum yield in rice to model ideal plant types for higher yields. Today, genetic breeding lines growing in IRRI experimental fields have many of the characteristics the model predicted would be needed. These new plant types, along with new tropical hybrids, are expected to break the barrier to increased yield potential.

Research focused on sustainability of rice systems has been concerned for a number of years with the natural resources of the rainfed lowland and upland ecosystems. The vulnerability of these systems to degradation is well known.

Of equal concern are the highly productive irrigated lowlands that are the primary rice granary for urban areas. In terms of agricultural development, intensively cropped irrigated systems are relatively young. Recently identified decreases in the productiv-

ity of major inputs and unanticipated changes in the resource base are not completely understood.

On another dimension, we have begun to measure the release of methane from flooded rice fields and the influence of different cultural practices on that release. This is just the first step toward minimizing increasing levels of "greenhouse gases" in the atmosphere.

IRRI's research team managers are concerned about how, and how soon, we can meet the challenges. To ensure the relevance of IRRI research and to use the Institute's limited resources wisely and efficiently, the research is structured into integrated projects within ecosystem-based programs, for irrigated, rainfed lowland, upland and deepwater and tidal wetlands rice systems. A cross-ecosystems program seeks to develop new tools and acquire new knowledge that links changes at the rice genome level to the plant and crop system and to the major ecosystems where rice is grown. Project planning is based on diagnostic analysis at the farm level and on socioeconomic analysis of demands and trends in labor, land and capital.

IRRI seeks to meet the world's highest standards in carrying out its research. A strong disciplinary base maintained through our scientific divisions ensures that state-of-the-art knowledge is applied in all projects.

We do not rely solely on internal strength to ensure research quality and excellence. For the last two years, we have implemented a peer review process. Independent external experts examine how well and how efficiently we do our work. Increasing emphasis is being given to project planning that sets realistic objectives within an agreed time frame. We monitor our progress carefully.

Changes in who is doing the research are also visible. The enormity of the research challenge—particularly when the focus is on the need for food—during a time of diminishing research support requires strong partnerships that harness all available resources. One collaboration deserves special mention—the consortia of research institutions that have agreed to pool their resources to address improving the productivity, stability and sustainability in the highly variable and heterogeneous rainfed lowland and upland systems.

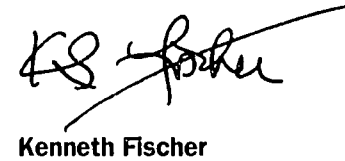
International research has had only minimal impact on these systems, and minimal benefit to the resource-poor farmers dependent on them. This was due in part to a mistaken belief that the more site-specific technology needed required less strategic research, less need to understand the processes that control productivity and sustainability.

Consortia are tooling up to bring adequate resources to bear on conducting strategic research at key sites that sample the variability of the ecosystems. This will provide the basis from which new technologies can be developed.

This new chapter in ecoregional research is made possible because strong research partners have developed within Asia over the last 30 years. As each member of a consortium brings new tools and knowledge to apply across ecosystem variability, the research will more adequately address the multiple, interactive constraints to improved rice yields and will enable development of technology relevant to farmers working in rainfed and upland ricefields.

Strategic research requires applying sophisticated scientific techniques. While the capability of national program scientists to conduct the work has been enhanced, their access to research funding is decreasing. The new initiatives will need continuing help if the potential is to be achieved.

Earlier this report highlighted many of the collaborative arrangements we have with scientific laboratories in industrialized countries and with IRRI's traditional national agricultural research system partners. The following section describes additional highlights of IRRI's 1991 research activities. ■



Kenneth Fischer
Deputy Director General
for Research

Irrigated rice ecosystem

Irrigated rice research projects

Germplasm improvement
- Integrated germplasm improvement
- Hybrid rice

Crop, resource and pest management
- Crop establishment, water and tillage management
- IPM technology development and implementation

Production, environment and livelihood impact
- Indices of sustainability and productivity
- Rice-wheat systems
- Global climate change
- Rice grain, seed quality, post harvest and biomass issues

Irrigated ricefields supply 90 percent of the rice needed by urban and rural landless consumers. Sustaining the productivity gains made so far is as important a priority as raising productivity. IRRI research for the irrigated rice ecosystem focuses sharply on the resilience of intensively-cropped systems.

Some of the research is designed to identify factors that are contributing to a flattening or even a decline in growth of productivity. Other experiments are examining technological interventions that can reverse these negative trends.

The objectives are to extend the yield frontier through varietal improvement and more efficient crop management and to sustain productivity gains through more efficient use of inputs and through rehabilitation and maintenance of the physical, biological and human resource base. Technologies designed to increase the efficiency with which the rice crop uses inputs should also improve the ricelands and the profitability of rice production.

Almost all irrigated rice research projects have strong collaborative linkages with leading Asian universities and research institutions that work on irrigated rice. These collaborations are being streamlined and enhanced to

- Delineate the irrigated rice ecosystem by the major agroclimatic environments it encompasses.
- Identify institutions within the countries that have major irrigated environments who could collaborate as key partners to solve critical research problems.
- Encourage IRRI irrigated rice research project teams to strengthen and expand their collaborations with those institutions.

Collaboration with advanced laboratories is an important component of the research underway, particularly in work to develop an ultra-high yielding plant type, to understand the causes of long-term decline in the productivity of irrigated rice systems and to examine the impact of rice production on climate change and of climate change on rice production. ■

HIGHLIGHT

Progress on an ultra-high yielding rice plant type

Developing a new rice plant type with a much higher yield potential than current modern varieties is a priority objective. Some 275 crosses of donors for large panicles, sturdy stems, few tillers and thick green leaves—most of them tropical japonicas—have been made. Selection in early generations is going on now. ■

Increasing and sustaining irrigated rice production is crucial in supporting increasing, and increasingly urbanized, populations.

HIGHLIGHT

Sustainability of rice production systems

Reanalysis of long-term experimental data on double and triple cropping of rice reveals some disturbing trends.

One experiment on the IRRI research farm has involved three crops a year since 1968. Yields of the highest yielding varieties have declined year-by-year, to a total 40 percent drop. Another IRRI site in the Philippines has been continuously double-cropped. Wet season yields have declined steadily.

In a double rice crop experiment conducted by India Agricultural Research Institute scientists in Hyderabad, dry season yields declined by 40 percent across 12 years. In several other long-term studies, yields at best remained constant.

All the long-term experiments follow a similar concept: management practices are optimized at any point in time to include the best varieties, complete water control, recommended nutrient inputs and the most current pest management strategies.

Work to identify the factors involved is underway. Quantification of system output/input efficiencies will provide indices of change in the resource base. The first step is to examine the relationship between productivity and specific soil properties that are key determinants of soil quality. Better understanding of farmer knowledge and perceptions of soil quality and short-term/long-term tradeoffs will help in developing new strategies to manage rice production that will reverse and prevent yield declines. ■

HIGHLIGHT

Nitrogen uptake in continuous cropping constraint to high yields

Modern rice varieties are not achieving their full yield potential, even in optimally-managed experimental plots. Data from long-term continuous cropping experiments in the IRRI Research Farm and at other sites in the Philippines indicate that nitrogen uptake is a key factor.

Plant uptake of nitrogen is governed by the supply of nitrogen from the soil and from applied fertilizer, and by the rate of nitrogen uptake by the root system.

One hypothesis is that current fertilizer practices—developed when soils had a greater capacity to supply nitrogen when required by the crop—are no longer able to supply nitrogen to the root system at the right time.

An experiment on the IRRI farm compared recommended nitrogen rates applied in two splits before panicle initiation with an application strategy that synchronized nitrogen supply with plant growth stage. Yields with more frequent application were significantly higher.

Additional nitrogen applied at anthesis could have made the difference. The flag leaf is the primary source of assimilates for grain filling, and net carbon assimilation in the flag leaf is largely determined by nitrogen content.

More field experiments are underway at IRRI and in collaboration with the Philippine Rice Research Institute (PhilRice). The data will be used to improve simulation models that help identify the plant characteristics most important for increasing yield potential. This knowledge will enable developing strategies for managing a dynamic nitrogen supply environment, quantified by the nitrogen supplied from indigenous soil resources and applied fertilizer, by dry matter partitioning and by grain yield. ■

HIGHLIGHT

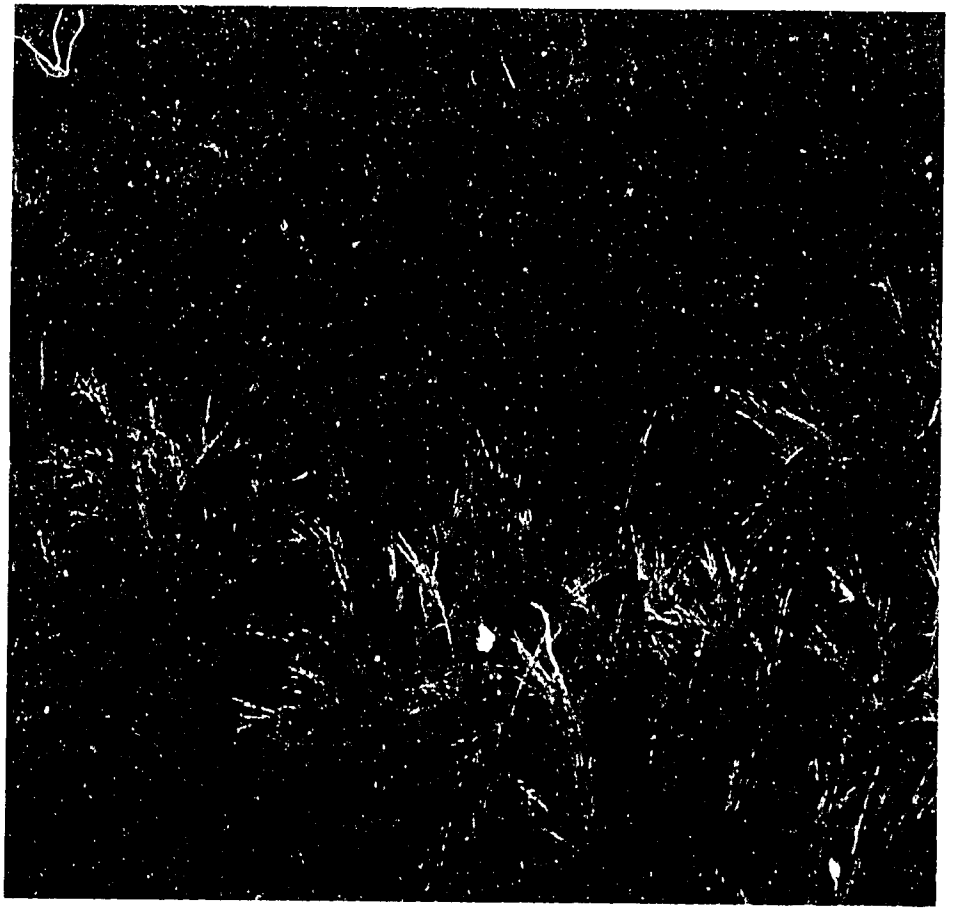
New source of cytoplasmic male sterility for hybrid rice

Increased genetic diversity is needed in hybrid rice. Wide hybridization techniques were used to develop a new source of cytoplasmic male sterility.

Two restorers—IR54R and IR64R—of wild abortive-type cytoplasm were crossed with 45 accessions of *Oryza perennis* and 4 accessions of *O. rufipogon*. One line in the fifth backcross generation carrying the cytoplasm of *O. perennis* accession 104823 and the nuclear background of IR64 was found to be stable for complete male sterility. Genetic tests show it has different cytoplasm from the wild abortive type.

This new cytoplasmic male sterile line has been designated IR66707A. The search for an elite line that will restore fertility, to enable IR66707A to be used in developing new hybrid rices, is underway. ■

Hybrid rice varieties adapted to the humid tropics are expected to yield 15-20% higher than conventional varieties.



HIGHLIGHT

Insecticide application favors pest buildup

A prerequisite to selecting and deploying effective pest control is understanding the components of the ricefield ecosystem. Applying insecticides disrupts the balance of the system, and frequently hurts friendly insects more than it hurts pests.

Recovery from chemical applications is significantly higher among pest species than among predator species. Brown planthoppers and green leafhoppers have higher reproductive rates and more mobility than do the predatory wolf spider and veliids that eat the pests and their eggs. Their populations build up faster after the field is sprayed, and that can damage a crop more than if no insecticide had been applied. ■

Applying insecticides can disrupt balance of a ricefield ecology, harming the predators that help control rice pests more than it hurts the pests.

HIGHLIGHT

Direct seeded rice yields better under water deficit

Direct seeding has been gaining popularity in some irrigated areas of Malaysia, the Philippines and Thailand. One advantage is a better ability of rice to withstand periodic drought from erratic water supply, a problem in many irrigation systems.

Direct seeded and transplanted rice performed differently in a study in farmers' fields of the Upper Pampanga River Integrated Irrigation System in the Philippines. Water supply from that reservoir is limited in the dry season. Test conditions represented different degrees of water shortage.

Under adequate water, direct seeded and transplanted rice yielded about the same. But when water deficit stressed the crop during its vegetative and reproductive phases, direct seeded rice yielded significantly better. ■

Rainfed lowland rice ecosystem

Rainfed lowland rice research projects

Sustainable resource management
- Resource management for enhanced productivity
- Integrated nutrient management

Germplasm improvement
- Genetics, physiology and breeding

Rainfed lowland rice farmers in South and Southeast Asia depend on the monsoon rains to grow their crops. But the monsoon is erratic—some years early, some years late. Some years have less rainfall than others. An area may be hit by drought and flood within the same season.

Much of the unfavorable rainfed lowlands have poor hydrological conditions and related low soil fertility. Resource-poor farmers face complex and changing crop management decisions.

Most of the farmers who operate at the subsistence level select low-risk cropping options. Traditional management involves growing one monsoon season rice crop a year, using locally-adapted varieties. This gives low but relatively dependable harvests, and continues the cycle of poverty.

New rice technologies for these areas must be robust. Improved varieties must perform better than traditional varieties in unfavorable years and much better in more favorable years. New practices must be affordable and support environmental security.

To improve rainfed lowland productivity, better understanding of constraints and opportunities is needed. The wide variability in hydrology and soil fertility of rainfed lowland areas makes diagnostic surveys in different environments important. The data generated helps focus multi-disciplinary research.

The 40 million hectares of rainfed lowland rice in South and Southeast Asia constitute about 30 percent of the total rice area in those regions but contribute less than 20 percent of total rice supply. These fields have potential for much higher productivity, if key problems can be alleviated. Systematic interdisciplinary research will have spill over benefits to underutilized rainfed wetlands in Africa and Latin America.

A central pillar in the work plan is the Rainfed Lowland Rice Research Consortium initiated this year. Scientists in agricultural research institutions in six countries are working closely with each other and with IRRI scientists on the major problems that limit rice productivity in the rainfed lowlands. ■

HIGHLIGHT

Managing soil fertility

Rainfed lowland soil fertility involves factors different from those related to the fertility of irrigated ricelands. Practices used to manage soil, water and crop in the pre-rice period greatly influence the availability of soil nutrients to the rice crop, particularly when there are long fallow periods.

Earlier work showed that nitrate-nitrogen that accumulates in large amounts in the soil before rice is planted may be lost through leaching or denitrification when the soil is flooded. Leached nitrates also may contribute to groundwater pollution.

A collaboration of the International Fertilizer Development Center, the University of Hawaii, USA, and IRRI is generating more efficient and environmentally-sound technology for managing nitrogen.

Depending on plant growth and degree of tillage during the dry to wet season transition period, up to 108 kg of nitrate-nitrogen per hectare accumulates in the top 60 cm of soil during the three months before the rains start. But one week after the soil was flooded in an IRRI experiment, only about 10 kg nitrate-nitrogen remained.

A weedy fallow decreased nitrate build-up but also lessened nitrogen loss. Legumes such as mungbean and sesbania are even more efficient in capturing the soil nitrate and contributing additional nitrogen through biological fixation. That nitrogen can be incorporated into the soil with the plant residues to increase wet season rice yields.

Fertilizer needs of rainfed lowland rice in poor soils depend on the way rice is established. Sowing pre-germinated seeds (wet seeding) on soil that was flooded, then puddled enabled the crop to utilize more soil nutrients than did sowing dry seeds before the soil was flooded. Adding fertilizer—particularly phosphorus—increased dry-seeded rice yields more than wet-seeded yields. The highest yields with either crop establishment method were with additional nitrogen and phosphorus. ■

HIGHLIGHT

Dry seeding to increase productivity

Most rainfed lowland farmers transplant their rice crop in soils that have been flooded and puddled. Water scarcity precludes growing a dry season crop before wet season rice.

A significant period during which light rains fall at the beginning of the wet season is lost before enough rainwater accumulates to soften the soil for puddling and transplanting. After transplanted rice is harvested, another period of low rainfall at the end of the rainy season is usually not sufficient for a profitable post-rice crop.

Dry seeding the rice crop can advance and shorten the rice growing season, leaving a more hydrologically-favorable time for a post-rice crop such as mungbean. The rice crop is established by plowing the dry ricefield and sowing dry seeds, which germinate as the first rains fall.

Difficulty in controlling weeds has discouraged farmers from adopting dry seeding. Small-scale mechanized technology for direct seeding, fertilizer application and weeding, however, may allow rice to compete more strongly with weeds during crop establishment. More effective and environmentally-safe herbicides at reasonable prices also are opening opportunities for innovative crop intensification.

Farmers in one rainfed lowland area of the Philippines follow different practices. In 1991, 12 dry seeded their rice, 19 transplanted. Of the 12 who dry seeded, 8 used herbicides. Dry-seeded rice yielded 0.6 tons per hectare more than transplanted rice. Of the farmers who direct seeded, those who used herbicides produced 1.5 tons per hectare more than those who did not use herbicides.

The dry-seeded crop was established 40-55 days ahead of the transplanted crop, giving it the benefit of early rains. Earlier harvest gave the post-rice mungbean crop more time to benefit from late rains. ■

Upland rice ecosystem

Upland rice research projects

Sustainable land and resource management

Germplasm improvement and crop management

Rice farming practices in the uplands vary from shifting cultivation (short cropping periods followed by longer fallows) to permanent agriculture, on fields ranging from steep slopes to well-drained flat areas. Farm size, field size and production methods also vary greatly, and technology that improves one system will be quite different from that suitable for another.

This makes research complex. Work is needed in a number of environments because different constraints limit productivity. The overall aim, however, is the same: to develop economically viable, environmentally safe cropping systems that will increase productivity.

In all environments, rainfall is irregular and inadequate. Weed infestations are heavy. Soils are

Shifting cultivation farmers often use environmentally-threatening slash-and-burn methods to clear a field for planting rice.

infertile and eroded. Diseases and pests are endemic. Resource-poor farmers cannot afford fertilizers, insecticides and herbicides. Suitable cultivars have not been developed. Rice yields are low and unstable.

Yet there is potential to increase food production in many areas where upland rice is grown. Under the best environmental and cultural conditions, improved rice cultivars have yield potentials of 5-6 tons per hectare. But farmers need simple, low-cost technology that does not degrade the environment if they are to approach potential productivity.

Upland rice ecosystem research takes a multidisciplinary, farmer oriented approach. Strong collaboration through the Upland Rice Research Consortium established this year is shifting work to sites representing upland environments with different combinations of constraints. ■

HIGHLIGHT

Diagnosing upland rice constraints

A first step in expanding research in sites representing different combinations of cropping constraints is diagnosis: What are the problems? How do farmers cope with those problems? Are there better solutions?

Such a diagnosis was made of Sitiung, Sumatra, Indonesia. Sitiung is a transmigration area. Rice farming systems include permanent cultivation on level and gently rolling lands and shifting cultivation on sloping lands. Productivity is stressed by poor soils and rice pests (diseases, insects, nematodes, weeds) and by foraging by animals (pigs, rats, monkeys).

Farmers report low and declining yields and poor response to fertilizers (subsidized and applied in large amounts in some areas).

Indonesian and IRRI researchers identified some of the work needed: better understanding of soil constraints to increased yield, ways to add nutrients, and development of acid-tolerant cultivars.

In a diagnostic survey of Matalom, Leyte, Philippines, 56 weed species were found growing in ricefields. They caused more than 20 percent loss of yield even with hand weeding and more than 40 percent loss with no weeding at all.

In Hazaribagh, eastern India, upland farmers grow crops only in the wet season, in a 4-year rotation

Upland rice systems research is complex, given the number of environments where different constraints limit productivity.

(millet-blackgram-rice-fallow). One village experimented with water impoundment to extend the cropping season. Family and exchange labor built 16 reservoirs that provide water for 7 to 10 months. That has enabled farmers to plant vegetables in the dry season, increasing the availability of food in the village. ■

HIGHLIGHT

Nitrogen contributions of leguminous hedgerow trees

Planting leguminous trees could recycle nutrients in hedgerow intercropping systems. But no data are available on the long-term contribution of nitrogen by trees.

IRRI collaborated with CSIRO, Canberra, and the University of Queensland, Australia, to estimate biological nitrogen fixation by *Gliricidia sepium* and *Cassia spectabilis*. The study was carried out in Claveria, Northern Mindanao, Philippines.

Data indicate that *Cassia* does not fix nitrogen. *Gliricidia* accumulated up to 60 percent, about half from biological fixation and half from uptake of soil nitrogen. *Gliricidia* in a hedgerow could recycle soil nitrogen, with its prunings used as green manure for growing rice in the alleys between the hedges. ■

Deepwater and tidal wetlands rice ecosystems

Deepwater and tidal wetlands rice research projects

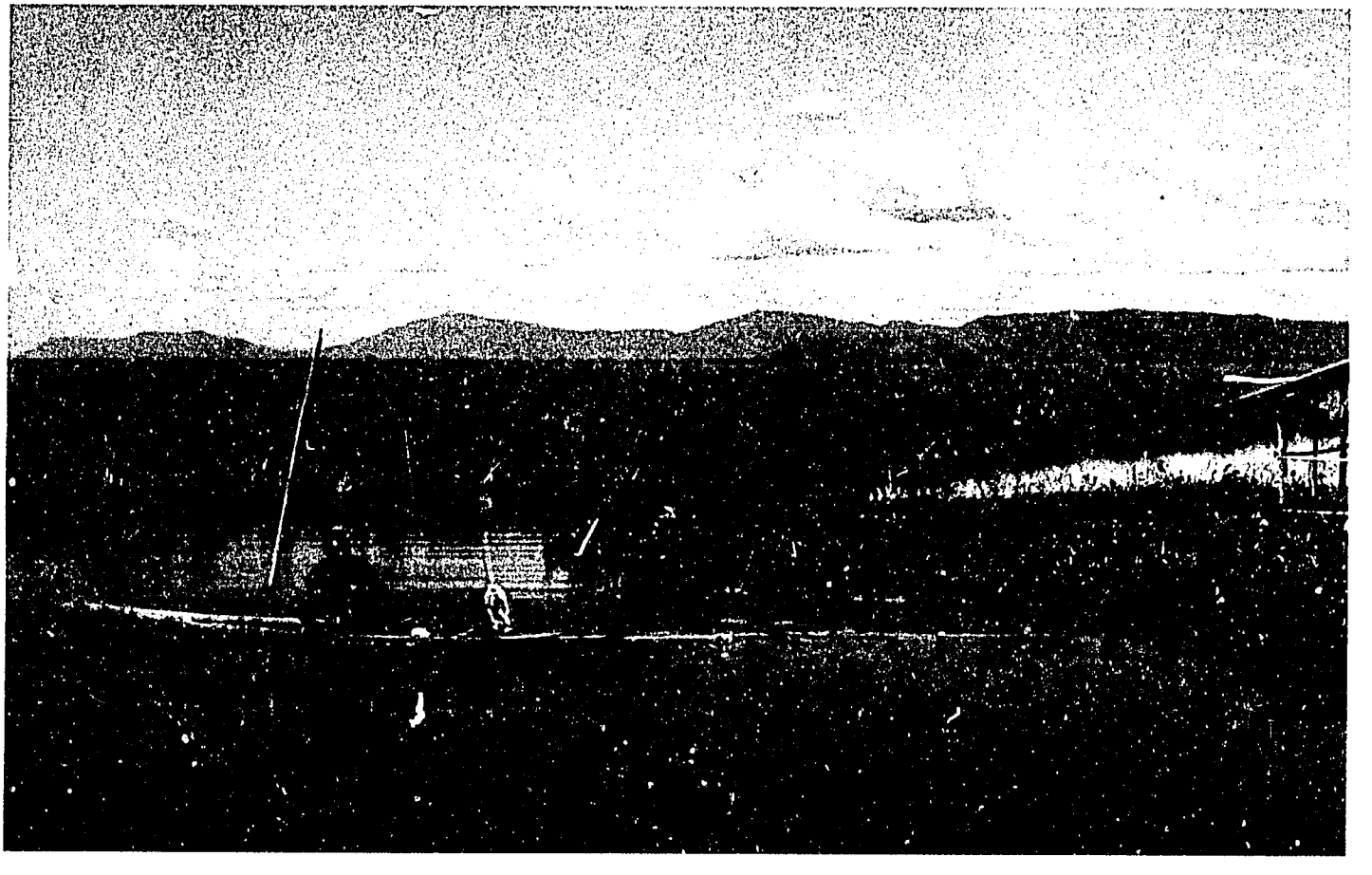
Productivity and land use efficiency of deepwater areas
- Improved germplasm
- Improved soil and crop management

Improved germplasm and management for tidal wetlands rice

Deepwater rice is subjected to a variety of constraints because of the way it grows: the crop is planted in rainfed lowland fields where flooding of more than 50 cm later in the cropping season can persist for a month or longer. Floating rices are grown in areas where flood levels can exceed 100 cm.

Some areas may be subjected to severe drought early in the season, followed by different patterns of deep flooding. Traditional deepwater rice cultivars have a long history of adaptation; each variety fits a limited set of environmental niches. Their stability within those niches gives deepwater rice farmers a degree of sustainability.

Some 7 million hectares of deepwater rice are harvested annually, mainly in northeastern India, Bangladesh, Myanmar, Thailand,



Cambodia and Vietnam. Inputs are low and yields average only 1.5 to 2 tons per hectare.

While improved breeding materials have been developed, few improved varieties have been released to farmers. Breeding is slowed by

- Long growing period. Plants require 6-8 months to mature, including at least 2-3 months before flooding.
- Photoperiod sensitivity. Growth period is affected by daylength, which ensures flowering in relation to the retreat of flooding.
- Seasonal fluctuations. Drought or flood can vary considerably from year-to-year.
- Different flooding regimes in different locations require different physiological responses. Elongation ability affects the rice plant's adaptability to depth and duration of flooding.

Despite the limitations, a number of improved deepwater rice lines are under development, with different growth durations and different elongation abilities and with resistance to important pests and diseases. Breeding lines and varieties have been exchanged by national programs and new varieties have been released in India, Cambodia, Myanmar and Indonesia.

Research on nutrient balances and factors that affect yields is providing much better understanding of the potential of the deepwater rice crop. Other field crops, herbage for animal production and rice-fish activities have been incorporated into more productive farming systems for many regions.

In the tidal wetlands ecosystem, rice is grown near seacoasts and in inland estuaries that are directly or indirectly influenced by tides. Some freshwater tidal wetlands occur near inland estuaries some distance from the sea. About 4 million hectares are currently cultivated.

Salinity is the main problem near seacoasts and at the mouths of estuaries. Vast areas in Indonesia and Vietnam and in West Africa and small areas in Bangladesh, India and Thailand have acid sulfate soils, sometimes associated with high organic matter (peaty soils). The basic need is improved varieties tolerant of tidal submergence and problem soils.

IRRI does prebreeding research and investigates the soil characteristics and processes that cause mineral toxicities and deficiencies. This sets the stage for the national programs to develop suitable varieties and management technology. ■

HIGHLIGHT

Salinity tolerance involves a complex of traits

A major need in tidal wetlands rice is tolerance of salinity. Extensive screening of germplasm at IRRI and elsewhere has not identified a suitable variety to act as a donor.

Nona Bokra, Pokkali and other traditional cultivars have high salinity tolerance, but they also have many undesirable agronomic characteristics. The progeny of crosses of these land races with improved rices have less tolerance for salinity than their traditional parent, probably because of limited selection pressure when segregating materials are evaluated in the field.

Tidal wetland rice breeders at IRRI resorted to a more costly method to identify high salinity tolerance in the progeny of such crosses. Segregating generations of a cross of salt-sensitive IR28 and salt-tolerant Nona Bokra were grown in the phytotron with controlled nutrients, salinity, humidity and temperature. That enabled identification of advanced lines with improved plant type and higher tolerance. Those lines are now available to breeders.

Better understanding of the physiological basis of salinity tolerance is needed to expand this work. IRRI and the University of Sussex, UK, carried out a series of physiological studies and found that salinity tolerance is a complex character that involves a number of traits.

Each trait may be inherited independently. Even the traditional cultivars most tolerant of salinity—Nona Bokra and Pokkali—score high on only two of four important characters.

This opens a way to increase salinity tolerance by pyramiding traits—recombining varieties which already have agronomic acceptability. Potential donors are being screened for the particular traits needed. ■

Cross-ecosystems research

Cross-ecosystems research projects

Genome characterization and manipulation
- Evaluation of conserved germplasm
- Genome manipulation

Crop ecology and pest science
- Systems analysis and modeling of rice production systems
- Pest science and management

Environmental characterization, impact analysis and research prioritization

Work in IRRI's cross-ecosystems program is designed to significantly improve rice science and technology through research at major levels of integration.

- The genome
- The ecosystem (including pests and beneficial organisms)
- The environment

The research agenda is flexible, to be responsive to new problems and new opportunities. Its strategic focus serves as a bridge from basic research carried out at advanced institutions elsewhere to other IRRI programs and national rice research systems. Much of the search for new knowledge and techniques has a longer time frame than does the work done in ecosystem-specific programs.

One example is work to characterize traditional varieties and wild rice species. This will accelerate plant breeding to attain the tailored improved germplasm needed in the

different ecosystems. Classification of the germplasm conserved by the International Rice Germplasm Center—the storehouse of broad genetic diversity—was improved this year by incorporating isozyme profiles into the IRGC database. Plant breeders access that database to select germplasm for carrying out their breeding strategies.

Manipulation of the rice genome is becoming more precise, using new techniques that will speed the development of improved rice types for all ecosystems. In 1991, we captured resistance to yellow stemborer and tungro found in the germplasm of wild species through wide hybridization and embryo rescue.

Marker-assisted selection of germplasm moved forward with the tagging of recessive gene xa-5 for resistance to bacterial blight. New molecular marker technology using Randomly Amplified Polymorphic DNA (RAPD) allows more rapid gene tagging that Random Fragment Length Polymorphism (RFLP).

Optimizing use of nutrients and water is a key issue in most rice-producing systems. Special attention is being given to the processes that determine water and nutrient availability in the soil, their uptake by the rice plant and their utilization by the crop. Further update of computer models of root gas transport and rhizosphere chemistry showed that rice rhizosphere conditions greatly influence nitrogen transport to absorbing root surfaces.

Pests of all types threaten the stability of rice production everywhere. Research on the etiology, biology and population dynamics of pests and predators, and on pest-rice interactions provide the basis for development of technologies that can be used in Integrated Pest Management (IPM) strategies. IPM is an economically efficient, environmentally sound approach to pest control.

Computer models of the population dynamics of brown planthopper and blast were validated in 1991. This extend their usefulness for delineating zones of high risk to pests and simulations of the effects of different pest outbreaks on the rice crop.

Studies of the long-term socio-economic and environmental impacts of new rice technology enable placing a social value on research. New methodologies for assessing impact are being developed. The focus in 1991 was on analyzing the possible impacts of proposed technology, as a basis for research planning. Modeling of country and global rice supply–demand–trade will enable assessing the impact of technology, making medium- and long-term projections and analyzing policy options. ■

Resistances to rice pests found in the germplasm of related wild species is captured for cultivated rice through wide hybridization and embryo rescue.

HIGHLIGHT

Rice tungro bacilliform virus found in xylem cells

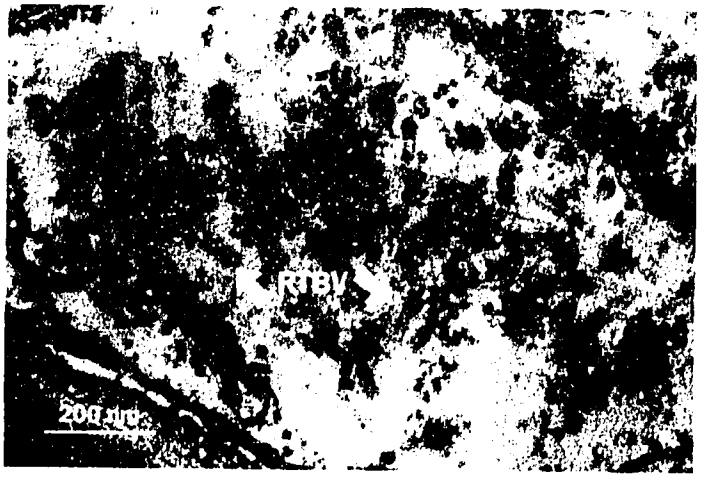
The viruses that cause tungro disease—rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV)—were believed to be limited to phloem tissues in rice plants. This year, RTBV was found in xylem tissues of tungro-infected rice.

This may explain why cultivars resistant to the tungro vector green leafhopper still get the disease. While the green leafhopper will feed on both phloem and xylem tissues, on hopper-resistant cultivars it feeds mainly on xylem tissues. Even when the green leafhopper carries both viruses, inoculated plants are infected only with RTBV.

This leads to the hypothesis that RTSV cannot multiply in the xylem tissues. The cultivars identified as resistant to RTSV infection may not have true resistance, but are artifact of screening tests where the green leafhoppers fed only on xylem tissues.

IRRI's screening method is being modified to speed the search for resistance to the viruses that cause tungro in rice. ■

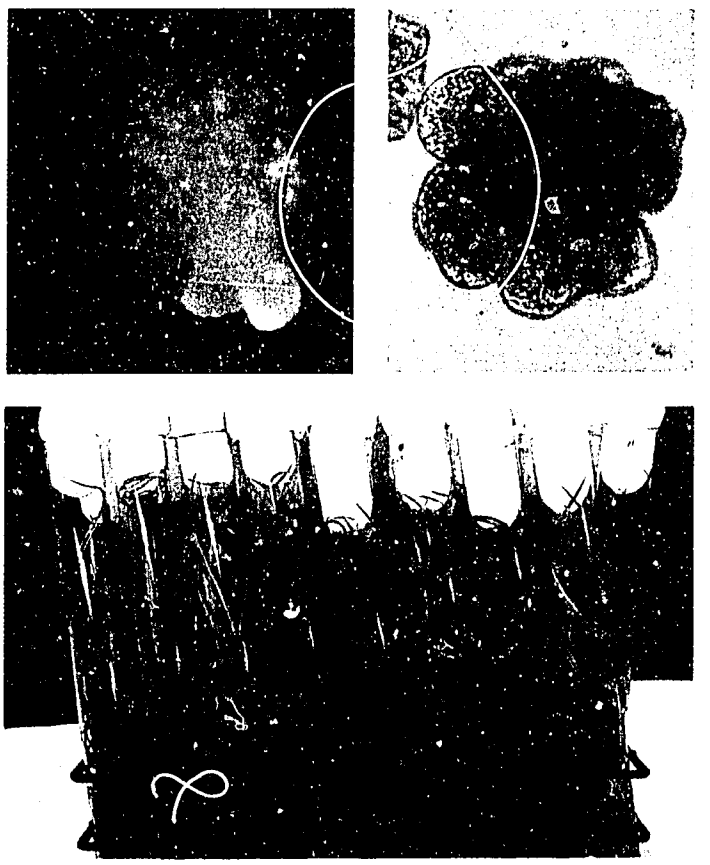
Rice tungro-causing viruses were believed limited to the phloem tissues in rice plants. Now, the bacilliform virus has been found in xylem cells, opening another window to seek control of the disease.



HIGHLIGHT

Indica and japonica rice plants generated from protoplast culture

Plant regeneration from protoplasts is a key factor in developing transgenic rices with useful genetic properties. Plants have been regenerated from protoplasts of both indica and japonica rices and the focus now is on introducing foreign DNA into protoplasts. Expression of the marker gene GUS was achieved this year in callus derived from protoplasts of indicas IR43 and IR58 and japonicas Zhonghua 6 and Line 02428. ■



The regeneration of rice plants from protoplasts now makes it possible to introduce foreign DNA into rice.

HIGHLIGHT

Using GIS in pest surveillance

The potential of geographical information systems (GIS) to extend analyses of pest outbreaks was explored in collaboration with the Rural Development Administration of Korea. Ten years of pest surveillance data from 152 stations were used to map spatial distributions of rice pests.

Brown planthopper outbreaks relate directly to early immigration and prevailing temperatures. Simulated pest distribution during the damaging month of September compared well with actual pest densities, except in the southeastern valley area. Overlaying the simulated map with elevation and rice area maps should identify brown planthopper risk zones.

Striped stem borer densities started to expand in some areas in the early 1980s and peaked in 1988. This corresponded with changes in hectarage planted to japonica and to japonica-indica cultivars. Japonica varieties have a longer duration. Delay in harvest allowed borers more time to mature, enabling them to hibernate over winter.

Now GIS will be used to identify ecological variables favorable for stem borer development, particularly in the middle west epicenter of the pest's distribution. ■

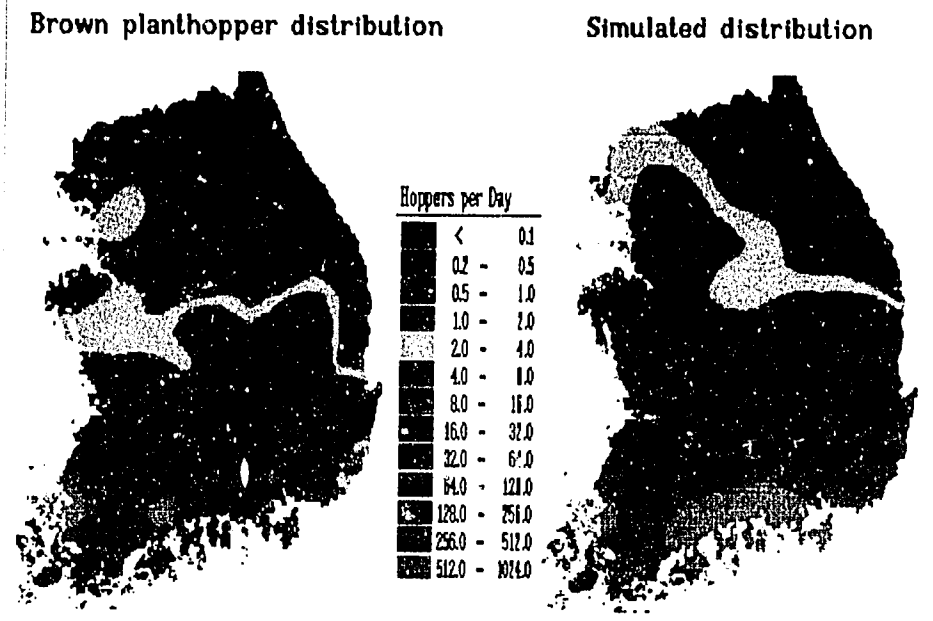
HIGHLIGHT

Combining simulation and GIS

Crop simulation models make it possible to analyze the behavior of complex agricultural systems in relation to the environment. Combining models with Geographic Information Systems (GIS) enables interpreting extensive data sets from different disciplines and from different locations to identify important constraints to rice production.

The models can be used to predict potential yield under different weather conditions, to conduct risk analysis using long-term weather data and to optimize crop management strategies. A stepwise approach was used to analyze yield losses due to drought in a rainfed rice environment in the Philippines.

Soil and climate and associated data stored in a GIS were used to generate maps of unique combinations of soil, climate and administrative units. The suitability of each



Geographic information systems models can be used to predict potential rice production problems under different weather conditions.

combination for rice cultivation was assessed, using expert knowledge. Quantitative techniques were used to evaluate production constraints. Rice yield without irrigation was predicted as a function of soil characteristics and weather (assuming optimal nutrition and no pests).

In Tarlac Province, the model predicted a yield gap between rainfed and irrigated rice of 2.5-5 tons per hectare. Assuming a fixed growndwater table 1 meter deep, potential yield was about 7 tons per hectare.

The next step is to validate the models and determine the variables needed for accurate predictions.

Use of modeling is expanding in national programs collaborating in the Systems Analysis and Simulation for Rice Production (SARP) project. The methodology has high potential to identify production options and to evaluate the impact of new technology in different agroclimatic zones. ■

HIGHLIGHT

Responses to infection by rice tungro viruses

Two rices from Africa, cultivated *Oryza glaberrima* and closely related wild rice *O. barthii*, are very susceptible to tungro. They could be new indicators for tungro infection. ■

HIGHLIGHT

New races of bacterial blight pathogen found

A set of repetitive probes helped type the DNA of *Xanthomonas oryzae* pv. *orzyae*, the cause of bacterial blight disease in rice. Races 1 and 5 each were found to consist of more than one distinct lineages.

X. oryzae pv. *oryzae* strains representing the different lineages were tested on cultivars that contain 10 known resistance genes for bacterial blight. Significant differences in lesion length for two lineages within each pathogen race were detected on several cultivars. This means the lineages are really different races.

Strains of the new races and other pathogen lineages will be used in screening for new sources of resistance to bacterial blight. ■

HIGHLIGHT

Tagging disease-resistance genes

Tagging resistance genes with molecular markers facilitates developing improved breeding lines with more diverse and complex resistance. We identified molecular markers linked to two genes for resistance to bacterial blight: recessive gene *xa-5* was tagged with three RFLP markers and *Xa-10* was linked to two RFLP markers and two RAPD markers. The work was done in collaboration with Cornell University, USA, and Kyushu University, Japan. ■

HIGHLIGHT

Classifying conserved germplasm

Oryza sativa has two major ecogeographical races: indica and japonica. Classification of the germplasm conserved in the International Rice Germplasm Center (IRGC) by race will greatly assist rice breeders in selecting the best germplasm for their breeding program.

A broad range of information on the more than 70,000 accessions in the collection is already available in the database. That information will be used to develop sets of germplasm for evaluation under different agroecological conditions. Accessions for each set will be selected to represent broad genetic diversity and promise in a particular rice ecosystem. ■

HIGHLIGHT

Research on research prioritizing

An international collaborative research project on research prioritization has been established with national programs in Bangladesh, China, India, Indonesia, Nepal, the Philippines, Thailand and IRRI.

The objective is to shorten the time between emergence of new ideas or techniques and their application in IRRI programs and by the national programs. ■

HIGHLIGHT

International Rice Genealogy Database aids breeding

The International Rice Genealogy Database contains records of the genetic ancestry of rice varieties and of the crosses made to develop them. The data set now includes genealogies of more than 2,000 post-IR8 modern varieties released in 68 countries, mostly in Asia, Africa and Latin America, and about 1,600 traditional varieties that farmers still grow or that rice breeders use in their crossing programs. With these data, the ancestry of most cultivars can be traced back to the original land races.

The genealogy database is being expanded and integrated with other existing germplasm databases—the IRRI history of crosses, the IRGC database, and the INGER database. Almost 100,000 crossing records from national programs are in a compatible format.

To expand the genealogy records, rice scientists everywhere are asked to provide duplicate lists of their hybridization work, information on the genealogies of older varieties in their regions and announcements of the release of new varieties. ■

International programs

IRRI's International Programs strive to

- Enhance national agricultural research system–IRRI and national program–national program collaborations and sharing of responsibilities.
- Improve IRRI collaboration with other international agricultural research centers and with non-governmental organizations.
- Strengthen linkages between research and international programs.

IRRI's two large programmatic areas are in fact a continuum of activities. Research and international programs are administrated separately to facilitate achieving the Institute's two major objectives: conducting research and strengthening national agricultural research systems

Both programmatic areas seek to address technical and socioeconomic concerns of rice production. This means their efforts must dovetail. That is made possible through

- Collegial relationships at all levels.
- Special interest working groups, such as those on Germplasm Evaluation and Utilization and Integrated Pest Management.
- Interactions among research and international program leaders and division center heads through the Institute Program Committee.
- Involvement of international program staff in research activities, and of research program staff in international program activities.
- Continual exchange of information.

Efforts to improve the collaboration of national programs and IRRI include

- Support of the establishment of Rice Research Consortia and of special projects, such as the Rice–Wheat Collaboration.
- Development of mechanisms for collaborative training by national programs and IRRI, including decentralizing training from IRRI headquarters to collaborating key universities and research institutions in several Asian countries.
- Reorganization of the rice research networks coordinated at IRRI, to incorporate an ecosystem orientation and to increase national program leadership.

Collaboration in IRRI's host country has been strengthened through

- A University of the Philippines at Los Baños (UPLB)–IRRI cooperative council, with two standing committees, on research and training and on administrative affairs.
- Annual planning of collaborative work in areas of mutual interest by UPLB, the Philippine Rice Research Institute (PhilRice) and IRRI scientists.
- Collaboration with the Department of Agriculture in evaluating technology for national applications.
- Collaboration with the Department of Science and Technology on biosafety.

IRRI is intensifying its efforts to increase collaboration among national programs, beyond the networks and consortia. Through country programs supported by bilateral funding, interactions between countries with similar rice ecosystems and similar rice production problems are enhanced. Efforts include

- Fostering the development of linkages among Thailand, Laos, Cambodia and Vietnam for collaborative research and training, particularly in the rainfed lowland and deepwater rice ecosystems.
- Training scientists from Bangladesh and Nepal in India, to take advantage of that country's strengths.
- A tripartite agreement of Egypt–Korea–IRRI for research emphasizing japonica rice and rice blast disease issues.

Improved IRRI collaboration with sister international centers is being pursued. An IRRI–IITA–WARDA agreement signed in 1991 clarified the division of responsibilities for rice research in Africa. IITA will maintain its work to conserve African rice germplasm and will continue prebreeding activities; WARDA will be responsible for rice breeding and crop and resource management research in West Africa; IRRI will respond to requests for assistance from national programs in the eastern, central and southern African region (ECSA).

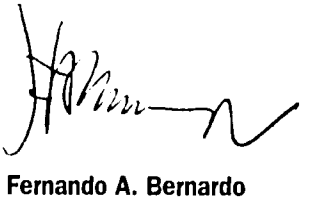
The first IRRI–CIAT–WARDA collaborative workplan meeting on upland rice was held in January 1991. IRRI agreed to focus its collaborative efforts on drought tolerance and rice blast disease and on the exchange of information.

IRRI also collaborates with CIAT, ICRISAT, AVRDC and CIMMYT in research on rice-based cropping systems and anticipates intensified collaboration with ICLARM on rice-fish farming systems research, under the umbrella of the Asian Rice Farming Systems Network (ARFSN).

IRRI seeks out non-governmental organizations to assist in the dissemination of rice-related information and improved technologies at the middle and grassroots levels, particularly of IRRI-designed engineering tools and equipment. Collaboration with non-governmental organizations is bolstered through network and country project activities.

The arena for strengthening the rice research capabilities of national systems is vast. IRRI undertakes the task on the basis of the strengths of its research programs and involvement with national programs and voluntary organizations that address rice research needs and technology and information exchange.

All those who collaborate do so in pursuit of increased rice production and enhanced socioeconomic conditions for rice producers and consumers, especially the economically disadvantaged, and of improved sustainability of rice production systems.



Fernando A. Bernardo
Deputy director general
for international programs

Germplasm conservation and dissemination

Germplasm conservation, evaluation and dissemination

Conservation of rice genetic resources

International Network for Genetic Evaluation of Rice (INGER)

A wide range of initiatives are being pursued to accelerate rice germplasm conservation and dissemination. Collecting activities, particularly for wild rices, continues in collaboration with other institutions. Three important regions of genetic diversity were explored in 1991: India, Papua New Guinea and Myanmar.

Finding, preserving and sharing rice germplasm resources with rice scientists in national programs are complemented by tight safeguarding of the collection in the International Rice Germplasm Center and by dispatching duplicates to other safe centers. IRGC's management and services are being improved to accelerate germplasm conservation and dissemination.

Collecting and preserving rice germplasm—particularly of wild rices, is important.

Renovation of genebank facilities began this year. Technical standards for seed conservation are being enhanced and the area for cleaning and processing the seed of new accessions into the Base Collection is expanding. Procedures for drying and packaging seeds for long-term conservation have been improved, and that is facilitating handling and inventory control.

A Germplasm Evaluation and Utilization Working Group has been organized to strengthen linkages with IRRI research programs. Coordination and integration of IRGC and the International Network for Genetic Evaluation of Rice (INGER) in the Genetic Resources Center has begun.

INGER is a mechanism for global collaboration of rice breeders. It involves scientists of national rice research systems, IRRI, and other international centers working to improve rice.

Through worldwide exchange, evaluation and utilization of elite germplasm, the genetic base of essential breeding materials broadens rapidly. Donor lines with tolerances for stresses are shared more widely, improving production stability in stress-prone environments.

A recent study of the impact of INGER on varietal improvement worldwide showed that, since 1975

- Nearly 2,000 lines have been used in national and international breeding programs to transfer useful traits to popular local varieties.
- 210 INGER entries originating from 27 national programs and from IRRI, CIAT and IITA have been released as varieties in 55 countries in Asia, Africa and Latin America.
- Yield increases obtained by planting these improved varieties have been significant. ■

HIGHLIGHT

Rarest relative of rice rediscovered

The world's rarest wild rice—*Oryza schlechteri*—had not been seen for 80 years. A two-day hike into the mountain jungles of Papua New Guinea enabled locating the illusive species and collecting seed and tiller samples. Plants are now growing at the Erap research station of the Papua New Guinea Department of Primary Industry and at IRRI.

Does this rare plant contain genes which could be useful in improving rice production? *O. schlechteri* evolved in isolation from *O. sativa* and survived for millenia undisturbed by humans. This leads to the expectation that the species has a wide range of inherent mechanisms that enable it to respond to a changing environment.

Scientists in a number of disciplines will be involved in unlocking its mysteries and tapping those useful for modern rice breeding. Its conservation also will make its genes available to future rice improvement work. ■

HIGHLIGHT

A new INGER nursery

Cultivation of a dry season boro rice crop has been increasing in areas where low-yielding deepwater rice had been grown. Major constraints are low temperature at the seedling and early vegetative stages. Availability of suitable varieties was limited. A preliminary exchange and evaluation of materials identified varieties suitable for the boro crop in Bangladesh and eastern India. ■

HIGHLIGHT

Improved conservation of rice germplasm

Procedures for conserving the valuable germplasm held in trust at IRRI are continuously upgraded. This year, IRGC

- Tested the viability of stored germplasm. Regular monitoring is now routine.
- Repacked germplasm and rationalized seed distribution procedures.
- Improved the *in vitro* culture of rare germplasm and of germplasm with low seed stocks.
- Performed isozyme and cytological characterization on special sets of germplasm. The procedure is now routine.

The renovation of IRGC facilities underway now will ensure that the rice germplasm at IRRI will be conserved under the best possible conditions for at least 100 years. ■

HIGHLIGHT

Expanding the available rice genepool

With gene transfer across species being facilitated by continuing advances in biotechnology, genes from distantly-related species are becoming important resources for rice breeders. Many plant genera related to *Oryza* may be of use in rice improvement—some are tolerant of salt water, some produce unisexual flowers, others have traits of unforeseen importance.

This broadens the responsibility of the IRGC, to conserve these species and make them available to breeders. Among the genetic resources now conserved are plants of *Zizaniopsis*, *Chikusichloa* and *Hygroryza* genera. ■

Information and knowledge exchange

Information and knowledge exchange

- Library services
- Publication of research results
- Copublication of IRRI material
- Rice database and database information services
- Conferences and workshops
- Public awareness

The information and knowledge exchange program involves activities in five areas: library services, scientific communication, rice databases, conferences and workshops, and public awareness. Together, they fulfill the Institute's responsibility for providing current information to rice scientists and research policymakers, to supporters of research and IRRI, and to all those interested in rice research and IRRI's work everywhere in the world.

This year, improvements were made across the full gamut of activities.

IRRI-published field guides help rice researchers, extension workers and farmers diagnose production problems.

Library and documentation
A systems analysis of library operations is the first step toward full computerization of library procedures. That will speed response to user requests. The Rice Literature Search System now has 180,000 entries representing original documents in the IRRI Library collection.

Scientific communication
A new Publications and Communication Committee is helping set priorities for publishing. IRRI released 17 books in English in 1991.

Rice databases
A task force representing programs and divisions/centers developed a work plan for establishing corporate databases. These will be on-line and accessible electronically.

IRRI researchers are now connected with the global INTERnet network, enabling them to communicate with colleagues in advanced institutions and an increasing number of other organizations around the world. This is part of CGNET II, a network that will link national systems and CGIAR institutions with each other and with the global scientific community.

Conferences and workshops
IRRI was host to or the cosponsor of 32 conferences, workshops and meetings in 1991. For the researchers who attend, these meetings are important opportunities for scientific information exchange and for planning future collaborative projects.

Public awareness
Explanations of IRRI's purpose and achievements are disseminated worldwide through special publications and press releases. A new publication is *IRRI hotline*, a compilation of achievement summaries circulated to decisionmakers in the donor community.

An all-new "Rices of IRRI" multiprojector slide program is being shown to the some 30,000 visitors who come to the Institute each year. A basic set of slides describing IRRI activities is available to the media, with a set also maintained at the CGIAR secretariat in Washington, DC, USA.

Within the Philippines, the Department of Agriculture adopted "Farmers and Fishermen, You Are Our Heroes," composed by an IRRI liaison communicator, as its official song.

Nearly 150 journalists—newspaper, magazine, radio and television reporters and writers—visited IRRI, including 18 from international media. They interviewed scientists and administrators and produced their own stories. ■

Crop and resource management networks

Crop resource management networks

International Network on Soil Fertility and Sustainable Rice Farming (INSURF)
Asian Rice Farming Systems Network (ARFSN)
Integrated Pest Management Network (IPMN)

Crop and resource management networks coordinated at IRRI include the Asian Rice Farming Systems Network (ARFSN), the International Network for Soil Fertility and Sustainable Rice Farming (INSURF) and the new Integrated Pest Management Network (IPMN). All involve aspects of rice production.

ARFSN, supported by the International Development Research Centre (IDRC), monitors farming systems trials in 15 irrigated, 14 rainfed lowland, 8 upland and 8 deepwater rice ecosystem sites. Activities in each site are focused on identifying more productive rice-based farming systems for small-scale farmers.

INSURF, supported by the Swiss Development Cooperation (SDC), involves subnetworks for irrigated, rainfed lowland and upland ecosystems. The emphasis is on longterm fertility trials, to study the sustainability of soil productivity.

IPMN, also supported by SDC, involves scientists in China, Indonesia, Malaysia, the Philippines and Thailand.

A Crop and Resource Management Networks Advisory Committee has been organized to promote coordination and increase interactions among the networks and between the networks and rice research consortia and country programs. ■

Crop and resource management networks evaluate new rice technologies in different environments, to identify more productive rice-based systems.

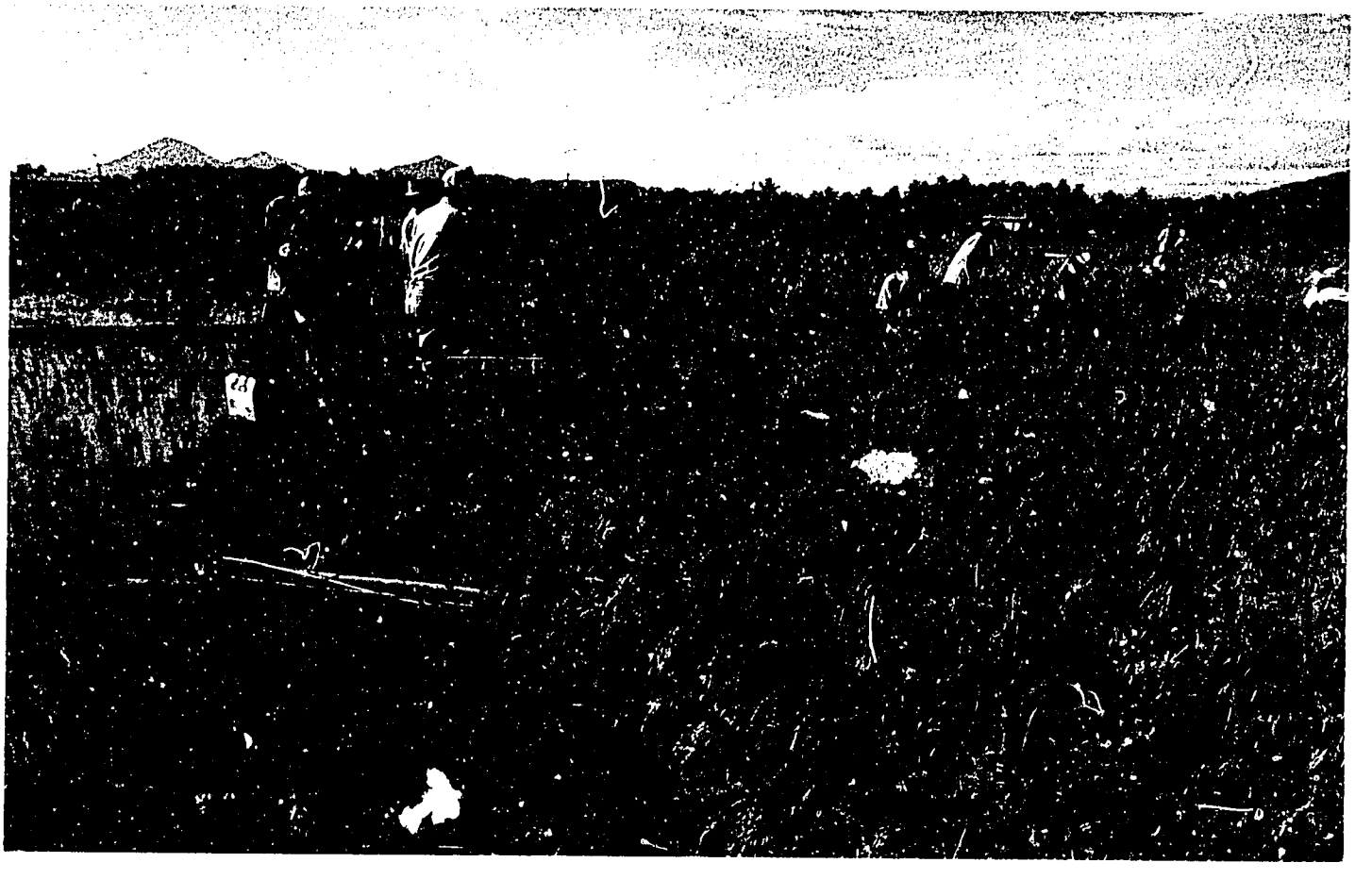
Training

Training

Degree and postdegree training
Group training
- Management
- Courseware development
- Course transfer and collaborative training

Since IRRI's training program started 30 years ago, nearly 7,000 scientists have been involved in short courses, degree programs, short term internships and post doctoral fellowships. Most of these alumni are now major collaborators with IRRI scientists in rice-related research in their home countries. Many are in important positions of research management and administration.

The training program itself has evolved since 1962, from relatively basic courses in rice production and research methodologies to courses and fellowships that teach new, highly sophisticated techniques. The objective remains the same: to increase the capabilities of researchers in national programs so that they may solve domestic rice production and utilization problems.



In 1991, more than 170 scholars and trainees from 28 countries in Asia, Africa, the Americas, and Europe were involved in IRRI programs. An additional 286 from 27 countries participated in 19 short courses at IRRI headquarters. And 63 fellows from 19 countries collaborated in post-doctoral research.

Some collaborative training is now conducted by national programs, in-country. IRRI's role varies: in some cases, to train trainers and make available training materials; in others, IRRI trainers participate directly. All in-country training involves IRRI alumni. ■

HIGHLIGHT

Human resource development in Cambodia

Cambodia—devastated by internal turmoil—has no PhD-trained scientists and only a few scientists hold master's degrees. The Ministry of Agriculture needed to rapidly increase the number of trained personnel in all areas of rice research, to meet the overwhelming need to increase rice production.

IRRI is helping. Since 1987, 67 Cambodians have participated in short courses at IRRI; 25 of them in 1991. But space in those courses is limited, and Cambodia needs trained people today.

In early 1991, IRRI Training Center staff worked with Cambodian research managers to design a medium- to long-term plan for developing human resources in rice production and utilization.

Implementation involved first training Cambodian scientists at IRRI, in technical and training methodologies. Then IRRI staff assisted a Cambodian team in conducting two rice production courses in Cambodia, in the Khmer language. IRRI training materials (manuals, slide modules, skills booklets) were translated to support the instruction.

That national team will continue to offer rice production and adaptive research training.

In addition, a special English language instructional program developed by the Training Center is enabling more Cambodian scientists to qualify for advanced training at IRRI headquarters. One MS degree candidate has completed his coursework and is collecting data for his research thesis in Cambodia. Another Cambodian scholar will begin a PhD program at a Philippine university in 1992. ■

IRRI is helping train Cambodian agricultural research workers at the same time as IRRI and national scientists collaborate in ongoing experiments.

National and regional collaboration

Activities in national and regional collaboration focus on collaborative research and training as important ways to strengthen national rice research systems. IRRI scientists participate in national workshops and conferences and in documenting and disseminating findings from the research they conduct with national scientists to relevant in-country groups, including extension and non-governmental organizations. ■

Work by IRRI in-country is important in strengthening national rice research systems and in expanding the stretch of rice research across different envrionments.

Bangladesh

Bangladeshi scientists presented 14 of 22 lectures in a Gender Analysis Workshop and Training meeting co-sponsored by the Bangladesh Rice Research Institute (BRRI)–IRRI collaborative project. Participants came from Bangladesh, Bhutan, India and Nepal. ■

Bhutan

Bhutan–IRRI collaborative research involves farmers, to help develop improved rice varieties, better crop management technology and more productive farming systems. In 1991, No. 11 was identified as the best rice cultivar for mid-altitude double cropping and IR64 and E18-84-W4 and ADT36 from India were identified as best at lower elevations. For 15 May-15 June plantings, IR64, Milyang 54 from Korea and local variety Zakha yield the highest. ■

Brunei Darussalam

Brunei's Kilanas Agricultural Research Center is testing improved breeding lines and developing improved agronomic practices. In 1991, IR841 was released as an official variety because of its high quality grain. Yields are high, but IR841 is somewhat sensitive to the iron toxicity that is an important constraint in Brunei's rice-growing areas. ■

Cambodia

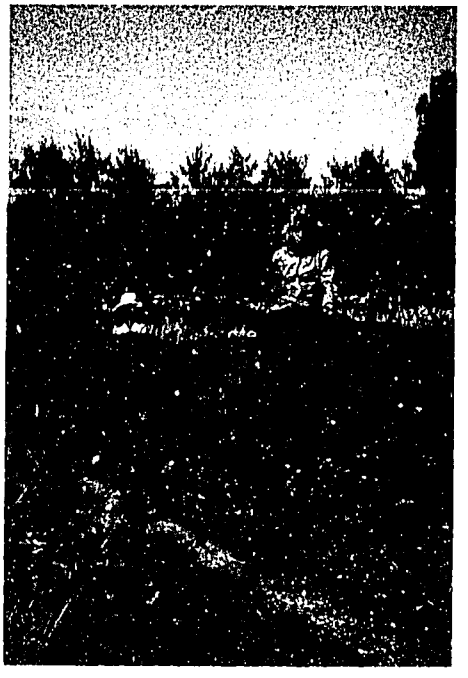
Significant progress has been made in the Cambodia–IRRI collaborative project. Research on rice varietal improvement focuses on breeding for drought and pest resistance. Nine of more than 1,250 traditional varieties have been found to be excellent donors for drought tolerance. Three IR advanced lines were found resistant to brown planthopper. More than 500 trials on soil fertility are underway in 15 provinces. ■

China

A significant area of China-IRRI research collaboration is development of hybrid rice. Most of the male parents used in producing F_1 hybrids in China are modern varieties developed at IRRI. Now the collaboration is working to produce a 2-line hybrid. ■

Egypt

Two major research efforts are underway: developing short duration varieties with improved resistance to blast and stemborer and developing varieties with tolerance for salinity. Improved grain quality, particularly high quality, slender grain, is important in both projects. A Egypt–Korea collaborative project to develop improved resistance to blast using japonica rices has been initiated. ■



India

The International Council for Agricultural Research (ICAR) and IRRI collaborate across a range of rice research efforts. India is strongly involved in the Rainfed Lowland Rice Research Consortium and in the Rice–Wheat project with CIMMYT and IRRI. Additional efforts involve strategic and applied research, including Systems Analysis and Simulation for Rice Improvement (SARP) and rice germplasm conservation and utilization. India also is moving into regional training: in 1991, two Nepalese scientists were trained in Pantnagar as part of the rice–wheat project. ■

Indonesia

Indonesia is a major participant in the rainfed lowland and upland rice research consortia organized in 1991. Other collaboration with IRRI involves varietal improvement, work on biological nitrogen fixation and development of green manures. ■

Lao PDR

The Lao–IRRI collaboration focuses on development of low-cost rice farming technologies for rainfed lowland and upland systems, complemented by development of human resources in rice research. A network of research sites for on-farm and on-station trials has been established in six provinces, in cooperation with the provincial agricultural services. Training was conducted in country, at IRRI and in Thailand. ■

Madagascar

The third phase of Madagascar–IRRI collaboration began in 1991. An important focus is institutionalizing multidisciplinary teamwork and interdepartmental collaboration in research and training with the National Center for Applied Research on Rural Development, Madagascar (FOFIFA) and national universities. Additional on-farm research activities are being developed. ■

Malaysia

The Malaysian Agricultural Research and Development Institute and IRRI collaboration primarily involves exchanging materials and information, through the networks coordinated at IRRI. Promising IRRI breeding lines have been sent to research centers of the Departments of Agriculture in Sarawak and Sabah, East Malaysia. One IRRI line, IR8192, was released as Lumayan in Sabah. ■

Myanmar

Significant outputs of the Myanmar–IRRI farming systems project are the introduction of sesbania as a green manure for rice and rapid expansion of rice-upland crops and rice-fish farming systems; those now cover hundred thousands of hectares in several provinces. ■

Philippines

A number of agencies are involved in the Philippine–IRRI collaboration: the Philippine Rice Research Institute (PhilRice), the Regional Integrated Agricultural Research System of the Philippine Department of Agriculture, the University of the Philip-

National and regional projects enable IRRI scientists for work with national scientists in nearly all rice-growing envrionments of the world.

pines at Los Baños and other regional universities, the Bureau of Plant Industry and the National Irrigation Administration. The Philippine National Seed Board approved the release of PSB Rc 2 (IR32809-26-3-3) as Nahalin and PSB Rc 4 (IR41985-111-3-2-2) as Molawin as new varieties for commercial production. ■

Thailand

Thailand–IRRI collaboration involves three main projects: deepwater rice research in the flooded areas of the central plain, rainfed lowland rice research in the northeast and upland rice research in the north. This year, an IRRI entomologist assisted in designing a strategy for containing a brown planthopper outbreak that devastated 250,000 hectares of rice and involved 80,000 farmers in central Thailand. ■

REGIONAL HIGHLIGHTS

Africa

The largest single activity of IRRI in Africa is the International Network for Germplasm Evaluation of Rice (INGER), in collaboration with IITA, WARDA and national programs. More than 30 African countries have been growing nursery sets. INGER–Africa facilitated the release of 34 African varieties and 49 non-African varieties in Africa and 3 African varieties in Brazil and Cambodia. In 1991, 9 varieties were released to farmers of Guinea Bissau, Mali, Uganda and Nigeria. ■

Latin America and the Caribbean

The Latin America–Caribbean Rice Improvement Network is a part of INGER sponsored by CIAT. Analysis of the database on rice research in Latin America enabled identification of a genetic core that represents 80 percent of the genes of irrigated rice varieties. That permitted estimating the contribution of IR lines and Asian land races to Latin American cultivars. One-third of the varieties in the arid zone and one-fourth of those in the tropics have IR ancestors. A genetic core of 14 land races contributed about 70 percent of the genes for 143 varieties grown in Latin American countries. Most of them came from Asia. ■

Finance and administration

Support to research and international programs moved ahead on several fronts in 1991. Highlights include

- Consolidated research farm operations and farm workshop services; physical plant services; transport and logistics, and warehousing and stores.
- More cost-effective repair and maintenance programs and increased mechanization of research farm operations.
- Increased staff development and training for both nationally and internationally recruited staffs.
- Expanded use of computerized systems in support of financial management.

Unexpected challenges were further decreases in funding and the impact of reduced funding on achieving IRRI's work plan.

An immediate problem was the May fire that destroyed part of Chandler Hall and barely missed damaging the IRRI Library and its irreplaceable collection of rice research literature.

This calamity emphasized the need for rehabilitation of IRRI's infrastructure. In the short run, temporary quarters were needed for administrative staff displaced by the fire. In the long run, the security of the entire Institute needed to be assessed and improved. Reconstruction of the part of Chandler Hall destroyed began immediately.

A late 1991 grant of DM10 million from the Government of Germany accelerated achievement of the capital renovation program. Contracts are being let for renovation of major administrative, research and service buildings. Central research farm fields are being redesigned to allow for greater mechanization.

The Institute is moving into a very full agenda for 1992-1993. Objectives must be achieved with a much smaller staff than before. At the same time, the administrative load on researchers should be reduced so that they may focus more energy and time on achieving the objectives of the Institute's work plan.

IRRI staff needed more sophisticated supervisory and management skills. A series of training programs for staff at all levels began in 1991.

With a staff committed to achieving IRRI's goal and meeting its objectives, the Institute is moving forward in the 1990s in a positive, cost-effective manner.

M.F.L. Goon
Deputy director general
for finance and administration

Finance

Computerization of the Institute's financial management system is progressing. Full computerization will implement the staff receivables and fixed assets systems, consolidate the budgeting process and provide a system for monitoring financial reports to donors. ■

Administration

A number of new activities initiated in 1991 reflect efforts to strive for greater productivity with fewer resources.

Materials management. Providing competitively-priced supplies and equipment of high quality is a major priority. The new materials management unit merges purchasing, shipping and materials control. Review of organization, staff placement and development and design of systems set the stage for skills training and computer education programs. The objective is short turnaround time in procuring quality products at competitive prices. Computer-based information systems will improve efficiency.

Human resource development. A major review of personnel policies for nationally recruited staff set the stage for better communication between Institute management and staff. Input came from representatives of employee associations, management and trustees.

The new *Personnel Manual for Nationally Recruited Staff* explains IRRI policies and expectations.

Emphasis on performance evaluation, management and training is providing staff at all levels with tools to enhance their contribution to meeting Institute objectives and to create opportunities for their own career development. The performance appraisal process was modified in 1991 to more accurately reflect program objectives and to improve its usefulness as a tool for improvement.

More than 400 supervisors participated in seminars designed to strengthen evaluation techniques, create more open dialogue and develop a basis for improved performance. Internationally recruited staff also participated in workshops to enhance their performance appraisal of the staff members they supervise.

Training in performance appraisal was complemented by a series of performance management

courses to develop skills in planning, making decisions and setting objectives.

Half of IRRI's 1,785 national staff participated in at least one of 16 courses offered in 1991.

To improve the Institute's responsiveness to the needs of central research farm labor, their skills, knowledge and interests were surveyed. A computerized database will help in applying that information to improve labor management and in counseling for career development.

Twenty internationally recruited staff took part in management training in 1991, in a course modeled after the CGIAR course.

Visitors and conference services. IRRI continues to attract large groups of visitors: in 1991, almost 32,000 persons from 41 countries.

Some 85 percent of the visitors were students and teachers. Nearly 2,000 farmers and agricultural technicians visited to learn about IRRI's work to improve rice production.

Government officials, ambassadors and cabinet ministers were briefed by IRRI scientists on Institute programs and activities. They also toured laboratories, greenhouses and experimental fields.

A multi-projector slide program that explains the world's need for rice, IRRI's goals and objectives, and the work being done is each visitor's first exposure to the Institute. The tours and briefings that follow are designed to answer the needs of each visitor.

Important briefings take scientist time and can disrupt laboratory work. To make the process more efficient and more interesting for the visitors, the plan for renovating the Institute's infrastructure was adjusted to include an Exhibit Center. The center will be located in the renovated Chandler Hall and will be a focal point for visitor information. ■

Operations

Operations faced perhaps its most demanding year in IRRI history in 1991. The fire in Chandler Hall and its aftermath complicated the major building and renovation program that was already underway.

Rebuilding in Chandler Hall begun less than 3 months after the fire, with plans finalized for conversion of the area now occupied by management to an Exhibit Center. Renovation of the F.F. Hill Laboratory building into a new administration building also began.

Parallel with extensive rehabilitation work, completion of the new biofertilizer building moved forward. Plans were initiated for a research containment facility. Renovation of the Laboratory, Training and Conference Center (LTCC) building and the Service Building also began.

Further mechanization of the Central Research Farm was facilitated by redesigning the experimental plots that permit use of larger equipment. Farm equipment operators were trained. Steps also were taken to reduce natural habitats for rodents, snails and insects that affect field experiments. The Central Research Farm assumed responsibility for all pest control activities in the Institute. Centralization of the farm labor pool was completed.

New automotive and farm vehicles and machinery are increasingly complex; 58 employees participated in 18 automotive training programs.

In the continual collaboration with the University of the Philippines at Los Baños (UPLB), IRRI will develop and operate a joint landfill waste disposal system. It will include recycling and composting components, to reduce impacts on the environment. ■

1991 financial statements

The International Rice Research Institute
(A NON-STOCK, NON-PROFIT ORGANIZATION)

FINANCIAL STATEMENTS
DECEMBER 31, 1991 AND 1990

Report of Independent Accountants

To the Board of Trustees of
The International Rice Research Institute
(A non-stock, non-profit organization)

We have examined the statement of assets, liabilities and fund balances of The International Rice Research Institute (a non-stock, non-profit organization) as at December 31, 1991 and 1990, and the related statements of sources and applications of funds and of changes in financial position for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

As explained more 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, except in the manner of accounting for commitments as actual liabilities.

In 1991, the Institute recognized depreciation expense on property and equipment for the year ended December 31, 1991 and restated the 1990 statement of assets, liabilities and fund balances to reflect the prior years' accumulated depreciation on these assets. Consequently, our present opinion on the 1990 financial statements, as presented herein, is no longer qualified with respect to property and equipment.

In our opinion, except for the effects on the financial statements of recognizing commitments as actual liabilities, as described in the second paragraph, the financial statements referred to above, as restated, present fairly the assets, liabilities and fund balances of The International Rice Research Institute as at December 31, 1991 and 1990 and its sources and applications of funds and the changes in its financial position for the years then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the prior year.

Joaquin Cunanan & Co.
Makati, Metro Manila
February 21, 1992

Statement of Assets, Liabilities, and Fund Balances
December 31, 1991 and 1990

	1991	1990
ASSETS		
CURRENT ASSETS		
Cash and short-term placements (Note 3)	$33,586,509	$27,103,415
Accounts receivable - donors (Note 4)	7,244,122	3,797,893
Receivables from officers and employees	296,850	145,609
Advances to projects and other receivables	1,230,336	1,260,254
Inventory of materials and supplies	1,789,387	1,544,635
Prepaid expenses	214,419	310,122
Total current assets	44,361,623	34,161,928
PROPERTY AND EQUIPMENT, net of accumulated depreciation (Note 5)	20,866,246	21,839,801
	$65,227,869	$56,001,729
LIABILITIES AND FUND BALANCES		
Current Liabilities		
Accounts payable and accrued expenses (Note 6)	$16,352,355	$11,858,549
Loan payable	-	2,200,000
Grants applicable to succeeding periods (Note 7)	13,863,696	6,905,918
Other liabilities (Note 8)	683,534	409,851
Total current liabilities	30,899,585	21,374,318
Accounts Payable and Accrued Expenses (Note 6)	7,764,981	7,215,834
Other Liabilities (Note 8)	1,279,342	1,327,440
Capital Replacement Fund (Notes 2 and 3)	1,833,892	-
Fund Balances		
Invested in property and equipment (Notes 2 and 5)	20,866,246	21,839,801
Core operations (Note 2)	(1,381,614)	-
Working capital	2,718,501	2,718,501
Self-sustaining operations	196,599	428,769
Communication and publications	463,772	416,012
	1,997,258	3,563,282
Cumulative translation adjustments	586,565	681,054
	23,450,069	26,084,137
	$65,227,869	$56,001,729

Statement of Sources and Applications of Funds
December 31, 1991 and 1990

	1991	1990
Sources of Funds		
Core operations:		
Grants	$25,984,979	$26,271,254
Earned income	1,729,086	1,259,813
Foreign-currency transaction adjustments	2,281	9,756
Balance - previous year	-	217
	27,716,346	27,541,040
Capital - transfer from core operations	3,963,277	2,977,887
Working capital:		
Provision from operations	-	516,501
Balance - previous year	2,718,501	2,202,000
	2,718,501	2,718,501
Complementary projects - grants	8,293,172	9,123,392
Self-sustaining operations:		
Revenue	939,125	1,455,162
Balance - previous year	428,769	404,837
	1,367,894	1,859,999
Communication and publications:		
Revenue	262,030	229,458
Balance - previous year	416,012	560,759
	678,042	790,217
Cumulative translation adjustments	(94,489)	681,054
	$44,642,743	$45,692,090
Applications of Funds		
Core operations	$29,097,960	$27,541,040
Capital	3,963,277	2,977,887
Complementary projects	8,293,172	9,123,392
Self-sustaining operations	1,171,295	1,431,230
Communication and publications	214,270	374,205
	42,739,974	41,447,754
Fund Balances		
Core operations	(1,381,614)	-
Working capital	2,718,501	2,718,501
Self-sustaining operations	196,599	428,769
Communication and publications	463,772	416,012
	1,997,258	3,563,282
Cumulative translation adjustments	(94,489)	681,054
	1,902,769	4,244,336
	$44,642,743	$45,692,090

Statement of Changes in Financial Position
December 31, 1991 and 1990

	1991	1990
Sources of Funds		
Excess of revenue over expenses		
Core operations and self-sustaining activities	($ 1,660,513)	$1,076,523
Add (deduct) items not affecting cash during the year:		
Depreciation of property and equipment	1,833,892	-
Translation adjustments	94,489	(681,054)
Gain on disposal of property and equipment	(13,670)	(23,544)
Funds provided by operations	254,198	371,925
Disposals and write-off of property and equipment	4,048,975	808,375
Decrease in:		
Accounts receivable-donors	-	3,646,708
Receivables from officers and employees	-	48,460
Advances to projects and other receivables	29,918	-
Prepaid expenses	95,703	1,842,230
Increase in:		
Short-term accounts payable and accrued expenses	4,493,806	3,300,950
Current portion of other liabilities	273,683	-
Long-term portion of other liabilities	-	210,728
Grants applicable to succeeding periods	6,957,778	-
Long-term accounts payable and accrued expenses	549,147	1,816,380
Capital replacement fund	1,833,892	6,686,899
Cumulative translation adjustments	-	681,054
Total Sources of Funds	18,537,100	19,413,709
Applications of Funds		
Acquisitions/adjustments of property and equipment	4,895,642	7,471,730
Increase in:		
Accounts receivable-donors	3,446,229	-
Receivables from officers and employees	151,241	-
Advances to projects and other receivables	-	113,103
Inventory of materials and supplies	244,752	299,159
Decrease in:		
Grants applicable to succeeding periods	-	1,006,517
Current portion of other liabilities	-	96,563
Long-term portion of other liabilities	48,098	-
Cumulative translation adjustments	94,489	-
Funds invested in property and equipment	973,555	-
Payment of loan payable	2,200,000	-
Total Applications of Funds	12,054,006	8,987,072
Increase in Funds	6,483,094	10,426,637
Cash and Short-term Placements		
January 1	27,103,415	16,676,778
December 31	$33,586,509	$27,103,415

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 non-stock, non-profit 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 priveleges 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.

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 CGIAR-prescribed accounting practices conform with generally accepted accounting principles, except in the manner of accounting for commitments.

The CGIAR adopted depreciation accounting effective January 1, 1991. Consequently, the Institute recognized depreciation expense of $1,833,892 during the year ended December 31, 1991 and restated the fund balance invested in property and equipment at December 31, 1990 to reflect the prior years' accumulated depreciation totalling $20,585,040 on these assets. The adoption of the depreciation policy reduced the balance of funds invested in property and equipment at December 31, 1991 and 1990 by $22,418,932 and $20,585,040, respectively, and increased core operations expenses by $1,833,892 for the year ended December 31, 1991, resulting to a deficit of $1,381,614 in core operations fund balance as at that date.

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

Foreign currency transactions - The financial statements of the Institute are stated in US$. Philippine peso and other foreign currency-denominated transactions are translated to US$ for reporting purposes at standard bookkeeping rates which approximate the exchange rates prevailing at the dates of the transaction. Exchange differences resulting from 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 are pledged on an annual basis and are recognized in the accounts when there is probability of collection in the year the grant is pledged. These 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. Grants are identified with specific periods and are taken up in the financial statements without regard to the date on which these are actually received. Excess of grants received over expenses is shown as "Grants Applicable to Succeeding Periods", a liability account in the Statement of Assets, Liabilities and Fund Balances.

Expenditures and commitments - Liabilities for purchases of goods and services are taken up in the accounts as incurred and/or as obligated without regard to the actual timing of payment. Obligated expenditures, also called commitments, are those which are contracted and/or committed for goods or services to be received or performed at a future date.

As of December 31, 1991 and 1990, goods and services not yet received but treated as expenses and accounts payable amounted to $11,669,660 and $6,019,839, respectively.

Inventory of materials and supplies - Inventory of materials and supplies is stated at cost using the moving average method.

Property and equipment - Property and equipment acquired prior to 1991 are carried at cost or estimated value. Acquisitions during the year are stated at cost and are acquired through a capital grant or grant designated by the Institute or donor for the purpose. Depreciation is computed on the straight-line method over the estimated useful lives of the related assets. Replacement and renovation of assets and property are financed through funded reserves equivalent to the accumulated depreciation charged annually to operating expenses.

3. Cash and short-term placements

Cash and short-term placements at December 31 consist of:

	1991	1990
Unrestricted	$ 3,726,376	$ 2,718,501
Restricted	29,860,133	24,384,914
	$33,586,509	$27,103,415

As of December 31, 1991, the restricted cash balance includes $452,278 which represents fund set aside for replacements of or improvements on property and equipment.

4. Accounts receivable - donors

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

	1991	1990
Core grants		
Unrestricted	$3,272,162	$2,205,017
Restricted	1,276,704	758,435
Complementary project grants	2,695,256	834,441
	$7,244,122	$3,797,893

The Secretariat of CGIAR assists the Institute in following up the release of core grants by donors. Substantially all of the receivables from core grant donors at balance sheet date have been obligated for expenditures.

5. Property and equipment; leases

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

	1991	1990
Cost		
Research center:		
Buildings and improvements	$20,274,416	$19,851,161
Site development	266,581	3,345,674
Research, machinery and equipment	12,631,451	11,204,867
Transportation equipment	4,919,074	4,311,391
Furniture and fixtures	903,104	717,879
Library items	437,369	437,369
Construction in progress and other projects	3,853,183	2,556,500
Balance forwarded	$43,285,178	$42,424,841
Less: Accumulated Depreciation		
Research center:		
Buildings and improvements	9,346,003	8,838,572
Site development	43,534	31,518
Research, machinery and equipment	8,896,708	7,950,738
Transportation equipment	3,623,369	3,343,212
Furniture and fixtures	509,318	421,000
	22,418,932	20,585,040
	$20,866,246	$21,839,801

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

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.

6. Accounts payable and accrued expenses

The short-term and long-term accounts payable and accrued expenses consist of outstanding commitments and accrued liabilities at December 31 as follows:

	1991	1990
Outstanding commitments for core and capital operations	$18,463,165	$13,937,282
Outstanding commitments for complementary projects	1,061,768	532,554
Accrued expenses	4,592,403	4,604,547
	24,117,336	19,074,383
Less: Short-term portion	16,352,355	11,858,549
Long-term portion	$ 7,764,981	$ 7,215,834

Accruals of unused sick and vacation leaves represent about 73% and 75% of the accrued expenses in 1991 and 1990, respectively.

7. Grants applicable to succeeding periods

Grants applicable to succeeding periods at December 31 consist of grants received in advance for the following:

	1991	1990
Restricted projects	$ 3,037,475	$2,780,698
Complementary projects	10,826,221	4,125,220
	$13,863,696	$6,905,918

8. Other liabilities

The current and long-term other liabilities substantially represent reserves for estimated expenditures to be incurred for trainees participating in various programs. The estimated expenditures cover post-doctoral scholars, research fellows and trainees' stipends, board and lodging, other direct expenses and reimburseable overhead costs to be incurred by the Institute. Funding for these reserves is derived from charges against grants for trainees, including special projects.

9. 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 in Philippine peso to qualified employees/members, upon their separation from the Institute, under certain conditions.

Contributions to the fund amounted to $546,437 in 1991 (1990-$471,000).

10. Reclassifications

Certain accounts in the 1990 financial statements were reclassified to conform with the 1991 financial statements presentation.

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MICHAEL F. L. GOON, MBA, *deputy director general for finance and administration*
HUBERT G. ZANDSTRA, Ph D, *deputy director general for research programs*

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RAM CHET CHAUDHARY, Ph D, *plant breeder*
RICHARD P. LANDO, Ph D, *technology transfer specialist*

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BRIJNANDAN GHILDYAL, Ph D, *liaison scientist*

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M. LARUE POLLARD, Ph D, *editor*
WILLIAM H. SMITH, BS, *editor*[2]
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ROBERT T. RAAB, Ph D, *training and courseware specialist*[1]
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[1]Joined during the year.
[2]Left during the year.
[3]Joined and left during the year.
[4]On study leave
[5]Died during the year.
[6]Transferred from Agronomy, Plant Physiology and Agroecology Division.
[7]Transferred from Plant Breeding, Genetics and Biochemistry Division.

The Consultative Group on International Agricultural Research (CGIAR)

CGIAR is an informal association of 40 public and private sector donors that supports a network of international agricultural research centers. IRRI is part of this global system.

More than 1,000 scientists representing 60 different nationalities conduct research at CGIAR centers and in collaboration with national program scientists in some 40 developing countries.

The International Research Network

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 among low-income people.

CIAT—Centro Internacional de Agricultura Tropical, with headquarters in Colombia. Focus on crop improvement and improving agriculture in the lowland tropics of Latin America through research on rice, beans, cassava, forages and pastures.

CIMMYT—Centro Internacional de Majoramiento de Maiz y Trigo, with headquarters in Mexico. Focus on crop improvement of maize, wheat, barley and triticale.

CIP—Centro Internacional de la Papa, with headquarters in Peru. Focus on crop improvement of potato and sweet potato.

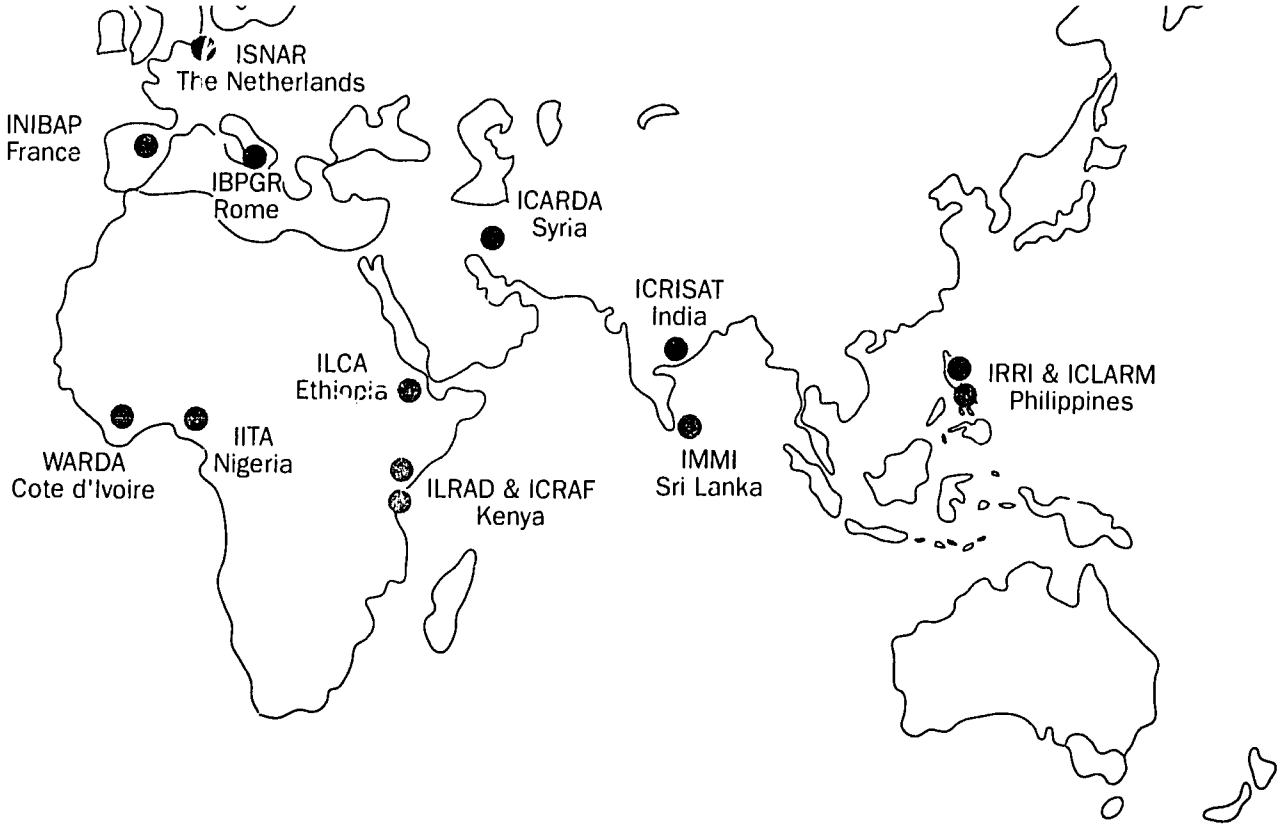
IBPGR—International Board for Plant Genetic Resources, with headquarters in Italy. Focus on conserving gene pools of current and potential crops and forages.

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

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

ICRAF—International Council for Research in Agroforestry, with headquarters in Kenya. Focus on initiating and supporting research on integrating trees into land-use systems in developing countries.

ICRISAT—International Crops Research Institute for the Semi-Arid Tropics, with headquarters in India. Focus on crop improvement and cropping systems through research on sorghum, millet, chickpea, pigeonpea and groundnut.



IFPRI—International Food Policy Research Institute, with headquarters in the USA. Focus on strategies and plans to meet world food needs through research on all aspects of policy analysis.

IIMI—International Irrigation Management Institute, with headquarters in Sri Lanka. Focus on improving and sustaining the performance of irrigation systems through better management.

IITA—International Institute of Tropical Agriculture, with headquarters in Nigeria. Focus on crop improvement, land management, and farming systems in humid and sub-humid tropics through research on maize, cassava, cowpea, plantain, soybean, rice and yam.

ILCA—International Livestock Center for Africa, with headquarters in Ethiopia. Focus on farming systems to identify livestock production and marketing constraints in Sub-Saharan Africa through research on ruminants, livestock and forages.

ILRAD—International Laboratory for Research on Animal Diseases, with headquarters in Kenya. Focus on control of major livestock diseases in Sub-Saharan Africa through research on theileriosis (East Coast fever) and trypanosomiasis (sleeping sickness).

INIBAP—International Network for the Improvement of Banana and Plantain, with headquarters in France. Focus on bananas and plantain.

IRRI—International Rice Research Institute, with headquarters in the Philippines. Focus on global rice improvement.

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

WARDA—West Africa Rice Development Association, with headquarters in Cote d'Ivoire. Focus on rice improvement in West Africa through research on rice in mangrove swamps, inland swamps, uplands and irrigated lands.

Credits

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flyleaf	R. Cabrera
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p4	L. Johnson, Black Star
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	L. Johnson, Black Star
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