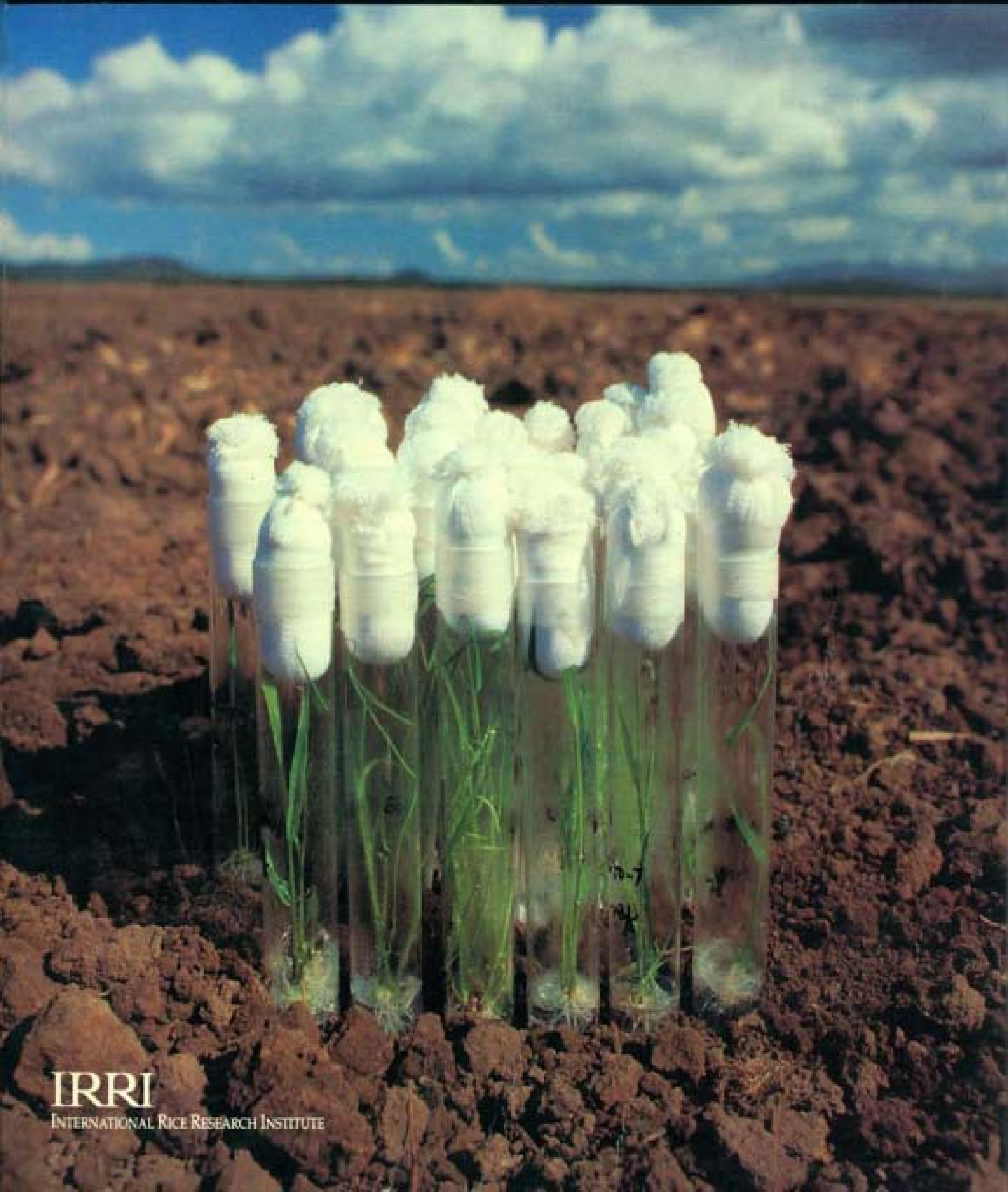
IRRI 1990-1991
A continuing adventure in rice research



IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

The IRRI mandate

The International Rice Research Institute—IRRI—is an autonomous, nonprofit agricultural research and training center. It was established in 1960 to help increase total food production from rice-based farming systems in developing countries, particularly in Asia.

Its purpose is to establish, maintain, and operate an international rice research institute designed to pursue any and/or all of the following objectives:

1. To conduct research on the rice plant, on all phases of rice production, management, distribution and utilization with a view of attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas of the world through improvement in quality and quantity of rice;
2. To publish and disseminate research findings and recommendations of the Institute;
3. To distribute improved plant materials to national, regional and international research centers where they might be of significant value or use in breeding or improvement programs;
4. To develop and educate promising young scientists from Asia and other major rice-growing areas of the world along lines connected with or relating to rice production, distribution and utilization, through resident and joint training programs under the guidance of well-trained and distinguished scientists;
5. To establish, maintain, and operate an information center and library which will provide, among others, for interested scientists and scholars everywhere a collection of the world's literature on rice;
6. To establish, maintain, and operate a rice genetics resources laboratory which will make available to scientists and institutions all over the world a global collection of rice germplasm;
7. To organize or hold periodic conferences, forums, and seminars, whether international, regional, national or otherwise, for the purpose of discussing current problems and for developing research strategies for elevating and stabilizing rice yields under different environments.

Contents

About the cover. . .

Upstream and downstream. New biotechnology tools enabled IRRI scientists to develop these rice plants from protoplasts or naked cells of tropical indica rice. This breakthrough allows scientists to introduce resistance genes—from plants that are not related to rice—into farm varieties.

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.

A continuing adventure in rice research

"At best, the world food outlook for the decades ahead is grave; at worst, it's frightening."
Forest F. Hill,
Ford Foundation,
1959

Thirty years ago and more, concerned people looked at poverty, hunger, and even starvation among people in what were then called "underdeveloped nations" and responded—in many different ways.

One pragmatic approach was to harness the power of science and focus research on increasing the ability of agricultural productivity to catch up with food needs.

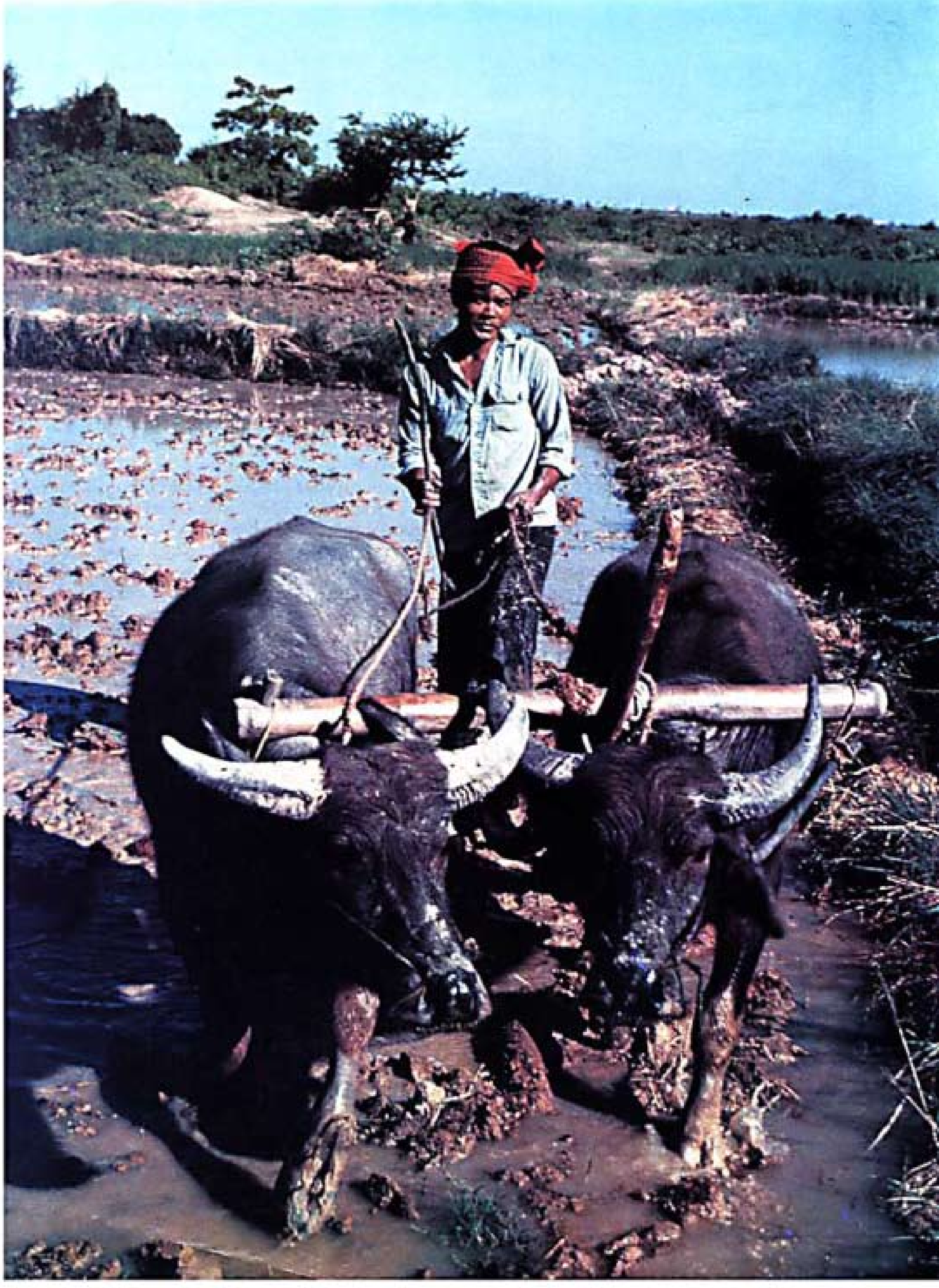
IRRI was established in 1960 to conduct research on rice that would contribute to averting a looming food crisis in the 1970s. Its achievements and those of the rice-dependent countries with which it collaborates have, over the last 30 years, repeatedly helped postpone collisions between food production ability and population demands.

"There are immediate opportunities to make significant benefits in the quantity and quality of rice available each year to feed the ever increasing number of individuals who depend on this crop for sustenance."
J. George Harrar,
Rockefeller Foundation,
1958

The need for agricultural research has not declined. While food production has been keeping up with population growth, projections of food needs for the next 30 years still raise the possibility of food shortages. Production increases are leveling off. Food distribution is uneven and returns to food producers inequitable. New concerns about the long-term stability and sustainability of food production must be addressed.

Rice is the world's leading food crop, and the major source of livelihood for the majority of rural people in Asia—the most densely populated region in the world. The nations in the arc extending from Korea to Pakistan comprise less than 13 percent of the earth's land surface and contain only 24 percent of its cultivated area. Yet they are home to an incredible 52 percent of the world's population. That is 8 persons per hectare of cultivated land, compared with only 1.5 persons per hectare for the rest of the world.

In most countries, rice is typically a labor-intensive crop. Farm sizes average 1 hectare or less. About half the harvest is retained by the farm household for home consumption (landless



"Greater progress has been made in the past 30 years in meeting the food grain needs of the world than in any similar period in history."
Robert F. Chandler, Jr., 1990

laborers often work for a share of the crop). Most of the rice that is sold is consumed within the country where it is produced; less than 5 percent of world rice production is traded internationally.

The central food policy question confronting Asian governments is how to simultaneously maintain low and stable rice prices for consumers, increase farmer incomes, and attain national rice self-sufficiency. Food and agricultural input price and trade policies can only address this complex issue in the short term. The more cost-effective way to increase rice production for the longer term is technological change. Given the rapid growth in population and the scarce land resources in Asia, this essentially means increasing land productivity through increased cropping intensity and higher yields.

The progress achieved within the last 25 years has been impressive. Rice production grew faster than population. Yields accelerated. Increases in crop area planted to rice slowed. As irrigation investments increased, intensively cropped areas expanded. Asia's share of the world rice imports dropped as national self-sufficiency ratios increased. Lower real prices of rice share the benefits of higher productivity with poor urban and rural consumers.

The knowledge available 30 years ago led to the breakthrough in rice plant architecture epitomized by IR8. Yield potential leaped upward.

The declining real price does imply that the growth rate of rice production is not as high as it would have been if prices had remained constant. It is also weakening incentives to increase rice production further.

With population growth and increasing income per capita, the demand for rice in Asia and worldwide is expected to grow on the order of 2.6 percent per year over the next decade and beyond. While this is slightly lower than historical rates, future increases in production to meet demand will depend almost entirely on high productivity, with even higher yield increases per year than those of the 1970s and 1980s.

The central rice policy issue in rice-dependent countries, however, is not the overall world rice supply. In most Asian countries where rice is the main source of livelihood and rice self-sufficiency a national objective, the relevant issue is how to produce cheap rice

A remarkable feature of the Asian rice economy is that the production growth of the last two decades has been sustained at a lower real world price for rice.

while maintaining a comparative advantage in rice production.

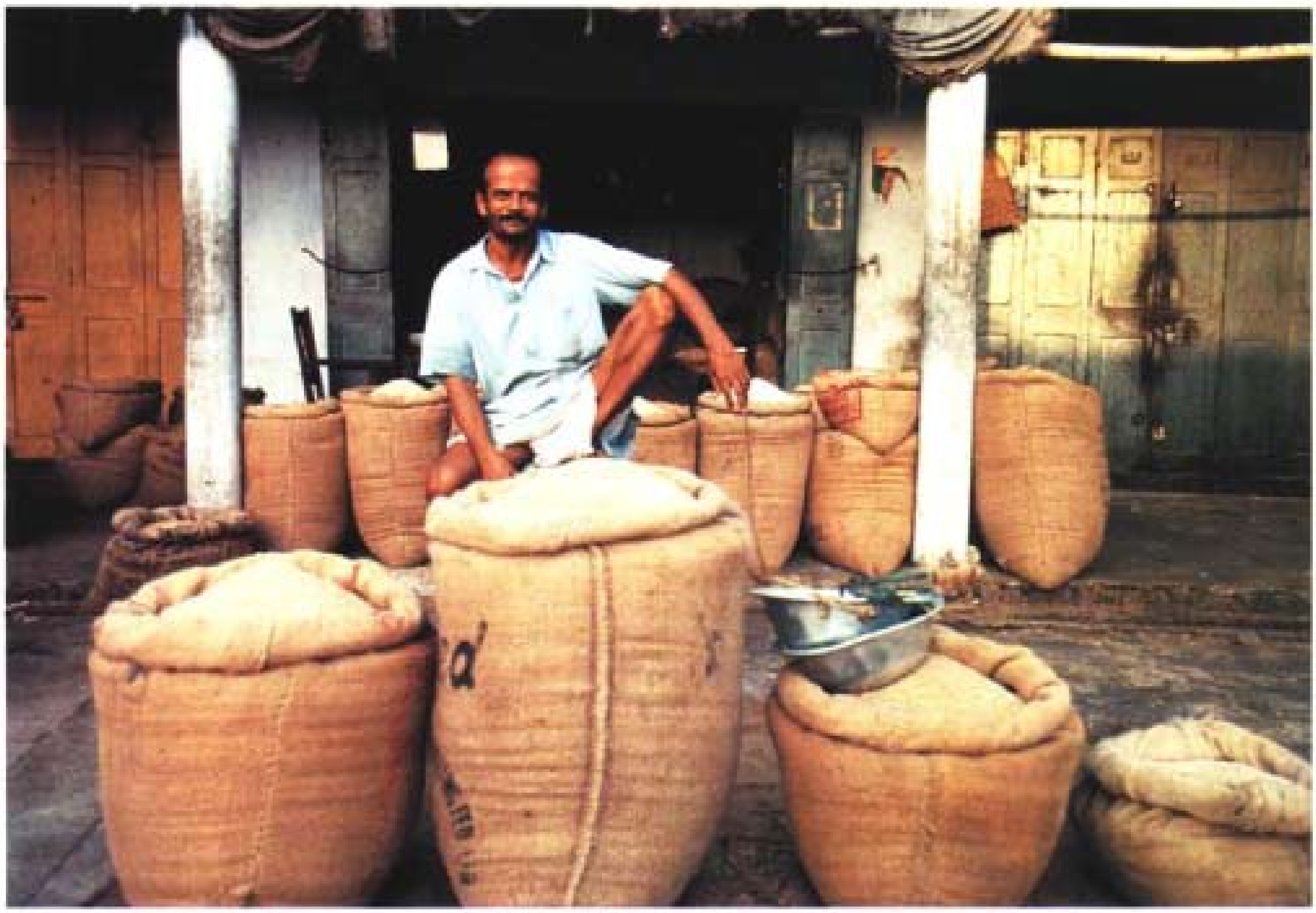
In unfavorable rainfed lowland and deepwater rice-growing areas, alternative uses of the land in the wet season are limited. In upland areas, pressures from increasing subsistence farming are threatening highly erodible slopes and important watersheds. Overall employment opportunities in economic sectors other than rice are extremely limited.

Addressing these issues is more difficult now than it was 30 years ago. Rapid population growth and increasing urbanization have sharply increased the cost of land in the more favorable rice-growing areas. The large majority of Asian rice consumers are still poor and cannot be expected to support high subsidies to rice farmers. Concerns about the environmental costs of highly intensive cultivation call into question the use of high levels of fertilizer and pesticide to increase productivity.

In Southeast Asia, rice is the principal food of some 80 percent of the population and is planted on 56 percent of the arable land.

Analysis of constraints indicates that, given current technology, prices, and production environments, farmers in general allocate their resources efficiently. The need is for even more sophisticated technology.

IRRI's research strategy focuses on raising the yield potential of irrigated rice, strengthening varietal resistance to multiple pests to reduce yield losses and to protect



As populations continue to expand, land planted to rice is being stretched beyond its viable limits in many regions.

the environment, and increasing the productivity of less favorable rice-growing environments.

Research to achieve these objectives will cost more than the research that was the basis for current technology, and the prospects for success are more uncertain. Basic work on rice genetics is not as far advanced as that on other grains. Genetic sources of resistance to rice pests and tolerance for adverse environments are fewer and more difficult to transfer into new varieties. The agronomic problems in the less favorable rice-growing environments are inherently more difficult than those in favorable environments.

Rice production increases to meet the growing demand for rice depend on increasing productivity, with higher growth rates for yield than ever before.

Greater understanding of the symbiotic balance between plant-soil-environment and the consequences of ever-heavier human pressures on the natural resource base are raising new questions. Those questions highlight the need for more sophisticated answers.

Environmental degradation is increasing. Poverty and hunger are still the lot of large numbers of people, in both urban and rural areas. A frighteningly large number of the problems are found in the countries of the world whose people depend on rice, both as their basic food and for their basic income.

Projections of the food needs that must be met over the next 30 years clearly indicate the importance of answering increasingly complex questions, if enough rice

Agricultural scientists are learning more and more, not only about how to increase yields, but also about the costs of those increases.

is to be produced from more limited and more vulnerable agricultural bases. Equity issues must be addressed, particularly in the face of increasing urbanization in rice-dependent countries. Agricultural bases must be protected to ensure sustainable food production for future generations.

There is only one pathway to increased yields: planting varieties with potential for high yields, using management practices that help the plant express its full potential. Ways to increase production are more varied: intensified cropping, expanded area planted, decreased losses caused by pests and inadequate handling.

The pathway to sustainability is strewn with obstacles and is still dimly lit. But sustainability may be the most important challenge of all.

Averting the food and environment problems predicted to confront the world during the coming decades demands creative thinking and increased investment.

Developing new, even higher-yielding varieties and associated management techniques that make it possible to attain yield potential without degrading the agricultural base, identifying impending problems, designing the research to seek answers demand increasingly sophisticated scientific methodologies (which must also be invented or adapted).

Increased yields must be stable and higher production sustainable. Farmers must be able to anticipate equitable returns to their investments. Consumers must find affordable prices in the market.

We believe rice science can keep up with the need for new knowledge and technology, that the adventure in rice research begun at IRRI in the early 1960s continues. ■

Fundamental changes in IRRI's approach to rice research were implemented during 1990. New directions for strategic and applied work on rice are based on the experience gained over the last three decades. That history laid the way to feed about 600 million more people with rice.

The milestones of IRRI achievements are briefly described here to illustrate the baseline from which we expect to meet the targets, attain the objectives, and reach the goals set in our agenda for the 1990s.

Klaus Lampe, IRRI director general, and a Filipino rice farming family.

Independent studies have consistently confirmed that the internal rate of return from international rice research over the last 30 years can reach at least 80 percent. This fact by itself, however, is not expected to influence resource allocations within the next several years.

IRRI's funding since 1960 has totaled some $434 million, without any adjustment for inflation. That is a minute fraction of the value of just one year's increased rice production. About 121 million tons of 1990's harvest in Asia's 11 leading rice-producing nations can be credited to genetic improvement and new farming technology. That is enough rice to feed half a billion people for a year. At an estimated 1990 price of $300 a ton, its value on the world market would be about $36 billion.

Over the next 30 years, the world must face several historically unprecedented challenges:

- World population is projected to reach about 8.5 billion people.
- More than half the world's population will live in cities.
- In Asia, nearly a billion more people will depend on rice as their staple food.
- Billions of people in Asia will still live in dire poverty.
- Millions of hectares will be converted from growing rice to uses by industry, infrastructure, and housing, or will be degraded and lost to food production.

Rice production in the tropics involves drudgery to a degree not comparable to any other crop. Technologies are needed that ensure profitability to farmers, maintain reasonable prices of rice to consumers, and minimize farm drudgery.

If rice farming is not made more attractive to today's farmers and their children, more and more agricultural laborers will migrate to the cities. Their status will move from being rural poor to being urban poor, swelling the number of dispossessed people who could one day become an uncontrollable political force driving enormous social instability. Maintaining world peace will depend on our ability to balance the interests of present and future generations.

The future of Asia's poverty-stricken, rice-dependent people is not solely IRRI's responsibility: policymakers, administrators, and researchers must all be aware of the risks and the challenges. The tasks necessary to increase food availability do not have the appeal of a space program: they are confined to the problems of our own planet. They are not considered to be high tech, at least not in the fashionable definition of that term. They are, however, essential to the maintenance of the ecological, social, and political sustainability that is so closely linked to world peace.

IRRI has a highly skilled, experienced staff, accumulated knowledge and wisdom, dedication linked to tradition, a record of achievement, and many others. Our research agenda for the next 30 years is oriented toward strategic research that will be more complicated, more expensive, and perhaps even more risky in terms of its chances for success.

So long as scientists are unable to alter the fundamental structure of the rice plant itself or of the environment in which it is grown, breaking today's yield ceiling to reach higher levels of productivity will follow the law of diminishing returns.

IRRI has decided to take the risk of exploring new avenues of research, international cooperation, and management of international research support services to cope with the new challenges. Let me cite just two examples:

- The first generation of a new plant type to increase the yield potential of irrigated rice, conceptualized in our strategy *Toward 2000 and beyond* only a little more than two years ago, is already planted on the IRRI Research Farm. For some other ecosystems, improved breeding lines are in advanced stages of development.
- Leaders of national rice research systems and IRRI are establishing the basis for a new style of partnership: the sharing of international responsibility in rice research through ecosystem-based research consortia that will link national program institutions with IRRI and with each other.

Research projects and rice technologies are being designed to provide answers to unemployment, starvation, malnutrition, and migration, especially in rural Asia where more than 90 percent of the world's rice is produced.

While IRRI focuses on Asia, the Institute also accepts its responsibility to help strengthen rice research and development in Africa and Latin America. Where appropriate, this will be done in close cooperation with its sister institutes, International Institute of Tropical Agriculture (IITA), West Africa Rice Development Association (WARDA), and Centro Internacional de Agricultura Tropical (CIAT), and with the relevant national institutions. A new effort in eastern, central, and southern Africa that began in 1990 is only the latest example.

IRRI's response to its global responsibilities can best be exemplified by current efforts to document and reduce the environmental impact of rice production. Our studies of emissions of methane and other gases into the atmosphere, the effects of these emissions on global warming, and the possibilities for increasing the nutrient uptake efficiency of the rice plant, are multipurpose projects. We must increase rice production efficiency and reduce pollution simultaneously.

The sustainability of higher rice production and productivity is an achievable goal. Without doubt, it is one of IRRI's most challenging tasks. We accept this challenge with enthusiasm and patience, in partnership with thousands of like-minded colleagues all over the world.

Klaus Lampe

Klaus Lampe
Director General

IRRI research 1960-1990

As research and related activities result in significant outputs, IRRI's strategy shifts. During the 1960s and early 1970s, the focus was on developing and refining a new plant type, to raise yields of tropical rice. Related work developed cultural technologies that enabled attaining yield potential.

As national research organizations gained strength, IRRI increased attention on incorporating characters into elite breeding lines to stabilize higher yields, and on refining crop management to reduce the need for purchased inputs.

Current activities are expanding scientific abilities in rice genetics and rice-environment interactions, and strengthening collaborative work with rice scientists everywhere.

IR8, the prototype semi-dwarf rice plant, is one-third shorter than its traditional tall parent Peta from Indonesia. In 1966, IRRI workers packed IR8 seed for distribution to national programs. Filipino farmers—2,359 of them from 48 provinces—came to IRRI by boat, bus, bicycle, and foot to collect 2 kg sacks of free seed.

The first decade

1960

IRRI incorporated with support from the Ford and Rockefeller Foundations and the Government of the Philippines, to help increase food production from rice-based farming systems, particularly in Asia. IRRI Manila office opens, construction of research center adjacent to the University of the Philippines at Los Baños is under way, staff recruitment is intense.

1961

Research begins at Los Baños headquarters. Breeding objective (the blueprint that resulted in IR8): to develop short statured, fertilizer-responsive rice varieties with stiff straw that are photoperiod insensitive and resistant to, or at least tolerant of, major pests. Germplasm collection's first use: donors of qualities needed to improve varieties for the tropics and subtropics.

1962

Research center dedicated 7 February by John D. Rockefeller, 3rd, and Philippine President Diosdado Macapagal. Pioneering studies on plant type in relation to yield begin. Library opens, beginning collection of the world's literature on rice. First scholars arrive for degree training program.

1963

Efficient procedure for crossing rice varieties developed (it is still being used in 1990). First IRRI-sponsored symposium brings together world experts on rice genetics and cytogenetics.

1964

Second generation of Peta/Dee-geo-woo-gen segregates 3:1 for short stature, indicating a single recessive gene. Genetic characters and response to nitrogen management and plant spacing evaluated. Basic studies on rice plant physiology and response to light and temperature in the tropics. First rice production short course has 10 participants from Philippine national agencies.

IRRI scientists explained the first crosses made to develop a high-yielding rice for the tropics during Dedication Day ceremonies. Early work led to the ability to breed resistances to rice pests into improved lines. Training programs, to transfer new research methodologies to national program scientists, began that same year.

1965

IR8-288-3 evaluated in cooperative trials in five countries: yields average more than 6 t/ha. Outreach program starts, in collaboration with Ford Foundation scientist posted to Bangladesh. International Rice Blast Nursery starts.

1966

IR8 yields 8.2 t/ha at IRRI in the dry season and is released for use by other breeders. Its new plant type and response to fertilizer double the yield potential of irrigated tropical rice. Seeds of IRRI breeding lines (6,000 packets) distributed for evaluation worldwide. Cooperative work starts in Pakistan and Thailand. Biofertilizer collection begins.

1967

IR5 released: it tolerates deeper water than IR8, withstands drought better, and has greater resistance to bacterial blight and tungro. Cooperative work starts in India, Sri Lanka, and Indonesia.

1968

An estimated 10 million hectares of IR8 being grown in the world. Rice yields in the tropics begin to rise. The Philippines, a traditional importer, announces it has rice to export. More than 1,500 crosses to incorporate desirable characters into rice have been made and more than 40,000 genetic lines tested. One line of wild rice *Oryza nivara* identified as resistant to grassy stunt disease.

1969

IR20 has resistance to four insects and diseases; IR22 has improved grain quality and high milling recovery. Worldwide, 15 varieties with origins at IRRI have been released by national programs, at least 15 more resulted from crosses with IRRI breeding lines. IRRI germplasm collection totals 12,880 accessions. More than 500 rice scientists and technicians from 25 countries have been trained at IRRI.

"The enormity of (natural disasters) forced the realization that simplistic solutions were not the answer to the world's food production problems. . . (and) further convinced those at IRRI of the essentiality of a science-based technology as one of the elements of a stable and economically sound food production system."
N. C. Brady, 1980
Director General
1973-81

Rice physiological studies were greatly accelerated when the Institute's phytotron came on line.

The second decade

1970

Physiological studies explain the critical 5-6 leaf index for optimal yield of improved rices: accumulated carbohydrate is actually translocated into grains during ripening. An 8-row germinated rice seeder can sow 1 hectare in 5 hours, compared to 120 hours needed to transplant. USAID joins the Rockefeller and Ford Foundations in continuing support of IRRI.

1971

IR20 shows wide adaptability to unfavorable soils; IR24 has resistance to green leafhopper, the vector of tungro disease, and other pests. Fixation of atmospheric nitrogen is more active in flooded soil planted to rice. Simple power tiller uses components readily available in rural communities in Asia. Consultative Group on International Agricultural Research—CGIAR—established, with IRRI as one of four centers in the system.

1972

Rainfed lowland rice yields reach 4 tons per hectare using a combination of high-yielding varieties, with adequate fertilizer and good insect and disease control: nitrogen plus weed control partially offset losses to drought. Small power tiller popular with small farmers because it is simple, easy to maintain, and low cost.

1973

IR26 has good grain quality and resistance to seven major pests. Genetic Evaluation and Utilization (GEU) program braids together work on agronomic characteristics, insect and disease resistance, grain quality, and stress tolerance. New phytotron enables scientists to simulate climatic conditions under which rice is grown. Modern semidwarf rices occupy 20 percent of the riceland in South and Southeast Asia.

1974

National program scientists organize to test rice-based cropping patterns in representative agroclimatic zones (ARFSN). Major constraints to the ability of small farmers to produce higher yields with modern rice technology include diseases, insects, water and weed control, and low use of fertilizer, plus credit, prices, and costs. Short duration varieties leave time and soil moisture for second crops.

Interdisciplinary work focuses on adverse rice-growing environments, where farmers need different characters for different conditions. Rice grain quality is another important characteristic: consumer preference varies from region to region.

"In no other area of human need and endeavor is there so much global interdependence as in agriculture. . .We live in this world as the guests of green plants and of the farmers who cultivate them."
M. S. Swaminathan, 1987
Director General 1982-88

1975

GEU focuses on the adverse ecological environments in which three-fourths of the world's farmers grow rice. IR32 is adaptable to single crop rainfed regions, IR34 to rainfed regions where farmers prefer intermediate-stature cultivars. Incorporating new genes for resistance into elite breeding lines diversifies genetic defense. National program scientists working with diverse germplasm under a wide range of agroclimatic and cultural conditions formalize their network (IRTP, now INGER).

1976

IR36 is resistant to nine pests and tolerant of seven adverse soils and drought. National programs use early generation IR lines in local crosses. Inheritance of bacterial blight resistance is genetically complex: sometimes a single dominant gene, sometimes a single recessive gene, sometimes both. Eight national programs plan cooperative work on fertilizer efficiency (INSURF).

1977

GEU focuses on improved germplasm for irrigated, rainfed medium deep and deepwater, and upland rice cultures. Problems include drought, high temperature, low temperature, waterlogging, acid sulfate soils, iron toxicity, and salinity. Brown planthopper resurgence traced to at least three BPH biotypes. Ragged stunt virus is transmitted by the brown planthopper. IR42 gives higher yields on adverse soils. Root-zone placement of nitrogen fertilizer doubles its efficiency.

1978

Some breeding lines have growth durations as short as 90 days. Elite breeding lines consolidate resistances to major rice diseases and insect pests found in traditional varieties. Nitrogen is found to be fixed naturally in the rice plant root zone by heterotrophic organisms in flooded ricefields. Collaboration with China, the world's largest producer of rice, begins.

1979

Rice production worldwide barely keeps up with population growth. IRTP distributes 17 nurseries to 52 countries. ARFSN involves 22 sites in 8 countries. IRRI has formal collaborative agreements with 10 countries. Work in hybrid rice takes advantage of earlier findings on cytoplasmic male sterility and outcrossing mechanisms. Germplasm center holds 47,743 distinct accessions; nearly 30,000 seed samples are distributed.

San Bartolome, the Philippines: 1970, 1980, 1990

IRRI scientists first visited San Bartolome, an irrigated rice-farming community in Central Luzon, the Philippines, in 1970—three years after one 50-kg sack of IR8 seeds reached village farmers. They were already growing modern varieties on about half their rice-lands. Cropping intensity was nearly one-and-a-half crops a year, for a total production of 4.4 tons per hectare. In 1980, modern varieties covered 95 percent of the cropland and production was 5.4 tons per hectare per year.

By 1990, cropping intensity had jumped to nearly two-and-a-half crops a year, producing 8.4 tons per hectare per year. Adopting modern rice varieties paved the way for farm diversification, village electrical services, new houses, new roads.

1970

1990

The third decade

1980

Improved lines with tolerance for excess or deficit moisture now available; many show tolerance for problem soils and adverse temperatures. New tissue and cell culture techniques make possible rapid advances in developing breeding lines with desirable tolerances and resistances. Work on biological nitrogen fixation shows potential of organic fertilizers for small farmers who cannot afford commercial inputs.

1981

Indonesia produces more rice than it needs, with higher per capita consumption. Seeds of traditional Khmer varieties preserved in the gene bank are returned to Cambodia (war destroyed much of the germplasm in farmers' fields). Cultural pest control techniques will be safer for the farmer. New ways to apply fertilizer result in higher yields with lower inputs.

1982

Some 11 million hectares in Southeast Asia are planted to IR36. Reports are coming in that its brown planthopper resistance is under attack by a shift in the BPH biotype population. IR56 is named in the Philippines to replace IR36. The search for resistance genes to a new strain of grassy stunt virus threatening rice crops is under way.

1983

Multidisciplinary experiments seek ways to reverse yield declines in improved varieties. Ricefields in the Philippines shelter 51 spider species: they eat rice pests (excessive use of insecticides kills beneficial insects). Conference on Women in Rice Farming Systems examines the impact of new technologies on women-specific tasks and roles. The International Rice Germplasm Center manages the largest collection in the world.

1984

New electron microscope enables identification of different-shaped virus particles and particle combinations related to tungro disease intensity. Standardized terminology for rice-growing environments is a first step toward a universal language for rice cultural types and environments. New techniques enable moving valuable genes across sexual barriers in domestic and wild rice crosses. At least 120 IRRI books have been published in 34 languages and distributed in 25 countries.

IRRI's 30th anniversary celebration

On 20 September 1990, IRRI marked 30 years of research focused on improving tropical rice harvests. Dr. Robert F. Chandler, Jr., founding director of the institute, recognized 21 pioneer staff currently serving at IRRI. It was a nostalgic day, interwoven with thoughtful discussion on the challenges of the next 30 years.
Dr. Chandler's address emphasized the closely linked nature of the global issues of food, population, and the environment: "There can be no uncertainty that in our finite world, human population and natural resources—both renewable and nonrenewable—are on a collision course. To avert such a calamity is the greatest challenge that faces mankind."

1990

Projects targeted to reach strategic objectives are under way in new ecosystem-based research programs and consolidated international programs. The reports that follow highlight the year's work.

1985

IR64 is first IR cultivar with highly palatable grain plus high yield potential and multiple pest resistances. Integrated pest management (IPM) uses combinations of pest-resistant rice varieties, need-based chemical controls, botanical insecticides, and simple techniques for pest monitoring. Women in Rice Farming Systems research initiated through the ARFSN.

1986

Intensified work on basic genetics will enable breeders to better exploit genetic resources. A simplified method for subspecific classification of rice varieties by isozymes is reliable, rapid, and economical.

1987

Nine wild rice species collected in Asia-wide collaborative effort. Factors identified that contribute to the development of high-density grain (heavier grains increase head rice recovery). Applications of biotechnology accelerate genetic studies and wide hybridization.

1988

New plant type to further raise yield potential: short to medium stature, medium to long duration, low tillering, early growth vigor, high nitrogen uptake rate, limited foliage expansion, high foliage nitrogen concentration, high storage of nitrogen in stems and leaf sheaths, strong vertical senescence and delayed senescence of flag leaf, many spikelets per panicle. IRRI's strategy *Toward 2000 and beyond* developed.

1989

More than 900 varieties with IR parentage have been released to farmers in 38 countries. IRGC holds 85,268 accessions. Biofertilizer collection totals 500 azolla entries, 204 blue-green algae, 45 aquatic legume species and their symbiotic bacteria, 21 strains of nitrogen-fixing bacteria. Library contains 93,191 references. *A farmer's primer on growing rice* now published in 38 languages. Some 6,000 national program scientists and technicians have been trained at IRRI.

Research programs

Both the problems and the methodologies have changed greatly since research began at IRRI. The driving need in 1960 was to increase the yield potential of rice; in 1970 and 1980, to stabilize yields and improve the ability of farmers to reach yield potentials.

Now the rice farming world is more complex. The further increases in productivity needed to keep up with population growth and rice demand must be linked with imperative concerns about riceland sustainability. That interaction is driving research direction in the 1990s.

Concerns for sustainability were discussed at the May 1990 meeting of the Consultative Group on International Agricultural Research (CGIAR). The Group considered the final report of the Inter-Center Committee on Sustainable Agriculture useful.

That report dealt with a shrinking genetic base, soil degradation, climate change, marginal production environments, and reduction in dependence on agricultural chemicals. The CGIAR discussion led to several proposals by which sustainability issues could be made a more permanent, integral, and concrete part of each Center's research programs.

IRRI responded to the challenges posed by sustainability issues by organizing an in-depth review of work already under way. The review dealt with the wide range of topics related to the sustainability of rice production systems imbedded in the Institute's programs. They include genetic diversity, the impact of increasing yield potentials, yield stagnation or decline in some production systems, soil loss, water-induced land degradation, soil nutrient depletion or imbalances, pest-induced losses, global climate change, environmental degradation, and impacts of pesticides on human health.

The review committee considered sustainability "a forward looking concept that addresses our ability to respond to changes in the physical availability of resources and to changes in social values." Sustainability has to do with maintaining or even enhancing basic resources, so that we do not limit our options for achieving objectives. IRRI's objectives, of course, relate to its contribution to satisfying the world demand for food at constant or lower social costs within a socially acceptable time period.

The reviewers encouraged IRRI in its development of a greater diversity of rice ideotypes. That will maintain more options and allow more rapid response to potential problems. They cautioned that improvements in yield potential would necessarily increase the potential for nutrient deficiencies in ricelands. They found IRRI's work to better understand the impact of pesticide use on human health noteworthy.

In the area of pest management, IRRI has increased its use of biotechnological tools in pest differentiation. This will allow effective monitoring of changes in the population composition of ricefield pests in response to various strategies to deploy host plant resistance, particularly in combination with cultural or insect behavior-based techniques for pest management.

Water-induced land degradation and soil loss are only two of a number of concerns for the sustainability of rice production systems that research must address.

The importance of measuring sustainability was emphasized. Identifying the resource factors that contribute to sustainability within each rice ecosystem would enable the development of measurement guidelines. Such guidelines should be developed in collaboration with other institutions with responsibilities for sustainability.

Continuing improvements in computer technology will be a major asset. They are enabling much more sophisticated work in plant and crop modeling. We can now look at systems and the interactions of their dynamic components—disease development and epidemiology, the effects of multiple stresses on rice crops, plant nutrient balances—and predict the impact of different combinations on yields, productivity, and aspects of sustainability.

Work in all five of IRRI's rice ecosystem-based research programs endeavors to incorporate opportunities on the leading edge of science into projects that, in one way or another, contribute to increasing and stabilizing rice production to meet the demand for rice as food for current and future generations. Some of the projects are far up the scale of strategic work, some are closer to applied work that national agricultural development programs can adapt to their particular situations.

All IRRI's research is closely linked to the needs of national agricultural research systems. Much of it is done in collaboration with advanced laboratories elsewhere and with the scientists in national rice research institutions. ■

The first year of implementation of IRRI's five-year work plan and its new program-based management structure, described in *IRRI 1989: Planning for the 1990s*, was a year of change, of new patterns for decisionmaking and internal communication. Program leaders formally took charge of the five ecosystem-based programs on 1 January 1990; division heads consolidated the staffs of old departments into scientific discipline-based units; and a research project-based budgeting, monitoring, and reporting system was implemented, in close cooperation with Finance.

H. G. Zandstra, deputy director general for research, discussing the second generation of crosses made to capture and evaluate qualities desired for a new high-yielding irrigated rice plant type with G. S. Khush, plant breeder, and B. S. Vergara, plant physiologist.

As program leaders and project coordinators gained confidence in carrying out their new roles, they developed operational procedures that inspired multidisciplinary scrutiny of research initiatives. They combined this with reallocation of human and financial resources and with mechanisms for resolving conflict.

The two-way aggregation of project budgets, by program and by division, turned out to give very useful clarity to the relationship between project activities and resource allocation. This led to shifts of staff among divisions and changed the patterns of research expenditures.

Project coordinators reviewed the research activities planned in 1989 and, in consultation with the program leader, identified modifications needed in project scope and in composition of the multidisciplinary teams required to carry out the research. Scientific staff time had to be allocated from divisions. Division heads faced limitations in staff resources, including at times the absence of particular disciplinary specializations because of reduced budgets and frozen positions. This posed new challenges in communication and shared decisionmaking.

The resulting budget enabled the IRRI Board of Trustees program committee to review, in much more detail than before, staff and funding allocations in relation to the project activities planned.

Internal program review

We modified the Institute's internal program review process to parallel the new project-based research management structure. It now involves project monitoring and evaluation, internal reviews, and program progress reports to the IRRI Board of Trustees.

In project monitoring and evaluation, research results and future directions are continuously assessed by project coordinators and program leaders, with the participation of the scientific staffs of IRRI and collaborating institutions. Project and program teams meet several times a year. New findings, insights from diagnostic surveys, methodological advances, the productivity of recent research, and technology adaptation are leading to shifts in project focus and priorities. Project descriptions and allocation of staff and operating funds change in response.

In-depth internal reviews may be initiated by Institute management or by the Board of Trustees. Reviews may be motivated by concern for the quality of work, by research priorities at the project or program level, or by the need to formulate new approaches. They can be evaluative or normative, or both. Most importantly, they are primarily seen as an instrument to support IRRI research.

Trustees are informed of the topics and scope of reviews planned. Review team members are selected to include external specialists and IRRI and collaborating institution scientists.

The third element is the annual program report to the Board. Program leaders assess research progress and analyze issues and constraints. At this time, major changes in budget requirements are proposed. The results of internal reviews and the program presentations together provide Board members with a complete review of progress and identify current issues in IRRI's research agenda.

The third dimension

Certain research concerns are not easily captured within either a project or a disciplinary context. These include such widely applicable research approaches and tools as biotechnology, integrated pest management (IPM), and systems analysis and modeling. We organized special interest groups for these subjects.

Scientific staff involved in one of these concerns meet once a month, to discuss initiatives, share results and methods, arrange access to specialized expertise, and set priorities for research and training. Special interest group participants also share resources and develop research collaborations.

These discussions can benefit several projects. For example, issues discussed within the biotechnology group include the development of nonradioactive restriction fragment length polymorphism (RFLP) techniques, wider use of anther culture and haploid breeding methods, priorities for protoplasm culture and regeneration, and use of DNA analysis for pest and pathogen differentiation.

Within the IPM group, improved yield loss assessment, methods of mapping pest occurrences, tungro virus disease research priorities, and approaches to extend the durability of host plant resistance—including that potentially obtainable from *Bacillus thuringiensis (Bt)* transformation—have received the most attention.

The modeling group, initiated late in 1990, already has helped identify the potential contribution of sources of increased yield potential—such as improved nitrogen use, reduction in nonproductive tillers, increased panicle size and grain density, and possibly a longer spikelet-filling period—to a higher yielding rice plant type. It is pursuing broader participation of IRRI scientists in collaborative research with national program scientists supported by the Simulation and Systems Analysis for Rice Production (SARP) project.

Hubert G. Zandstra
Deputy director general for research

Irrigated rice ecosystem

Irrigated Rice Research Projects for 1990-1994

Germplasm improvement
- High yield potential
- Multiple resistance

Crop, resource, pest management
- Fertilizer, soil, biologically fixed nitrogen
- Integrated nutrient management
- Pest dynamics
- Indigenous biocontrol agents
- Integrated Pest Management (IPM)
- Agronomic practices for direct seeding
- Water and tillage management

Livelihood and production environments
- Impacts of intensified cropping
- Global climate change
- Livelihood, environment impacts

Stable urban rice supplies, reasonable rice prices, and equitable returns to rice-farming families depend on growth in the productivity of irrigated ricelands. Asian rice production in the first 25 years after IRRI's founding grew by 66 percent—the result of the development and rapid adoption of modern high-yielding varieties and associated yield-achievement technology. But recently that growth has leveled off, and even the gains made so far are under pressure. The challenge is to reach and sustain the unprecedented growth in productivity projected to be needed to feed rapidly increasing populations, particularly in the cities, during the next 30 years.

To increase the productivity of irrigated rice, scientists and national policymakers face a number of major problems.

- A yield frontier that is not increasing.
- A narrow difference between technological yield potential and yields already achieved by farmers.
- Degradation of the flooded ricefield environment resulting from intensive rice monoculture.
- Degradation of irrigation infrastructures.
- Declining profitability of rice production.

Some problems are the responsibility of policymakers, some the responsibility of specialized agencies. IRRI predominantly addresses the technical problems of rice production itself. Our strategy for seeking answers that will overcome the problems of stagnant yields and declining productivity is three-pronged:

- Shifting the yield frontier and increasing yield stability.
- Increasing the efficiency of inputs.
- Minimizing the degradation of the ricefield environment.

Shifting the yield frontier

Rice yield potentials should be increased by 20-25 percent within

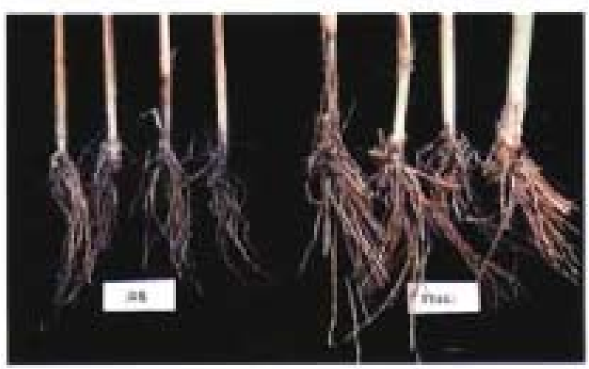
Modeling a new plant type concept

We used data from a number of field experiments to analyze the growth characteristics and yield potential of semidwarf rices when they were direct seeded rather than transplanted. Then we used simulation and modeling techniques to generate concepts that define a plant type that should have higher yield potential than the current high-yielding plant type.

The model predicted a plant type for greater resource use efficiency and higher yield potential when direct seeded. It would have the following characteristics:

- Greater foliar growth during crop establishment, with reduced tillering.
- Less foliar growth and enhanced assimilate export from the leaves to the stem during late vegetative and reproductive growth, along with sustained high foliar nitrogen concentration.
- A steeper slope of the vertical nitrogen concentration gradient in the leaf canopy, with more nitrogen present in the uppermost stratum of the canopy.
- An expanded capacity of stems to store assimilates.
- An improved reproductive sink capacity, along with a prolonged ripening period.

The simulation indicated that, theoretically, yield potential could be increased 25 percent, or more.



IRRI breeders crossed donor varieties for large panicles, very sturdy stems, and low tillering, and screened second- and third-generation crosses, in the first steps toward developing a new rice plant type to break the current yield ceiling.

the next 5 to 10 years, just to meet projected population increases. IRRI research is progressing on two fronts: changing the rice plant architecture and exploiting hybrid vigor.

Breeders have identified donor varieties for large panicles, very sturdy stems, and low tillering. These varieties are being used to develop new plant types with higher yield potential. While the probabilities of success in breeding are difficult to estimate, our best prediction is that yield gains in farmers' fields from a new rice plant architecture are some 7-10 years ahead.

Hybrid rices for the tropics are a bit closer to realization, perhaps within 5 years. The hybrid rices developed in China give 15-20 percent higher yields than do conventional high-yielding varieties. Experimental evidence indicates that similar yield potentials are possible in the tropics. Identifying suitable parents for hybrid rices adapted to tropical conditions is progressing rapidly, as is seed production technology.

Increasing yield stability

Yields can be stabilized by planting varieties that have genetic resistance to important diseases and insects. We are identifying new sources of genes for resistance among wild relatives of rice and transferring that resistance into high-yielding varieties. Usable breeding lines that carry these more durable resistances should be available within three years.

Biotechnology protocols are being developed for transforming rice using novel genes, such as the *Bt* gene for insect resistance and coat protein genes for tungro resistance. Those genes are likely to become accessible to breeders

Developing a hybrid rice for the tropics

Suitable rice hybrids and seed production systems have lacked commercially usable cytoplasmic male sterile lines adapted to the tropics. Two new lines—IR62829A and IR58025A—bred during the last two years show promise.

We evaluated several experimental hybrids derived from these lines in Egypt, India, Korea, the Philippines, and Vietnam. In certain locations in the Philippines and in Vietnam, IR64615H yields were much higher than those of the conventionally bred checks.

This hybrid is resistant to brown planthopper and green leafhopper, moderately resistant to stem borers, but susceptible to bacterial blight.

In dry season 1990, IR65488H (derived from IR58025A/IR54742-22-19-3R) yielded 8 tons per hectare, significantly higher than the 3-6 tons per hectare of conventional improved varieties, and similar to estimated wet season yield potentials. Physiological analysis showed that the high yield was due to increased total dry matter and a higher harvest index. The hybrids show high leaf area development early and slow senescence later. The hybrid with the highest yield had the largest number of spikelets per panicle.

In breeding hybrids, a thermosensitive genic male sterility system is considered to be more efficient than a cytoplasmic male sterility system. We found that a thermosensitive genic male sterile japonica mutant from Japan grown at IRRI was completely sterile at 31-24 °C, but partially fertile at 24-18 °C. We are transferring its gene to several indica and indica-japonica cultivars, for multilocation tests.

Improving rice grain quality

Rices with the grain qualities that consumers prefer command higher prices in the market. Usually, these rices have intermediate amylose content, intermediate gelatinization temperature, soft gel consistency, and pleasant aroma. They are softer when cooked, and more flavorful.

But very few of the modern high-yielding varieties have aroma, and traditional aromatic varieties continue to be grown, even though they have lower yields. Low productivity is compensated for by the higher selling price.

Early breeding efforts focused on higher productivity. Grain quality work was aimed at acceptable cooked rice texture. Now we have some promising new breeding lines with both superior grain quality and aroma; they are being tested in replicated field trials. One example is IR54950-181-2-1-2-3, a high yielding aromatic line with intermediate amylose content, intermediate gelatinization temperature, and soft gel consistency. It is being evaluated by the Philippine Seed Board now.

Aromatic varieties with higher yield potential could become available within two or three years. Increased production of higher quality rice should lower prices and bring more palatable rice within reach of low-income consumers.

Breeding for cold tolerance in boro season rice crops

Farmers in intensively cropped irrigated areas of Bangladesh and northeast India are switching from a rainy season to a post-rainy season, boro rice crop. Traditionally, boro rice was grown only in inland swamps. Farmers whose fields are prone to waterlogging and floods have been adopting the practice as a substitute for more vulnerable wet season rice. Some 3 million hectares are now cultivated.

Boro rice is seeded at the end of the wet season, in October and November, and harvested in April and May. During that period, soil moisture usually is within the next five years. Genes for partial, quantitative resistance to blast have already been incorporated into improved breeding lines for transfer into new varieties.

Input efficiency

Improved technologies for more efficient use of agricultural inputs are being developed in integrated pest management, integrated fertilizer management, crop establishment methods, and water management.

Integrated pest management, or IPM, increases the efficiency of pest control in two ways: by lessening the amount of pesticides applied and by exploiting nonchemical methods to control pests. IPM involves a mix of practices: using

adequate to grow the crop, with supplemental irrigation available from shallow wells. Growing boro rice converts what was an adverse environment into one with high production potential.

But the modern high-yielding varieties being planted suffer drastic yield reductions and require longer growing seasons because they are affected by low temperatures at the vegetative stage. The cold-tolerant rice varieties available from temperate regions and high altitude areas of the tropics are tolerant of low temperatures only during the seedling stage or reproductive phase, or both, but not during the vegetative period.

We have identified germplasm sources that could contribute the cold tolerance needed during the vegetative period of the boro rice crop. They are japonicas originating from high-altitude temperate regions. Collaborative breeding work aimed at improved lines began this year.

Designing diversified cropping for irrigated ricelands

Most irrigation systems in South and Southeast Asia are designed and operated for rice - rice cropping. But with returns to rice declining, farmers are looking for options—in particular, the ability to grow a nonrice crop in the dry season.

The question is, how compatible are rice irrigation systems with nonrice crop irrigation? We collaborated with the International Irrigation Management Institute (IIMI) and national programs in Bangladesh, Indonesia, and the Philippines to examine some of the issues involved in irrigation for diversified cropping.

In the Philippines, most rice irrigation system infrastructures can meet the irrigation needs of nonrice crops. Only irrigation schemes that suffer from poor water control or poor drainage at the main system level need to be upgraded. That would benefit both rice and nonrice crops.

But high water tables created by seepage and percolation from unlined canals and adjacent flooded ricefields leave many farmers with no alternative but to grow rice in the dry season. They need drainage within a field planted to a nonrice crop.

Temporary drainage channels enable farmers to diversify and grow a nonrice crop adjacent to a flooded ricefield.

pest-resistant varieties, managing the natural predators of rice pests, and employing crop cultural practices that require only judicious application of pesticides. The combination minimizes yield losses to pests without excess use of pesticides. Five countries—India, Indonesia, Malaysia, the Philippines, and Sri Lanka—now have official policies that support implementation of IPM.

Research activities include developing pest-resistant varieties and establishing optimum input levels and cultural management practices; evaluating IPM packages in farmers' fields; developing simple pest control decision tools for crop protection services, extension agents, and farmers; and monitoring IPM use by farmers across time.

Integrated fertilizer management starts with increasing the efficiency of fertilizer use (inorganic fertilizers account for the largest share of purchased inputs for higher irrigated rice production). We already know that basal application of nitrogen, with a second application just before panicle initiation, results in the highest yields. Efficient basal application requires thoroughly incorporating fertilizer into the soil during the final harrowing and land leveling before transplanting. Further gains are possible through deep placement rather than broadcasting. Now we need to generate deep placement technologies usable by farmers.

Flooded rice soil, however, is conducive to fertilizer losses. Even when fertilizer is applied for high efficiency, rice crop growth depends more on soil nitrogen than on the fertilizer applied. A rice crop of 5 tons per hectare will

We tested designs for temporary drainage channels to improve a field's subsurface hydrology for growing maize. Channels 50 cm deep and 30 cm wide constructed around 20- × 10-meter plots and connected to the existing drainage system lowered the average seasonal water table about 10 cm. Maize yields reached 7.3 tons per hectare—121 percent higher than yields in fields without channels.

Channel construction cost about $45 per hectare, but gross returns were $660 per hectare—26 percent higher than the returns from dry season rice. The channels are erased in preparing the field for wet season rice planting.

Wet seeding rice below the puddled soil surface

In the tropics, direct seeded rice is most often planted by broadcasting pregerminated seed on the surface of puddled fields. This can save labor and shorten the crop season, but there are serious constraints.

Stand establishment can be uneven and unstable. When land preparation and water control are poor, germinating seeds covered by wet soil can die and seeds that fall into standing water cannot get good anchorage. Seeds on the puddled soil surface are vulnerable to pests—especially birds. Unpredictable tropical weather also poses hazards: seeds can be washed away by heavy rain or suffer drying from direct exposure to strong sunlight.

Lodging is common in direct seeded rice. When seeds are broadcast on the soil surface, the base of the plant where the roots start to grow is on top of the soil. The plants do not anchor well and become top-heavy as they mature and produce grain.

Rice is one of the few plant species whose germinating seeds can grow without oxygen (the conditions in a flooded ricefield where the soil is not exposed to the air). But this particular physiological trait has been largely ignored in developing methods of crop establishment.

Plant physiologists theorize that the seeds of some rice varieties have a genetic ability to grow in anaerobic conditions, out of the flooded soil itself. This year, we began to evaluate the emergence of rice seeded below the puddled soil surface, with special funding from the Government of Japan.

In the first step, 267 varieties of *O. sativa* and 15 of *O. glaberrima* with wide genetic backgrounds were selected from the International Rice Germplasm Center. Pregerminated seeds were placed 25 mm deep in the soil of a plastic germination tray and submerged in 2-5 cm water.

Stand establishment differed. Ten percent of the *O. sativa*, but none of the *O. glaberrima*, were better than control variety IR50. That difference says that breeding varieties with the genetic ability to establish in flooded soil could, with the appropriate seeding technology, enable farmers to plant rice after conventional land preparation.

Seeds planted below the soil surface are protected from pests and unstable weather. They develop stronger root systems and are less susceptible to lodging. Stand establishment should be more consistent, and yields higher.

Evaluating arthropod biodiversity in irrigated rice

Understanding the interactions among rice insect pests and the insect predators of those pests (the friendly insects) can provide important clues to increasing the sustainability of pest management practices. We studied the biodiversity of prey and predator species in irrigated ricefields.

absorb about 50 kg of nitrogen from the soil. Managing the soil nitrogen and predicting the pattern of its supply to rice are important in stabilizing high rice yields.

The soil nitrogen also must be replenished, if soil fertility is to be maintained. That takes good management of the soil, crop residues, and water.

We are studying the natural processes of nitrogen gain and biological nitrogen fixation, and characterizing their role in different farming systems. Efficient biological nitrogen fixation systems and ways to stimulate biological nitrogen fixation are being sought. We are selecting for rice cultivars that are efficient users of soil nitrogen.

Farmers across Asia are switching from transplanting to direct seeding, in response to rising agricultural wages. Within just the last 10 years, nearly all the farmers in the central plains of Thailand and half the farmers in Central Luzon, the Philippines, have adopted direct seeding.

IRRI has been studying and refining technologies such as low-cost weed control and increased fertilizer use efficiency for a long time. Considerable progress has been made in understanding crop growth and nutrient management in direct seeded rice. Work on defining the best rice plant type and crop establishment techniques for direct seeding continues.

Investments in large-scale irrigation systems have declined sharply over the last few years, and existing systems are showing signs of rapid degradation. This raises serious concerns about the long-term contribution of irrigation to sustainable growth in agricultural productivity. The impact of

The brown planthopper lays its eggs on rice leaves. Hatching larvae eat the leaves and damage yield. The mirid bug predator eats hopper eggs, and that helps control pest buildup.

Diversity—the number of species found—increased with crop age up to maximum tillering. The major insect herbivores (those that eat rice plants) were flies and hoppers; their major predators were bugs and spiders. Hopper densities were lower when populations of such predators as mirid bugs, spiders, and ripple bugs were higher.

In fields sprayed with insecticides, biodiversity is significantly lower. The disruption caused by insecticides throws the system out of balance: it kills the rice pest predators as well as the pests. With fewer predator species present, herbivore pests, such as the brown planthopper, can reestablish and increase rapidly.

Controlling chronic insects

Despite several decades of using insecticides in rice, tropical rice farmers in less developed countries still have difficulty mastering chemical control technology. They fail to diagnose the numbers of such chronic pests as stem borers and defoliators that will cause economically significant damage. They choosé inappropriate chemicals. They apply less than the optimum level of pesticide for adequate control. And they spray often—too often.

We compared the yields of 15 farmer-managed rice plots in the Philippines across wet season 1989 and dry and wet seasons 1990. Each farmer controlled the pests in one plot as he normally would and left one plot untreated, as a check. Yield loss to insect pest damage was calculated as the difference from yields in additional researcher-managed experimental plots with complete pest protection in the same farmers' fields.

The farmers sprayed insecticides up to 4 times per crop. But their yield averages were similar—4.2 tons per hectare, no matter what. Averaged over the declining investments in the 1980s will be even more visible during the 1990s, as fewer new areas come under irrigation, and the extent of current areas declines.

Given the increasing difficulty and time needed to raise rice yields, exploring options for cost-effective expansion of irrigated area and generating technologies for higher water use efficiency are essential. Developing systems that exploit the interactions of input management practices, such as those that involve water and those that involve fertilizer, is important.

three cropping seasons, losses were 0.3 ton per hectare whether or not the crop was sprayed. In other words, farmers who sprayed did not prevent yield loss.

We are testing crop management practices that will help reduce yield losses, either by preventing pest damage or by enabling the crop to compensate.

Selecting a rice variety with the best growth duration for the agroclimatic conditions and determining the optimum seeding rate are examples of preventive measures. Applying supplemental fertilizer when an economic threshold of pest infestation is reached is a corrective measure that gives the crop energy to outgrow insect damage.

We tested short-duration IR58 and medium-duration IR74 at different seeding densities (planting was synchronized so that both varieties were grown under the same weather conditions) in Zaragoza, Philippines. Local farmers use a high seeding rate to get more tillers, in an effort to lessen the risk of low yields when insect pest pressure is high.

Insect pest densities were monitored. When the economic threshold was reached, different plots were treated with insecticide or with additional fertilizer. Yield loss was taken as the difference between plots protected by a blanket insecticide schedule and those untreated.

Both varieties were heavily damaged by whorl maggot and green hairy caterpillar simultaneously. Other insect pests were minor. Deadhearts and whiteheads caused by stem borer were minimal, and leaffolder damage was low.

Yield loss in short-duration IR58 was 0.8 ton per hectare (5.1 vs 4.3 tons per hectare); in medium-duration IR74, loss was only 0.2 ton per hectare (5.2 vs 5 tons per hectare).

Applying insecticide at the economic threshold infestation of whorl maggot did not improve yield, nor did adding extra nitrogen (in fact, extra nitrogen caused IR74 to lodge). The higher seeding rate also made no difference.

Insect damage causes important yield losses. Combinations of improved crop management and careful varietal selection, integrated with judicious pest control, can reduce those losses.

Minimizing degradation of ricefield environments

A more comprehensive understanding of the causes of long-term degradation of the flooded ricefield environment is essential if technologies and management practices that will arrest the degradation are to be identified. We need better understanding of the processes that lead to the waterlogging and salinity buildup that are causing large areas of irrigated ricelands to be abandoned. Technologies are needed to reverse that trend.

Attention to the long-term viability of rice - nonrice crop rotations, especially rice - wheat, is part of the work aimed at sustainability and at increasing total productivity with equitable returns to the farmer.

Quantifying the impact of modern technology on human health and on the environment is increasingly important. Current work on the impact of pesticides on human health is a first step in this area.

Global climate change and rice

It has been clearly established that atmospheric carbon dioxide concentrations are rising and will continue to increase in the foreseeable future. We also know that the stratospheric ozone layer has been partially degraded. Whether—or how—these factors are leading to a global climate change is still not established.

As concerns about global climate change increase, however, questions are being raised on the role irrigated rice production plays in adding to greenhouse gases in the atmosphere and on the impact that a global climate change would have on rice production.

The difference was crop duration. IR58 grew too rapidly during the vegetative stage to compensate for insect damage. It appears that in that environment, a medium-duration rice variety can better tolerate vegetative insect damage, at least during the wet season. Further tests in other environments, with different levels of chronic insect pests, will verify this.

Designing integrated technology for rice-based systems

We have been studying rice crop management and rice-based cropping patterns in irrigated and partially irrigated farmers' fields of Guimba, Nueva Ecija, the Philippines, for several years, in collaboration with the Philippine Department of Agriculture. Farmers' management decisions in relation to land and hydrology differences and their effects on system productivity are being mapped, to identify variability across seasons and technical reasons underlying widespread farmer practices.

In the irrigation service areas of deep tube wells, rice yields vary widely. Most farmers do not follow basal fertilizer application recommendations. In wet season 1990, medium levels of nitrogen applied basally six days before panicle initiation resulted in higher yields than when nitrogen was broadcast into the irrigation water at the same growth stage.

Improving rice - wheat cropping systems

A major problem in rice - wheat cropping rotations in the tropics is low wheat yields. Wheat culm population density is a critical yield factor. To get wheat yields of 2.2 tons per hectare, 4 million culms per hectare must be established. This is higher than would be needed in more temperate climates.

One problem is turnaround: shifting from a wet season flooded ricefield to a drained wheatfield for the dry season. At tropical temperatures, evaporation lowers residual soil moisture and increases soil strength. The result is poorer wheat emergence than in more moderate climates.

Tillage and seeding method, however, can improve yields of dry season wheat following wet season rice. In our experiments, no-tillage, slit-seeder seeding produced higher plant populations, manual row seeding gave more consistent plant populations under a range of seedbed conditions.

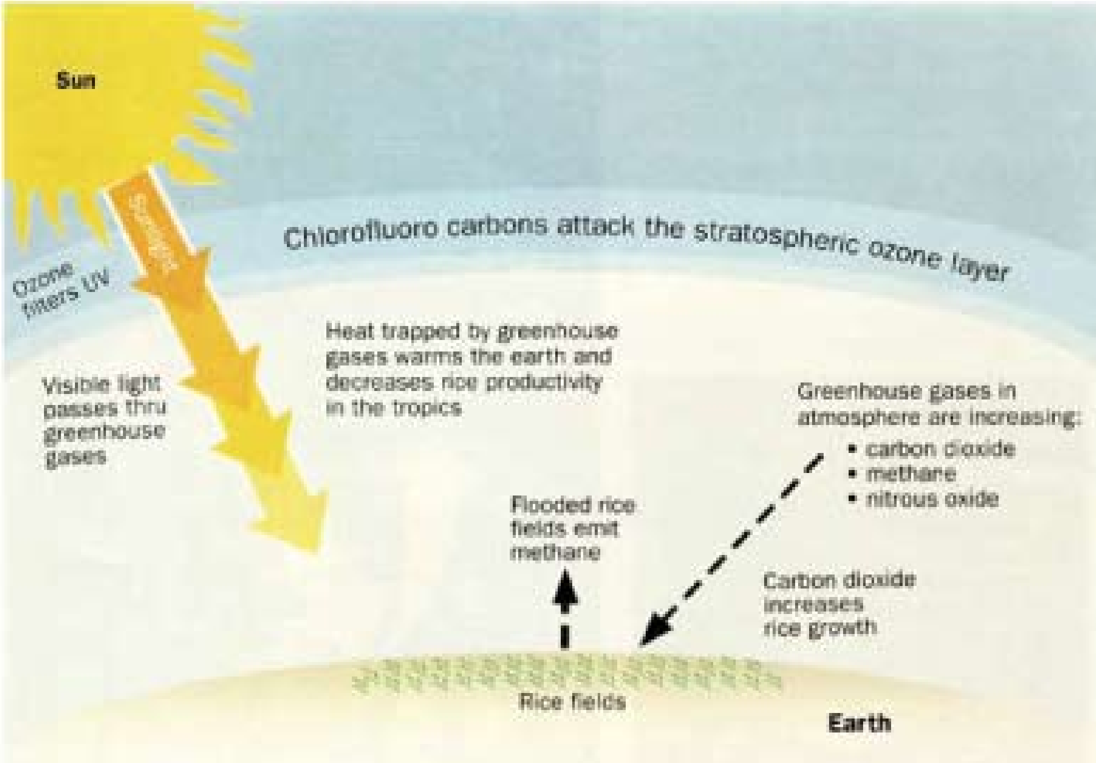
Monitoring pesticide use and farmer health and productivity

Concerns about the consequences of pesticide use on human health and the environment have been expressed for more than a decade. To try to quantify the effects of pesticide use on human health, we are studying two rice farming villages in the Philippines. Pesticides are widely used by farmers in a village in Laguna Province. Another group of farmers in a Quezon Province village have never used pesticides.

All farm inputs and practices, particularly pest management practices and methods of handling pesticides, have been recorded in 32 farm households in the Laguna village for three years. We added 22 randomly selected pesticide applicators who work in the area to the pesticide-exposed sample (56 people total); 40 farmers from the Quezon village are the control.

Detailed medical assessments (physical examination and CBC, blood chemistry, ECG, X-ray, and cholinesterase laboratory tests) were done to measure the acute and chronic effects of pesticide use. Acute effects are reflected in

Schemata of how global climate change could affect tropical rice. Visible light passes through the earth's atmosphere, while the stratospheric ozone layer filters ultraviolet band (UV-B) radiation. Greenhouse gases (chlorofluorocarbons) in the atmosphere trap heat and warm the earth's surface. Degradation of the stratospheric ozone layer by chlorofluorocarbons allows more biologically destructive UV-B radiation to reach the earth's surface. Flooded ricefields emit the greenhouse gas methane. Higher temperatures reduce the productivity of rice. At the same time, the greenhouse gas carbon dioxide can enhance rice growth. The effects of UV-B on rice are being studied now.



Our research is just getting under way, in a 5-year project funded by the U.S. Environmental Protection Agency, in collaboration with its Environmental Resources Laboratory in Corvallis, Oregon. Initially, the focus is on the impact of a possible climate change on rice production.

We are investigating the effects of ultraviolet-band (UV-B) radiation on rice and on rice diseases and the effects of increased carbon dioxide and higher temperatures on rice yields and rice pests, and are modeling plant responses to different climate change scenarios. At the same time, we are monitoring emission of climate-changing gases from flooded rice soils. ■

cholinesterase level; chronic effects are manifested more on the cardiovascular, hematologic, and neurologic systems.

In the first, benchmark examination, 56 percent of the pesticide-exposed group showed depressed cholinesterase levels. Three years later, 61 percent had depressed levels. Cardiovascular abnormalities were detected in 54 percent of the exposed group, but in only 7 percent of the unexposed group. Low hemoglobin levels were found in 25 percent of the exposed group, but in only 5 percent of the unexposed group. Three polyneuropathy cases (although these three farmers had normal blood sugar levels) were found in the exposed group, none in the unexposed group—even though there were more drinkers among that group. These health impairments can be expected to take their toll on farmer productivity.

We used a cost function model to quantify the impact of pesticides on farm productivity and on human health. When health effects are explicitly included, the net impact of pesticide use on farm income is negative.

We also simulated the effects of governmental policies on pesticide use and human health. The model predicted that a tax on pesticide purchases would lead to reduced use and improved health. When the tax was set higher than 50 percent, the model showed that productivity gains from improved health would more than offset reduced yields.

This implies the need to reassess how we calculate return to research investment. When health effects are not considered, the rate of return to rice research in general is overestimated, and the rate of return to research that reduces pesticide use underestimated. ■

Rainfed Lowland Rice Research Projects for 1990-1994

Sustainable resource management
- Ecosystem analysis
- Crop establishment
- Crop intensification
- Biological nitrogen sources and fixation
- Integrated nutrient management

Germplasm improvement
- Physiology and genetics
- Breeding and evaluation

Rainfed lowland rice ecosystem

A considerable part of the growth in rice production in recent years has come from rainfed lowland ricefields. With little prospect for significant expansion of the irrigated area, especially in South and Southeast Asia, rainfed lowland rice farms are under pressure to supply an even larger proportion of the rice that will be needed in major rice-consuming countries in the decades ahead.

Scientists study the broad subsystems within the rainfed lowland ecosystem separately. A farmer, however, often is confronted with a range of interrelated field conditions within a relatively small farm. A local landscape will include diverse and dynamic conditions that change from year to year with changes in rainfall patterns. A field that is a favorable parcel one year may be submerged the next, and a parcel that is drought stressed one year may be favorable the next.

Experienced rainfed rice farmers adapt their cropping practices to the complex risks, potentials, and problems they face. They strive not just for maximum yields, but for stable yields over time. Research to help develop technologies and rice varieties that enhance rainfed riceland productivity and stability is increasing, at IRRI and in the national programs.

Optimal use of conserved rainwater

Lack of water keeps many tropical rainfed lowland farmers from planting rice or another crop in the dry season. On-farm reservoirs that conserve direct rainfall and capture run-off for dry season irrigation give those farmers an opportunity to increase their cropping intensity.

Farmers who have built new on-farm reservoirs need information on ways to use the stored water more efficiently. We expanded the capability of a computer model, Farm Reservoir Optimization, to predict economic returns to alternative farm resource allocations. This will be the basis for developing some easy-to-follow guidelines for farmers to use in making crop management decisions.

The model takes into account water balances in the reservoir and the field to be cropped, considering variations in rainfall, then recommends crop and area allocations based on expected water supply and anticipated constraints in other resources. We used the model in dry season 1990 to predict outcomes from four farms with reservoirs in Tarlac, the Philippines. The most suitable crops for the area are soybean, mungbean, peanut, and rice.

Available water did not alter the crop choices, but the size of area planted to different crops changed with water limitations and with available capital. The highest return would have come from growing only soybean—US$505 per hectare. But soybean is a capital-intensive crop. With realistic farm capital limitations, growing both soybean and peanut was best, with the hectarage allocated to each crop depending on the amount of capital. While dry season rice is not economically competitive with other crops, farmers still would grow rice on one-fourth hectare for family consumption.

Optimal use of impounded water can be planned using an expanded computer model that predicts economic returns to farm resource allocations.

Many farmers in eastern India follow a complex crop establishment system called *beusani*. Rice is dry seeded before the rains start. About 30 days after seedling emergence, when the fields are flooded, the farmer plows through the seedlings (a). Then the field is laddered (b). To ensure a good crop stand, seedlings are redistributed and the field weeded by hand (c).

Farmer practices to improve rice crop establishment

In South Asia, some rainfed lowland rice farmers use a unique crop establishment method—*beusani* (sometimes called *biyasi* or *bidahani*). Rice is dry seeded just before the monsoon. Some 30-50 days after the rains start (with standing water in the field), the farmer plows through the seedlings. Then the field is laddered or planked and seedlings redistributed to fill gaps in the rows that plowing created.

To gain insights into the effects of beusani on the rice crop and on ricefield soils, we ran some tests on the IRRI farm. One experiment compared yields with beusani in broadcast dry seeded, row dry seeded, and transplanted rice. Transplanted rice yields were higher over all. Weed control was important in maximizing yields. In another experiment, dry seeded rice with a green manure intercrop yielded more than a beusani crop, and more than dry seeded rice with chemical fertilizer.

In diagnostic surveys, farmers using beusani in Orissa, India, said they really prefer to transplant their rice. They practice beusani when they don't have adequate water control or when labor is scarce during critical crop establishment periods. Dry seeding with beusani is the fastest way to plant a large area. Surprisingly, the surveyors found that total labor required was similar for transplanting and for beusani, but the labor for beusani was stretched out across the season.

Our conclusion is that, rather than focusing on ways to improve or replace beusani, the best strategy is to develop ways to manage dry seeded rice more efficiently. This will involve baseline surveys to map changes in dry seeded and transplanted rice yields and areas across time and to relate crop establishment practices to hydrology and weed population dynamics.

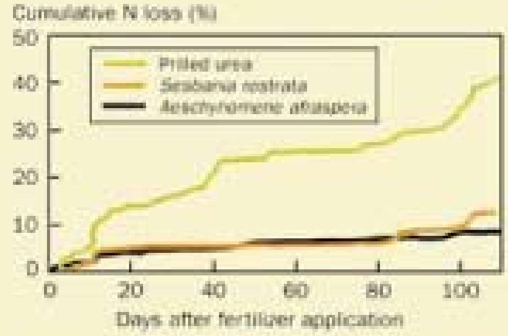
We will also emphasize work to design practices that reduce the labor required to control weeds in dry seeded rice (for example, by improving the design of local farm implements), to improve crop stands in dry seeded rice, to reduce soil compaction in dry seeded ricefields, and to develop improved cultivars for dry seeding.

We have done diagnostic surveys of rainfed lowland areas in Bhutan, Cambodia, Laos, Madagascar, Nepal, the Philippines, and Thailand, in initial IRRI-national program collaborations to characterize different agroecosystems. The short- and long-term causes of low or declining productivity identified will help in developing a strategic research agenda and provide a basis for designing collaborative work in key rainfed lowland research sites.

Ammonia volatilization with organic and inorganic fertilizer

While green manuring is recognized as beneficial to rice yields and to rice soil fertility, information about the fate of green manure in flooded ricefields is limited, particularly in the tropics. We know that part of inorganic fertilizer nitrogen applied to rice is lost through ammonia volatilization. What we do not know is the fate of organic nitrogen.

We measured ammonia volatilization in plots fertilized with urea and with the nitrogen-fixing legumes *Sesbania rostrata* and *Aeschynomene afraspera* and tracked volatilization losses across crop growth. Within 10 days after application, green-manured plots lost much less ammonia than chemically fertilized plots, particularly in wet season rainfed plots (7-12 percent vs 41 percent).



Cumulative NH_3 (nitrogen volatilized as ammonia) loss is much less from flooded ricefields fertilized with green manures *Sesbania rostrata* and *Aeschynomene afraspera* than from those with commercial prilled urea.

Now we are studying other pathways of nitrogen loss, such as denitrification. Experiments to simultaneously determine ammonia and denitrification fluxes and carbon dioxide evolution from the soil, floodwater, and crop canopy will help us better understand nitrogen use efficiency and increase knowledge on the contribution of rice cropping to global climate change.

Photosynthetic nature of stem nodule rhizobia

It is possible that the stem nodules found on some green manure legumes are self-energy-generating systems—the stem nodules may be able to fix nitrogen without taking energy away from the plant.

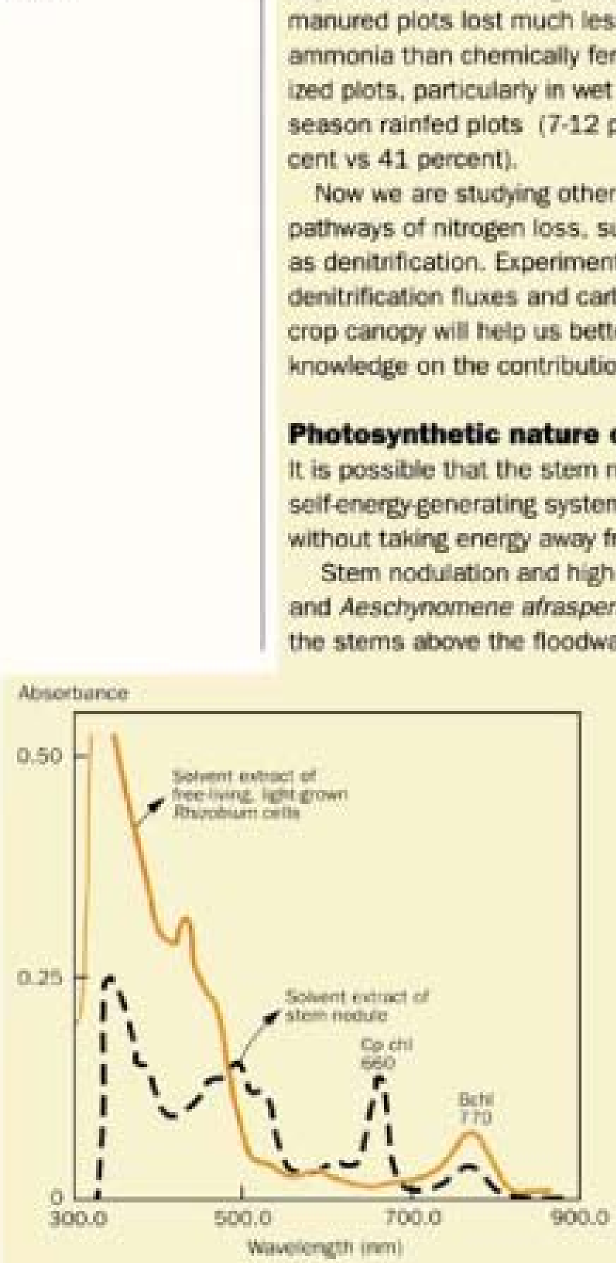
Stem nodulation and high nitrogen fixation in the legumes *Sesbania rostrata* and *Aeschynomene afraspera* evolved as an adaptation to flooding: nodules on the stems above the floodwater enabled the plant to get nitrogen from the air that it could not get from the flooded soil.

Features of stem nodule symbiosis include

- More infection sites as the plant grows.
- Tolerance for combined nitrogen fertilizer.
- Photosynthetic cells in the nodule cortex.
- Growth and N_2 fixation in free-living condition.

A novel feature of the stem-nodulating microsymbiont is its ability to form bacterio-chlorophyll 'a' (Bchl) and photosynthetic reaction centers resembling those of purple photosynthetic bacteria. But unlike photosynthetic bacteria, rhizobia of stem nodules produce pigment only under light and aerobic conditions.

We recently found that this feature is characteristic of stem-nodulating species of *Aeschynomene*. The absorption spectra of rhizobia and stem nodules show that



Spectrophotometric analysis of a strain of *Aeschynomene denticulata*. The absorption band of solvent extract of rhizobia at 770 nm suggests the presence of bacterio-chlorophyll 'a'; the nodule extract peak at 660 nm, the presence of chloroplast chlorophyll.

This year, we examined crop establishment and weed control methods practiced in direct seeded rice crops by farmers in eastern India; rainfed lowland and partially irrigated rice systems in the lower foothills of Bhutan; and the rainfed and irrigated rice - wheat system around Pantnagar in Northeastern India. The follow-up to assess trends and impacts of technology change will include periodic monitoring of a selected panel of farms, to evaluate changes in lands, soils, hydrology, yields, field problems, management practices, and returns.

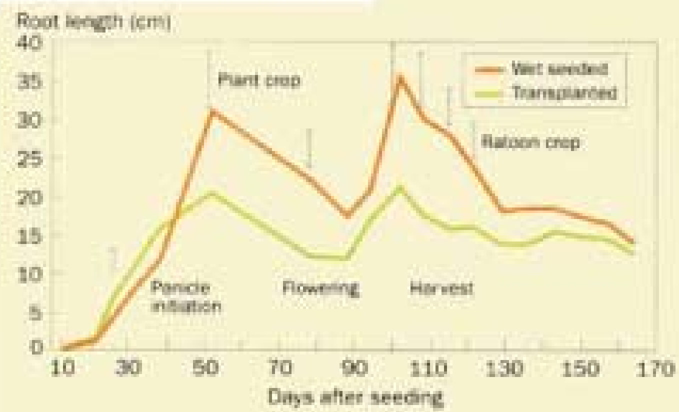
A. afraspera, A. denticulata, A. evenia, A. indica, A. nilotica, A. pratensis, and *A. sensitivia* produce Bchl under both symbiotic and free-living conditions. The *Sesbania rostrata-Azorhizobium caulinodans* stem nodule symbiosis does not.

This ability of the stem nodule bacteroid of *Aeschynomene* species to use light in a wavelength not used by the plant could be an advantage in crop production, by lessening competition for the energy the plant needs for carbohydrate and nitrogen reduction. A more extensive description of this mechanism would help identify its potential for increasing green manure and rice yields.

On the basis of phototrophic ability alone, these rhizobia could be assigned to a new genus. Our data on nutritional and biochemical characterizations, however, suggest they probably belong to the genus *Bradyrhizobium*. We are continuing studies to define their taxonomic placement.

Effects of crop establishment method on rice root growth

The extent of its root system has a great deal to do with how well a plant tolerates drought. But root growth has been hard to study. The minirhizotrons we installed in an IRRI experimental farm plot last year already have given us new insights. (Minirhizotron technology eliminates the need to destroy a plant to examine its roots, and allows us to watch the same root system in the field over time.)



Roots of wet seeded rice are longer than those of transplanted rice at all growth stages. The longer the roots, the more nutrients and water taken up, and the stronger the plant.

We evaluated the effects of crop establishment method and water deficit on seasonal patterns of rice root systems, in cooperation with the University of Arkansas, USA. Wet seeded rice had significantly longer roots than transplanted rice, from tiller elongation through harvest and the ratoon crop. This helps explain why wet seeded rice yields are higher than transplanted rice yields when the crop gets insufficient water.

We also compared root lengths of drought-susceptible and drought-tolerant rice cultivars. While water deficit reduced root lengths overall, drought-resistant N22 always had the longest roots. Follow- up studies of the relationship between drought resistance and root growth will help establish the genetic basis for that character.

Phosphate fertilizer efficiency on acid soils

Low phosphorus is an important nutritional deficiency in the acid and acid sulfate rice soils of tropical South and Southeast Asia. It is linked both to low available phosphorus and to an acid soil's high ability to fix soluble phosphorus fertilizer.

We evaluated phosphorus fertilizers with different solubilities in some lowland acidic rice soils of India, Indonesia, the Philippines, Thailand, and Vietnam. Triple superphosphate is highly soluble; finely ground phosphate rock and partially acidulated phosphate rock are somewhat less soluble, but are cheaper and easier to prepare.

In the laboratory, partially acidulated phosphate rock provided more soluble phosphorus than phosphate rock throughout the active reaction period: the higher the reactivity, the higher the acidulation. Both phosphate rock and partially acidulated phosphate rock maintained soluble phosphorus more

In 1990, our priority research focused on ways to intensify and diversify rice cropping systems; on improved crop, soil, and water management; and on developing breeding lines adapted to excess water or water deficit. ■

effectively, for longer periods, than triple superphosphate, especially in soils with relatively low exchangeable calcium content.

The rate of dissolution of the phosphorus sources over time depended more on the exchangeable calcium content of the soil and somewhat less on phosphorus-fixing capacity and acidity. It is possible that, while high phosphorus-fixing capacity enhances initial dissolution of phosphorus rock in acid soil, too high a fixing capacity may over time result in low available phosphorus concentrations in soil.

Tests in the field paralleled the laboratory results. It appears better to use more sparingly soluble sources to supplement phosphorus in acid soils for rice.

Improved germplasm for rainfed lowland environments

We are developing improved breeding lines adapted to a range of unfavorable rainfed lowland conditions in collaboration with Thailand. Northeast Thailand has ideal conditions for selecting breeding lines with tolerance for drought, submergence, and adverse soils. Using a shuttle breeding approach, we can advance promising lines into observation nurseries in five years. Three elite lines are showing promise.

- IR43450-SKN-506-2-2-1-1 is a nonglutinous, aromatic line with yields similar to those of traditional Thai variety Khao Dawk Mali 105, but with shorter duration. It showed resistance to ragged stunt virus under heavy infection pressure in Thailand in 1990.
- IR43506-UBN-520-2-1-1 is a waxy grain line with good yields under more favorable conditions. It has intermediate height and is strongly sensitive to photoperiod. It showed moderate resistance to ragged stunt virus.
- IR46331-PMI-32-2-1-1 is a nonglutinous line with high yields. It has intermediate height and is photoperiod sensitive. It showed excellent resistance to drought in screening at IRRI.

The abbreviations in the breeding line designations stand for screening sites in Thailand: Chum Phae (CPA), Khon Kaen (KKN), Sakhon Nakhon (SKN), Ubon (UBN), Surin (SRN), and Phimai (PMI). ■

IR43450-SKN-506-2-2-1-1, a short-duration, aromatic grain breeding line for the rainfed lowlands developed in the Thai-IRRI shuttle breeding project, performed well under drought-prone conditions in a farmer's field yield trial at Ban Khu Khad in Northeast Thailand.

Upland rice ecosystem

Upland Rice Research Projects for 1990-1994

Sustainable land and resource management

- Farming system productivity
- Farming system improvement

Integrated germplasm improvement and crop management

- Germplasm improvement
- Drought and weeds
- Blast and nematodes

The uplands account for 13 percent of the global rice area, but only 5 percent of production. That productivity must be increased, if the populations dependent on these farmlands are to get their fair share of food and income. Higher productivity in the uplands also could help slow migration of the rural poor to overcrowded urban areas.

Upland rice is grown on about 8 million hectares of hilly acid soils in Southeast Asia, mostly in Laos, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam. Another 4 million hectares of upland rice is grown in South Asia. Cropping in the uplands is intensifying—moving from traditional shifting cultivation featuring short cropping periods followed by long fallows to permanent annual crops—and soil losses are increasing.

Most upland agroenvironments are highly variable, risky, and difficult for the farmer. The variability includes differences in slopes, soils, cropping systems, and traditional cultivars. The risk involves erratic drought, insects, and diseases that can cause serious yield loss. The difficulty is that farmers are poor and live in remote areas with limited access to transportation, credit, and information.

These adverse upland conditions define two research concerns. The scope for increasing rice production is limited, which means that the impact of research investment will be limited. The problems involved in improving rice-based cropping systems are complex, which means that research will take more time and will cost more.

IRRI's strategy to increase food availability and income, while protecting the environment, involves two complementary approaches.

- Integrated, multidisciplinary research to improve farming systems in complex, fragile environments that have multiple, interactive constraints.
- Attention to the socioeconomic problems that constrain farm income and pressure migration to the cities. Farm families need an incentive to remain on the land, to rehabilitate and protect it.

IRRI's research objectives recognize major problems identified through surveys. The objectives are

- To evaluate changes in land protection and farm income brought about by applying improved crop management techniques in rice farming systems that include forage and marketable food and cash crops.

• To evaluate yields and yield stability of new, improved rice breeding lines against local cultivars.

The research is undertaken in key sites. The first representative upland sites were in Cavinti, Laguna, Philippines, near IRRI headquarters, and in Claveria, northern Mindanao, Philippines. Cavinti has high rainfall and poor, strongly acidic soils; the site had been abandoned by farmers because of soil depletion. Claveria has medium rainfall and relatively poor acidic soils; newcomers were beginning to cultivate previously unopened uplands. ■

Land management in the sloping uplands

With increasing population pressure, the trend among shifting cultivation farmers is toward longer cropping periods and shorter fallows. That accelerates soil nutrient depletion and soil loss. The farmers in the sloping uplands are aware of increasing soil erosion. They need improved technology to combat the problem.

Researchers at IRRI and in a number of countries where subsistence farmers work the uplands are identifying ways to reduce surface runoff and soil erosion. They are studying the use of farmer-participatory methods to develop and evaluate promising technologies. The overall goal is to enable upland farmers to make a transition, from solely rice to more environmentally protective and sustainable farming systems; from shifting cultivation to settled systems that involve a much higher proportion of perennial crops.

The approach is research on the total system, rather than on its individual components. Collaborative research in areas of India, Indonesia, Laos, and Thailand where rice is grown under shifting cultivation is focusing first on diagnostic surveys. Measuring soil erosion across several upland sites in a number of Asian countries will identify areas with different rates of erosion. Data will be analyzed in terms of soil types and depths, crop yields, and land use changes

over time. This will enable us to derive testable hypotheses about elements of system sustainability, and to evaluate such erosion control practices as cover crops and perennials that improve or enrich fallows, control weeds, and maintain soil cover.

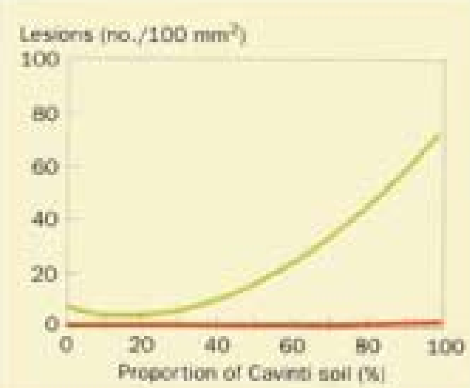
The challenge is to establish relationships between soil loss and sustainability. Agronomic productivity, changes in soil nutrient and physical characteristics, farmer practices, and changes in land use or farming systems, as well as demographic characteristics and national policies, must be factored in. This will increase our understanding of the reasons for and the effects of soil loss and provide a basis for developing more productive and sustainable technologies.

Increasing upland rice yields

Upland rice breeding work has been focusing on identifying useful donors to contribute improved characteristics and resistance to major productivity constraints. That will enable national breeding programs to develop new rice varieties that have a competitive advantage over traditional cultivars preferred by farmers.

We tested 2,000 rice lines in some 50 trials in acidic soils (pH 4 and 5) at the Philippine sites, using only moderate levels of fertilizer. Yields of the best traditional cultivars, Azucena and Dinorado, were about 2 tons per hectare. We identified 53 improved lines that yield up to 70 percent higher than these two local checks; the best have a yield potential of 6 tons per hectare. The traditional varieties are tropical japonica types; the best improved lines are also tropical japonicas.

Many of the improved lines have much shorter crop duration than the traditional varieties; that will give farmers more time to grow a second crop after rice. In addition, the tropical japonica improved lines have just as stable yields as the traditional varieties, with the added advantage of responsiveness to fertilizer.



Relationship between the proportion of blast-conducive Cavinti soil in a growth mixture and the formation of hypersensitive blast lesions in susceptible rice variety IRAT140.

Interaction between soils and rice blast development

Rice plants grown in some soils seem to be more susceptible to blast than rice growing in other soils. We are developing a bioassay method to estimate the relative blast-conduciveness of different soils.

First, we had to determine if leaf surface composition was involved with soil conduciveness. We partially removed the cuticle of leaves of blast-susceptible variety CO 39 by rubbing them with organic solvents, then inoculated them with a compatible isolate of *Pyricularia grisea* (= *P. oryzae*), the causal agent of blast. Blast symptoms appeared faster and more intensely on treated plants than on untreated plants.

We treated the leaves of resistant varieties IRAT140, Moroberekan, and IRAT104 the same way, and inoculated test plants with an incompatible isolate. Blast symptoms (small, necrotic, hypersensitive lesions) were much more intense on IRAT140 and IRAT104 growing in blast-conducive Cavinti soil. Few lesions appeared on plants growing in nonconducive Batangas soil. The difference between soils was particularly clear-cut with IRAT140, so we used that variety to test the bioassay method.

IRAT140 plants were grown in mixed Cavinti and Batangas soils, the leaf cuticle was partially removed, and the plants inoculated. The number of hypersensitive blast lesions increased as the proportion of conducive Cavinti soil increased. If we get the same results using compatible isolates of *P. grisea* on IRAT140 or other varieties, we will be able to survey soils for their relative conduciveness to blast disease in rice. ■

Deepwater and tidal wetlands rice ecosystems

Deepwater and Tidal Wetlands Rice Research Projects for 1990-1994

Productivity and land use efficiency of deepwater areas
- Improved germplasm
- Soil and crop management
- Intensified cropping systems

Productivity and sustainability of tidal wetlands
- Breeding lines with improved yield
- Soil and water management

Deepwater rice has been important in South and Southeast Asia for more than 1,000 years. Modern research started around the turn of this century. Cultivation practices and yield measurements of deeply flooded ricefields in Bengal were described in 1891, and an experimental farm was established at Dhaka in 1911. Other early deepwater rice stations were established in Bihar in 1914 and in Assam in 1921. The Habiganj Station, established in 1934, has kept daily records of floodwater depth for most of its existence.

In Thailand, the Huntra Experiment Station for deepwater rice was established near Ayutthaya in 1943. It became the main center for IRRI's deepwater rice research program in 1974, when a memorandum of understanding between the Royal Thai Government and IRRI made possible joint research and training projects.

IRRI centers its deepwater program in Thailand because the environment does not occur in the Philippines, even though some 10 million hectares of deepwater rice are grown in South and Southeast Asia. Thailand strengthened its

staff and facilities at Huntra and in Prachinburi and IRRI provided scientists and research support. Research activities have evolved from primarily plant selection to a broad spectrum of work in plant breeding, agronomy, physiology, pest management, and cropping systems.

Tidal wetlands rice has a similar history, with recognition of the need for research early in this century. Many scientists, however, worked in isolation because of the scattered location of the research sites. During the last four years, collaborative work on problem soils has been conducted by IRRI and research centers in India, Indonesia, Sri Lanka, and Thailand, with Asian Development Bank support.

One limitation to the work is logistical: extremely diverse environments are scattered over a 6,000 km belt in Asia. Similar adverse rice ecosystems are found in Africa and Latin America. Fitting improved rices into the wide range of environments is not easy. Deepwater rice plants must be selected for submergence and drought tolerance, for saline conditions, and for pest resistance. Tidal wetland rices must tolerate the stresses associated with acid and saline soils.

The mechanisms of inheritance of the physiological traits needed by specially adapted rices are complex, and plants must be sensitive to daylength so that they flower at the right time in relation to flood and rainfall patterns. Only one crop a year can be grown in the field and development of improved varieties is very slow. Because of the diversity of the environments, each new variety may have only a limited number of ecological niches, and plant

Sources of nitrogen for deepwater rice

We are using nitrogen balance studies to examine the fate of nitrogen in deepwater rice systems. In preliminary results, the nitrate nitrogen content before flooding in the top 60 cm of a soil with pH 5.5 averaged 4-5 ppm; it was only 2-3 ppm in a soil with pH 4.0. After flooding, both nitrate and ammonium levels were very low. Crops planted in soils with higher pH are normally less responsive to applied nitrogen.

Cropping systems for deepwater rice areas

In Thailand, sesame and mungbean sown at the beginning of the wet season and harvested before floods arrive yielded up to 1.5 tons per hectare when sown alone and up to 1 ton when sown as a mixture with deepwater rice. In 1989, intercropped rice yields were good and total returns higher than when only rice was grown. But in 1990, the rice crop was lost because of unusually high floods. That highlights the insurance deepwater rice farmers gain when they include a preflood crop in their system.

IPM for deepwater rice

Reducing pest damage could substantially improve deepwater rice production. IRRI and collaborating national programs have developed a coordinated system of integrated pest management research for deepwater rice areas of South and Southeast Asia, in an Asian Development Bank-supported project.

Scientists in Bangladesh, India, and Thailand studied the ecology of major pests and their natural enemies, the epidemiology of foliar diseases and nematodes, and production prospects. The yellow stem borer—the major deepwater rice pest in all areas—causes 15 to 20 percent yield loss (its incidence varies between years and among sites). Ufra disease caused by the stem nematode *Ditylenchus angustus* is the second major pest.

Rice varieties Rayada 16-06, Rayada 16-09, Bazail 65, and CNL 319 were found to have some resistance to infection by the ufra nematode. A breeding program to exploit that resistance has been initiated in collaboration with Assam Agricultural University.

One interactive research area is IPM and farming systems. Deepwater rice-fish culture offers farmers an opportunity to increase income. But a prerequisite of successful fish culture is the absence of harmful chemicals. In field trials on rice-fish culture in deepwater ricefields in eastern India, more than a half-ton of fish were produced per hectare, without reducing rice yields. The income from the fish can compensate farmers for not using pesticides on their rice.

Combined tolerance of rice for salinity and submergence

A common climatic hazard in tidal wetlands rice is submergence due to flash floods from freshwater rivers. On the other hand, such floods help reduce soil salinity in the tidal flats.

Current-available rice varieties with tolerance for salinity do not survive submergence. But some salinity-sensitive varieties can recover after being submerged for up to 12 days. We set out to combine these traits into one breeding line. The pre-breeding work started with hybridization of salinity-sensitive FR13A with several elite salinity-tolerant lines. The resulting progeny were screened for tolerance for both stresses.

We identified 11 promising lines for testing under controlled conditions and in floodprone farmers' fields. The best line is IR42598-B-B-B-B-12-1-2, derived from breeders must handle many different plant types.

Besides breeding, regional research on deepwater rice in Thailand, India, Bangladesh, and Vietnam focuses on plant nutrition, cropping systems, integrated pest management, and development of rice-fish culture. Cropping systems also must be adapted to specific combinations of a wide range of soil, climate, and flooding conditions. Increased understanding of the soil characteristics and processes that cause mineral deficiencies and toxicities will help in improving soil management techniques. ■

the cross FR13A/IR17494-32. With its improved plant type (semidwarf, high-tillering) and tolerance for both submergence and salinity, it should be an ideal donor in national programs to improve traditional tidal wetland rices.

Modified shuttle breeding for deepwater rice

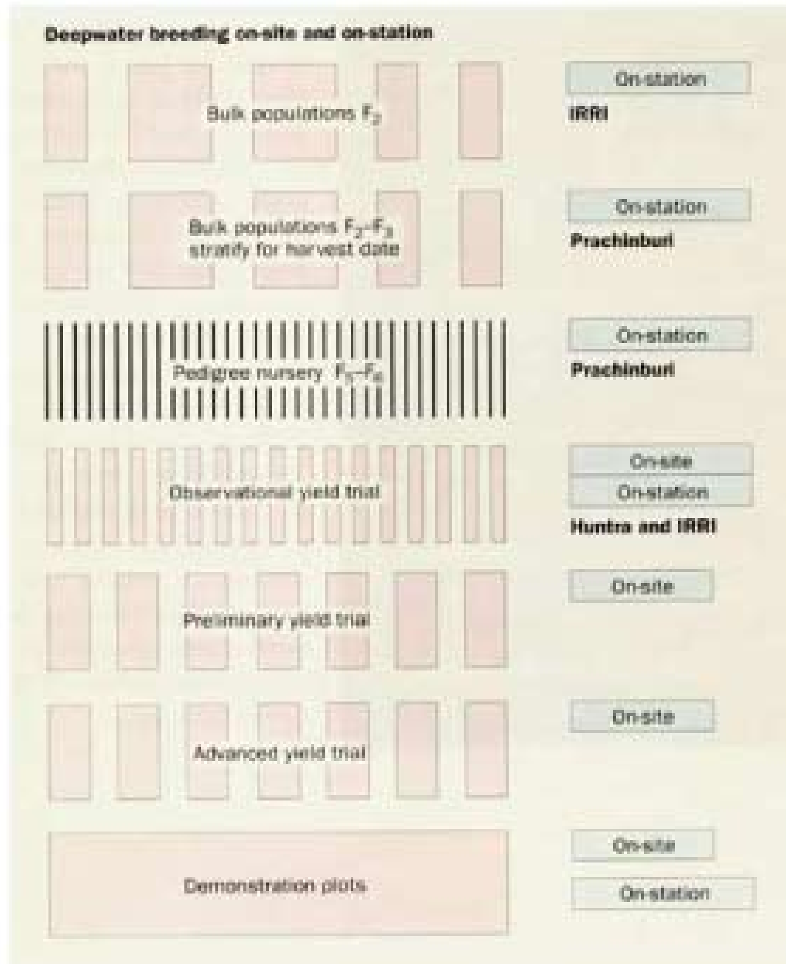
Shuttle breeding usually involves moving successive generations of seeds back and forth between sites, to take advantage of climate differences that enable scientists to grow more than one generation a year. This is not feasible in breeding long-duration deepwater rices: there is no time for seed handling between first season harvest and second season planting.

In IRRI's work to develop improved breeding lines, we use a modified schedule that involves only one change of location. Seeds of promising second-generation populations screened for survival in deepwater tanks at IRRI are taken to Thailand for field testing and to stratify the third to fifth generations for flowering date.

In 1990, we tested 445 second generation materials and grew 1,526 advanced lines in observational yield trials in shallow and deep water at IRRI. Bulk hybrid populations and 5,907 advanced pedigree nursery lines were grown at a maximum water depth of nearly I meter at Prachinburi, Thailand. Another 820 lines were grown at water depths up to 1.5 meters, in a preliminary yield trial at Huntra. ■

Deepwater rice farmers can grow nonrice crops in conjunction with deepwater rice during the 3-4 months before the floods arrive; that increases their income.

A modified shuttle breeding scheme halves the time needed to select and test an improved breeding line for deepwater rice areas.



Cross-ecosystems research

Cross-ecosystems Research Projects for 1990-1994

Germplasm evaluation
- Methods for evaluating conserved germplasm

Genome manipulation
- Saturated genetic maps and cloned genes
- Novel genetic variation
- Tools to improve breeding efficiency

Ecosystem characterization and impact analysis
- Biophysical/socioeconomic characterization
- Management/productivity simulation
- Socioeconomic and environmental impact
- Rice market projections and policy analysis

Improved pest management
- Plant-pest interactions
- Insect resistance and allelochemicals
- Biology-physiology of pests and beneficial organisms
- Pest population dynamics
- Seedborne pathogens and seed contaminants

Plant-soil-water-nutrient processes
- Soil, water, fertilizer dynamics/metabolic processes
- Processes at the root-soil interface

Rice quality and biomass utilization

Work in the cross-ecosystems program takes a long-term view. Many IRRI projects have only recently been made possible by newly discovered basic knowledge and newly developed specialized tools. They are addressing strategic problems that have impeded the resolution of important constraints to rice production.

Refined equipment and techniques for rapid analysis of complex traits in large numbers of samples and for intensive probing of microscopic features and processes are being used in the field and in the laboratory. Significant results already are extending rice knowledge and improving experimental techniques.

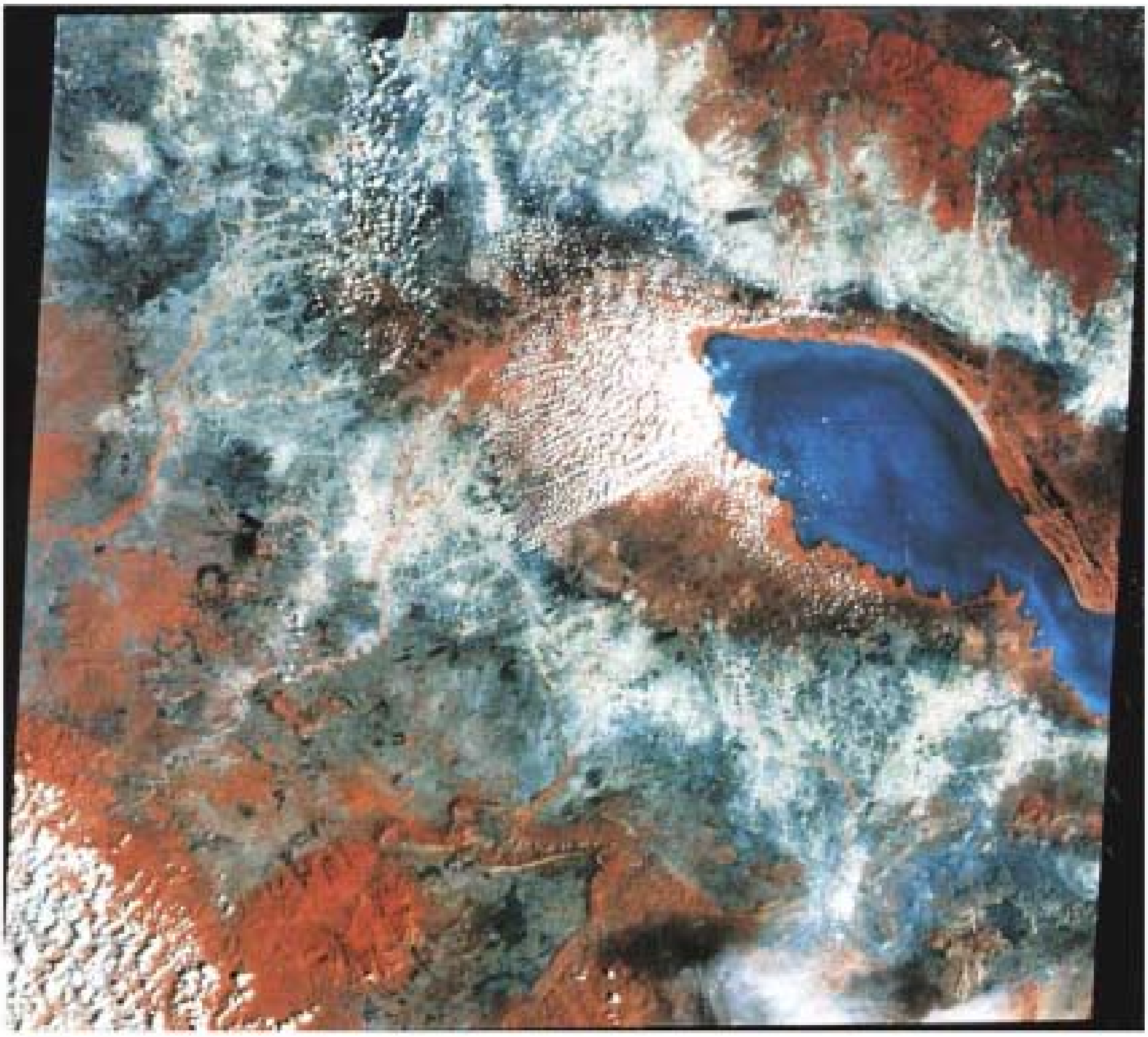
The use of computers, datalinks, and international telecommunications has increased substantially. This year, we started using computerized geographic information systems (GIS) in rice ecosystems analysis. Intensive use of these tools will be a strong feature of work to set research priorities that reflect regional constraints and opportunities.

Interdisciplinary, collaborative, and farmer-oriented diagnostic field surveys have been developed that rapidly provide useful data. Field and farmer monitoring over time will lead to assessments of the sustainability of different rice-based systems.

Procedures used in biotechnology entered the rice science world late in the 1980s. Even further improvements in rice germplasm can be expected to result from the development of rice genetic maps and from using innovative methods of gene transfer.

Improved diagnostic ability has led to the recognition of nutritional disorders and of diseases and insects (and some of their races and biotypes), as well as nematodes, that were not known in the 1960s. Now we can address the integration of methods to control diverse pest complexes and the interaction of pest control with soil and crop management strategies.

Computerized geographic information systems (GIS) is adding a new dimension to the analysis of different rice ecosystems. This shows a scan of Cambodia, made from the Thailand Remote Sensing Center.



Issues of equity are important in rice research: women, in particular, contribute up to 80 percent of the labor involved in rice farming.

Within the last few years, novel studies of the interactions of pest stresses and nutritional and physical stresses, and their effects on rice yields have become possible. Simulations of these effects and interpretation of the underlying mechanisms (such as the influence of plant nutrition on disease or insect resistance in rice) are under way. Simulations of soil, water, and crop processes also are expected to improve breeding strategies and accelerate development of crop management technology.

Within the last decade, research on issues of equity, for women and other members of rice farm households, has been strengthened. Research into value-added processing at home and postharvest processing equipment appropriate for use by women is accelerating.

Other research thrusts that have been continuous throughout IRRI's first 30 years report substantial advances this year and show promise for accelerated advances within the next 10 years. In-depth evaluation of accessions in the International Rice Germplasm Center collection is under way to identify genes of agronomic importance, such as those for stem elongation ability, tolerance for abiotic stresses, and resistance to difficult-to-control pests. This year, we identified three accessions with resistance to tungro disease. Efforts to identify accessions with resistance to important insects is supported by the development of a new insect diet that, for the first time, allows long-term rearing of the stem borers needed in screening different rices for resistance.

Resistance to rice tungro disease among wild rices

Tungro can devastate rice crops in South and Southeast Asia. The disease is caused by two viruses transmitted by green leafhoppers. So far, some rice cultivars have been developed that are resistant to green leafhoppers, but none are resistant to the viruses themselves.

When green leafhopper-resistant varieties are planted in large, adjacent areas, the insect rapidly adapts to the cultivars. That can result in new tungro epidemics. The long-term solution is to develop varieties resistant to the viruses. But the traditional rice cultivars identified so far as having some resistance or tolerance can still be infected.

We decided to look for additional sources of resistance among the wild rices conserved in the International Rice Germplasm Center. *Oryza latifolia* (IRRI Acc. 100169, 105141, and 105142) and *Oryza officinalis* (IRRI Acc. 101155, 105220, and 105365) show resistance to tungro. We are now examining whether this is resistance to the tungro viruses, tolerance for the infection, or resistance to the vector.

A data base of rices with virus resistance

We have a new rice virus data base (RVDB) that organizes information on genetic resistance to rice tungro, ragged stunt, and rice grassy stunt diseases. The system provides researchers with access to current information as rice accessions stored in the International Rice Germplasm Center are evaluated.

For rice tungro, about 20 percent of the world germplasm collection has been screened for visible symptoms, with 560 accessions identified as being susceptible to less than 30 percent infection. Most of these partially resistant lines originated in South Asia.

For rice ragged stunt, 17 percent of the collection has been screened; of the 336 accessions resistant to the virus, most are lines collected from Southeast Asia.

For rice grassy stunt, two virus strains are involved: RGSV-1 and RGSV-2. About 10 percent of the collection has been screened for RGSV-l; 809 accessions with resistance originate primarily from India, Indonesia, and the Philippines. A number of varieties from the Middle East and Africa also show resistance to RGSV-1. Eight accessions from China and India are resistant to RGSV-2.

The accessions identified can be used to impart resistance to new breeding lines being developed at IRRI and in national programs.

Crop management to minimize yield losses to stem borers

Well-managed crops of modern high-tillering rice varieties appear able to tolerate relatively high levels of stem borer damage.

We tested IR72, transplanted at two rates, with only 3 and with 12 seedlings per hill, with and without added nitrogen. Even without stem borer damage, yields without nitrogen were lower. With even mild stem borer damage, yields were much lower. With nitrogen, yield losses occurred only with high stem borer damage. Transplanting more seedlings per hill resulted in much less yield loss, because more tillers were left to compensate for whiteheads.

Soil characteristics that affect post-rice crop tillage

In tropical and semitropical flooded rice systems, a field planted to rice in the rainy season may be planted to a legume or cereal crop in the dry season. Tilling the drained ricefield is an important turnaround operation in establishing the following nonrice crop.

IRRI's procedure for measuring grain hardness has been shown to be a good predictor of consumer appraisals of eating quality. Designs of IRRI harvesters and rice mills were further improved.

A long-term multicountry study analyzed the impact of modern rice technology on different ecosystems. Now attention is turning to study of the interactions of rice market forces, international prices, and national agricultural policies. ■

Strip tillage using chisel tines to loosen deep soil 30-50 cm below the surface increases dry season crop yields. But there is a critical depth. Tillage that is too deep is counterproductive; it ends up compressing rather than loosening the soil.

We used a new mathematical technique to analyze field measurements of tillage force, soil loosening, and specific soil resistance. The critical depth in a Typic Hapludoll silty clay loam soil that had been puddled was around 25 cm, somewhat shallower than earlier estimates. The critical depth increased as the soil dried. The implication is that it is desirable to get mechanical characterizations of soils, so that depth of tillage after puddled rice can be kept to an agronomic and economic minimum.

Restriction Fragment Length Polymorphism (RFLP) studies

IRRI has taken a leading role in transferring techniques of molecular biology from basic research laboratories to an applied breeding program. IRRI researchers are tagging agronomically important genes via linkage to mapped isozyme and RFLP markers in a newly renovated laboratory.

Genes for resistance to the whitebacked planthopper and to blast disease and for photoperiod sensitivity have been located on the RFLP map for rice in a collaborative IRRI-Cornell University project. Work is continuing to locate genes for resistance to bacterial blight, blast, tungro viruses, green leafhopper, and brown planthopper; tolerance for salt and drought; wide compatibility; and grain quality.

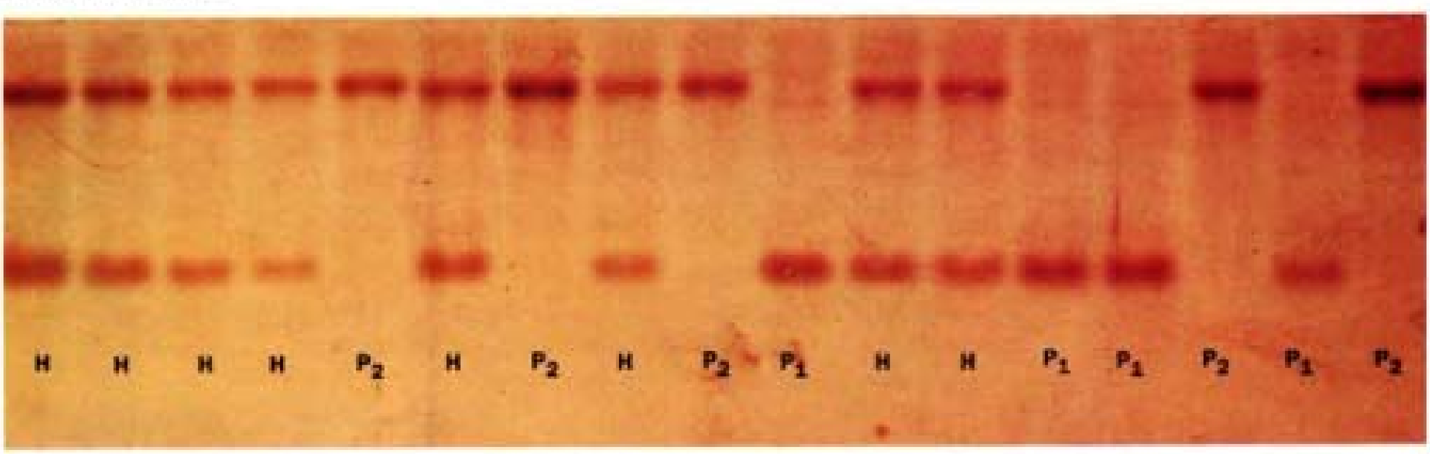
We have effectively adapted and refined nonradioactive, enzyme-based labeling techniques. This offers an important alternative to using radioactive ^{32}P for visualizing DNA probes.

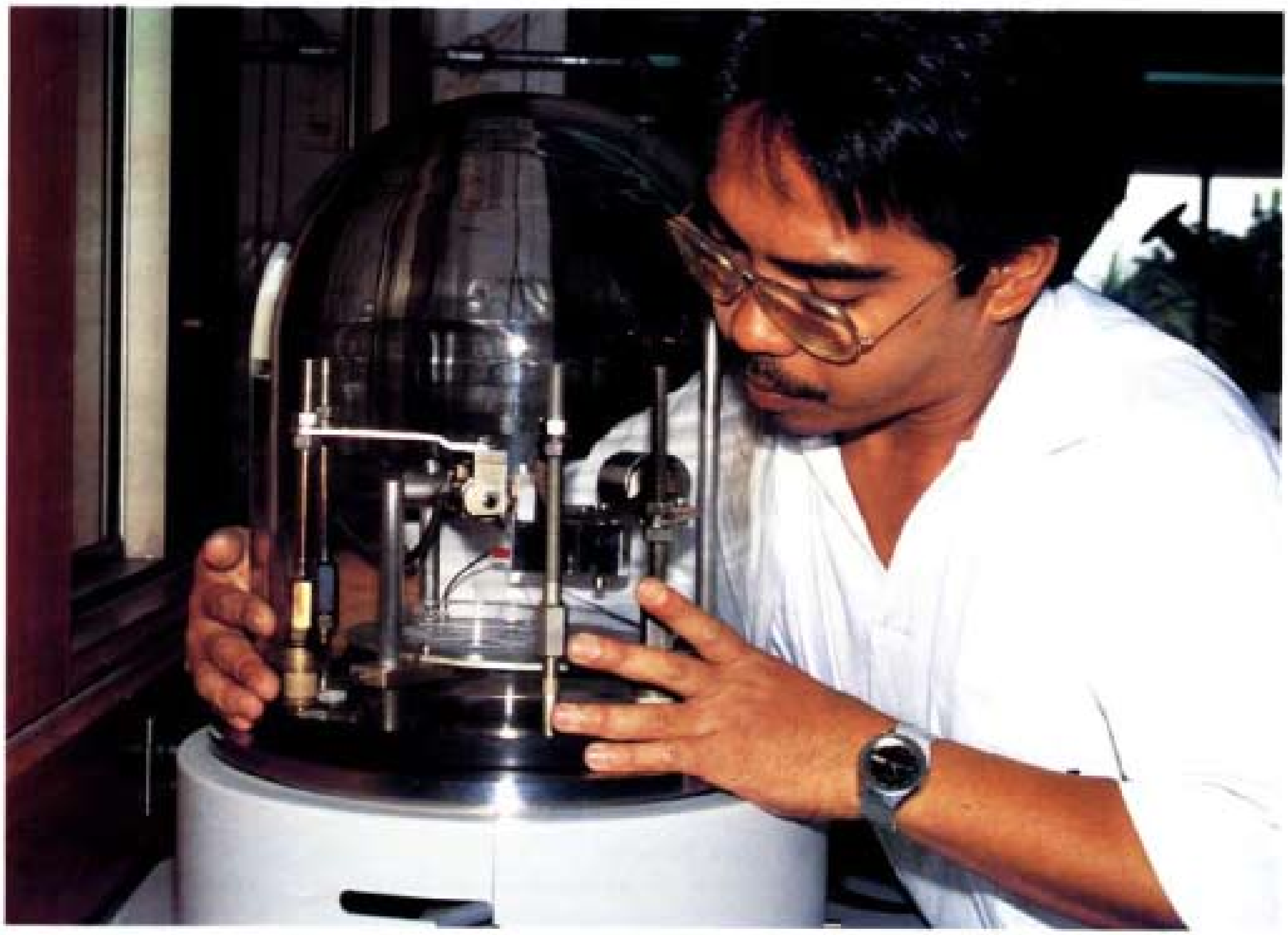
Alien gene transfer

Wild species of rice are important reservoirs of useful genetic variability, but transferring alien genes involves special techniques (such as embryo rescue). We have transferred genes for resistance to brown planthopper from the wild species *Oryza australiensis* and *O. latifolia* into elite breeding line IR31917-45-3-2-2.

Alien gene introgression for nontargeted plant traits (awns, growth duration, stigma, apiculus, and hull color) has been detected in advanced generation progeny. RFLP techniques are being used to characterize the alien gene introgression and to locate genes of interest.

RFLP pattern visualized using a nonradioactive digoxigenin-labeled DNA probe (RG-118) on a second-generation population derived from crossing IR36 (P1) and Ma Hae (P2). Heterozygotes (H) and parental types (P_1 and P_2) can be easily distinguished.





Biotechnology procedures are expanding knowledge in rice genetics and enabling innovative methods of gene transfer.

We now have elite breeding lines with genes for disease and insect resistances derived from *O. officinalis, O. minuta, O. australiensis,* and *O. latifolia.*

Rearing yellow stem borer on an artificial diet

Most improved rice varieties have low resistance to the yellow stem borer. Studies on the mechanisms of resistance found in some traditional rice cultivars and wild rices have lagged because of the lack of test insects. The need was for an artificial diet to use in rearing highly monophagous yellow stem borer larvae.

We adapted a diet used to rear beet armyworms by adding rice pollen. Now we can rear yellow stem borer moths that lay nearly 90 percent viable eggs. Volatile and nonvolatile allelochemical fractions of rice plants can be added to determine larval feeding preferences and the effects of feeding on rice growth and development. That will help identify resistance in different cultivars.

Rhizosphere studies

New techniques we are using to directly study the rhizosphere—that narrow zone of soil influenced by the rice roots—enabled us to see oxidation of soil iron by different parts of the rice root system.

The roots of rice grown in a box were separated from the soil by a nylon cloth plate that shut off root penetration but allowed material transfer. The 2-5 mm of soil adjacent to the root but outside the nylon plate was taken as rhizosphere soil. Oxidized iron precipitated onto the nylon plate.

We are using work like this to supplement mathematical modeling of the rhizo-sphere. With modeling, we can study the rhizosphere at a much finer degree of resolution than is possible through direct experiments. That helps us determine how root-induced changes affect nutrient transformations and uptake. And that will give us insights for breeding more efficient cultivars and for developing more economic management practices.

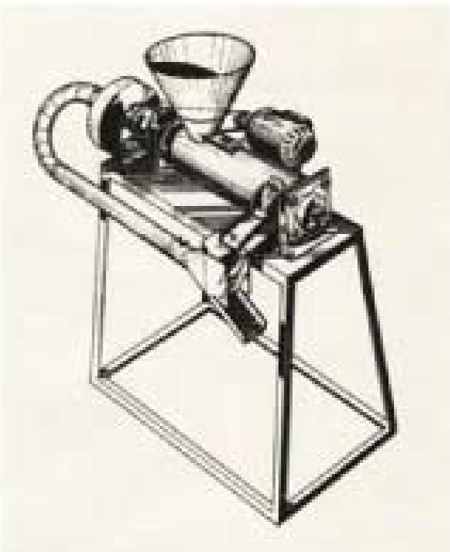
Screening for cooked rice hardness

Rice consumers in different parts of the world prefer different qualities in their rice: different flavor, different cooked texture. Rice breeders build these qualities into their crosses by using parents whose grain has the desirable characteristic. Screening involves selecting for both visual and physical grain properties.

The breeders rely on physicochemical tests to measure starch properties, verified by taste tests or by instruments that measure the hardness or stickiness of freshly cooked rice. But these tests do not differentiate breeding lines with similar starch properties.

IRRI has been using an Ottawa Texture Measuring System cell on an Instron Food Tester Model 1140 to measure cooked rice texture. We collaborated with the Institute of Food Science, Cornell University, to validate this procedure. IRRI's measurements correlate with food scientists' measures. But high-amylose, soft-gel rices still have hardness values similar to those of intermediate-amylose rices: freshly cooked rices with similar starch properties are not differentiated, even though consumers perceive the differences.

We are exploring whether accelerated aging of cooked waxy and nonwaxy rices before measuring their hardness will maximize texture differences.



A compact, low-power micro rice mill can process 60-80 kg rice per hour.

A small-size rice mill for small farmers

In most of Asia, a large part of the rice harvest is eaten by the farming family or sold in the local market. A farm family finds custom milling of relatively small amounts of rice expensive and wasteful; most of the rice is hand-pounded by the women in the family.

We set out to design a compact, low-power rice mill that would give optimum milled rice recovery and head rice percentage. The prototype is based on a Chinese design. It has a small hulling rotor supported by a self-aligning bearing on each end. In initial tests, capacity was 60-80 kg rough rice per hour, with 65-70 percent milling recovery and 50-70 percent head rice, depending on rough rice quality. The power requirement was 0.5-0.7 kW.

The prototype was evaluated by farmers in Central and southern Luzon, Philippines. Farmers who want to market milled rice said the capacity was too low, and suggested an output about three times faster. We built and tested a mill with a capacity of 160 kg per hour. The benefit-cost ratio was highest for the smaller mill: 3.8 versus 1.6 and 0.8 for the larger mill run by electric motor or diesel engine. The smaller mill also had the best milling recovery. ■

International programs

IRRI helps catalyze progress in rice science by enabling researchers all over the world to interact. Some interactions are routine: the Institute's list for mailing publications contains nearly 12,000 names of agencies, libraries, and individuals. Some are more specific: IRRI researchers are working on collaborative projects with scientists affiliated with some 400 other research institutions worldwide.

Some interactions strengthen less advanced national research systems, through the training of national scientists at IRRI and in key universities and through IRRI scientists stationed in-country to work directly with national scientists. Some involve research in countries that have target rice-growing environments, with collaborative work conducted by IRRI and national scientists specified in memoranda of understanding.

The exchange of technologies and information gains added impetus through projects that dissolve national borders and political barriers. Networks are major factors in meeting this objective.

Rice germplasm is central to international interaction. The International Rice Germplasm Center at IRRI is the world's major conservator of rice genetic resources. Its information-filled data banks and the seeds of some 86,000 rices and wild rice relatives it maintains in storage are accessible to rice breeders everywhere who are working to improve the varieties available to farmers.

IRRI's international programs facilitate technology evaluation and adaptation as well as the interactions of rice scientists. They pave the way for the meaningful, productive, timely, and cost effective research needed to resolve current and anticipated barriers to stable and sustainable rice production. ■

IRRI's International Programs in training, knowledge exchange, and support to national agricultural research systems are in the midst of exciting explorations of new opportunities. They promise to lead to even more challenging and productive international collaboration.

With the experience gained over 30 years, IRRI is shifting from technical support of developing agricultural research systems to collaboration with ever-strengthening national programs, in true partnerships based on mutual

F. A. Bernardo, deputy director general for international programs, conferring with Department of Agriculture officials in Bhutan.

respect and confidence. We expect this enhanced relationship to greatly increase rice research output relevant to the particular problems of different rice ecosystems.

We are moving away from offering all training courses at IRRI toward supporting training courses offered by national programs in-country, with the support of IRRI staff and IRRI alumni. This will unleash valuable training potential in national programs and encourage new forms of cooperation. It also will release resources devoted to the traditional courses at IRRI to meet new demands for training in more upstream research.

We are encouraging potential degree scholars to take their course work in key national universities, and opening more opportunities for thesis research fellowships at IRRI. The time IRRI scientists spend helping thesis research fellows is an investment toward future partnerships for collaborative research. Many national program leaders also rise from IRRI alumni ranks.

IRRI is taking steps to install on-line scientific information exchange through global communication systems while we continue to publish and distribute our reliable scientific information exchange periodicals, *Rice Literature Update* and the *International Rice Research Newsletter.*

Few realize what it takes, in terms of resources, technical skills, and diligence, to keep a genebank functional and truly useful to scientists around the world. While we continue to collect and conserve land races, and rejuvenate and multiply old but important seed stocks, we are increasing efforts to collect samples of unprotected wild species. They are invaluable soarces of the rare genes needed for further improvement in rice varieties.

The functional networks coordinated at IRRI continue to receive unwavering support from the national programs. The International Network for Genetic Enhancement of Rice (INGER), with funding from UNDP, coordinates the exchange and evaluation of elite breeding lines around the globe. Rigid evaluation in different rice environments over 15 years has led to the release of 184 breeding lines as varieties in 50 countries. These contributed to substantial increases in rice production worldwide. As more research efforts are directed to unfavorable rice environments, INGER is adjusting so that rice farmers in the less favorable rice ecosystems, who benefited less from "green revolution" technologies, may reap the benefits of ecosystem-specific technologies.

More than 100 Asian Rice Farming Systems Network (ARFSN) projects are under way in 17 countries. ARFSN develops crop diversification technology to increase the incomes of rice farm families and improve their nutrition. Many profitable cropping systems, such as legumes, maize, or wheat before or after rice, have been identified. Collaborating scientists are shifting more attention to unfavorable rice ecosystems.

The International Network for Soil Fertility and Sustainable Rice Farming (INSURF), with support from the Swiss Development Cooperation, continues its experiments on sustainability issues. A shift to sub-networks is sharing leadership and tapping national program strengths.

IRRI and some national programs are collaborating in a new Integrated Pest Management (IPM) for Rice Network. This will promote management practices that minimize the use of chemical pesticides and enhance environmental safety.

Common interests and overlapping objectives of network activities are encouraging us to explore ways to enhance their interaction and integration.

In Latin America, we continue to collaborate with the International Center for Tropical Agriculture (CIAT), and participate in jointly organized workshops, planning meetings, and field activities, to foster even better understanding and to increase research cooperation.

In Africa, the Consultative Group on International Agricultural Research (CGIAR) has given the West Africa Rice Development Association (WARDA) the mandate as the regional center for rice research in West Africa. IRRI is committed to providing support in areas where it has a comparative advantage, even as we increase attention to the growing demand for rice in eastern, central, and southern Africa. We have made new efforts to develop, in collaboration with the South Africa Centre for Cooperation in Agricultural Research (SACCAR), a program that will help unleash the vast potential for rice production in the region.

This is only a few of the new directions taken in our collaborative work with institutions worldwide. IRRI staff have the experience, expertise, and determination to succeed in this continuing adventure, in strong partnerships with national programs and with the encouragement and support of concerned donors.

Fernando A. Bernardo
Deputy Director General for International Programs

Germplasm conservation and dissemination

Germplasm Conservation and Dissemination Projects for 1990-1994

Conservation and dissemination

- Expand collection and increase knowledge
- Improve seed multiplication and help strengthen national programs for germplasm preservation

Seed health

- Maintain and improve standards

New initiatives in interrelated facets of rice germplasm conservation and dissemination are fostering better interaction among scientists involved in conserving, evaluating, and using germplasm worldwide. In 1990, inter-genebank collaboration was strengthened through an international workshop. Data bases on International Rice Germplasm Center (IRGC) accessions and their management were improved to enhance the exchange of information among IRRI scientists and with national rice research programs. Seed distribution was streamlined and increased, both within IRRI and worldwide.

With growing commitment to collect, conserve, evaluate, and make available rice germplasm, rice science has a continually expanding bank of genetic building blocks from which materials can be drawn for use in developing improved rice varieties. ■

Inter-genebank workshops promote collaboration

The first IRRI-sponsored workshop on genetic conservation of rice was held in 1977, when few national genebanks even existed. A major recommendation of the participants in that workshop was to share the responsibility for germplasm protection and use among international and national programs. In 1983, a second workshop reviewed progress in rice germplasm conservation and established a five-year agenda for collection.

Today, the community of rice scientists involved in the conservation of rice germplasm is much larger. Within the last 10 years, many national programs have acquired new seed storage facilities and better-trained staff. Improved information transmission technology worldwide offers opportunities to interlink these expanded resources.

Recent advances in biotechnology are driving a new wave of requests for the seeds of exotic germplasm, particularly the wild relatives of rice that are rich sources of useful genes, but difficult to find, difficult to conserve, and hence not as well represented in germplasm collections as traditional varieties and improved lines.

These developments and the rapidly changing environmental situation were the impetus for a third international workshop on rice germplasm conservation, held in May 1990 at IRRI with cosponsorship by the International Board for Plant Genetic Resources (IBPGR). Participants worked to improve inter-genebank coordination and to establish an agenda for germplasm collecting activities, conservation of seeds, and exchange of valuable accessions during the next 10 years.

Inter-genebank information exchange

Seed samples of threatened populations of wild rices were collected in Papua New Guinea.

Development of standardized and streamlined documentation has led to more effective communication and technical information exchange among germplasm workers. In 1990, the IRGC expanded its passport and evaluation data bases. A new software program IRRIGEN, written to run on microcomputers, will enable national genebanks to elaborate the descriptions of their own collections and to use computers more extensively in their multifaceted activities.

Inter-genebank collaboration in germplasm evaluation

The systematic evaluation of conserved germplasm plays a key role in the success of IRRI's breeding work. The 15-year-old Genetic Evaluation and Utilization (GEU) program resulted in broad screening, critical evaluation, and in-depth studies of a large portion of the IRGC acquisitions. Rices conserved in the IRGC that have made outstanding contributions to the development of improved varieties include:

Silewah from Indonesia was found to have excellent cold tolerance at the heading stage. In a 1990 visit to the village where this traditional variety was first collected in 1974, we found that it is no longer planted by farmers. Now, it is available only from genebanks.

E425 from Senegal was used at IRRI as a parent in breeding the new high-yielding dryland variety Makiling recently released by the Philippine Seed Board for planting in the uplands.

Oryza officinalis from Sukothai, Thailand, is a good source of resistance to several pests and diseases; it has been used in a number of crosses to derive high-yielding lines with multiple pest resistance.

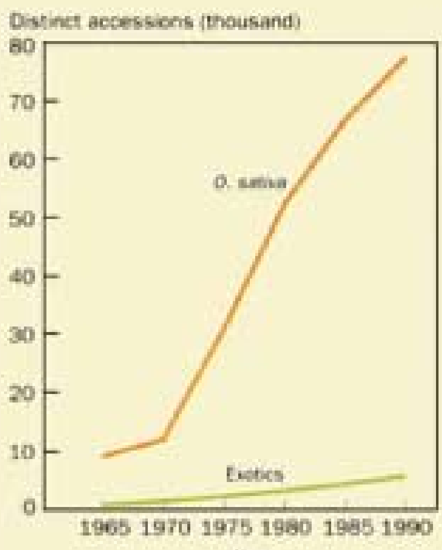
The International Rice Germplasm Center has an expanding bank of genetic building blocks, from which materials can be drawn to develop improved rices. They are kept in medium- and long-term storage for maintaining viability.

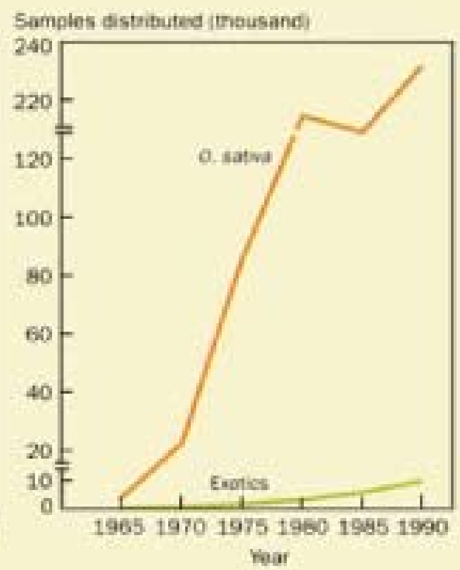
Cooperation in collecting germplasm

Recent Asia-wide cooperation in collecting unpreserved germplasm is resulting in increased understanding of the importance of wild rices and their conservation, both in situ and ex situ. Collaborative collecting activities were carried out in Myanmar and Papua New Guinea (among other countries), where little wild rice had previously been collected. Finding populations of *O. ridleyi* and *O. schlechteri* in Papua New Guinea was a highlight of the 1990 collecting activities. This is timely progress in protecting these precious genetic resources and making them available for evaluation and use in breeding programs.

Germplasm distribution and exchange

Worldwide distribution of germplasm from the IRGC increased sharply in 1990. More than 50,000 seed packets were sent to researchers and evaluaters, in response to requests from 266 scientists in 40 countries. ■





Accessions stored in the IRGC gene bank, and their use by rice breeders, continue to accelerate.

Information and knowledge exchange

Information and Knowledge Exchange Projects for 1990-1994

Library
- Improve services and expand international access

Scientific publication
- Further improve publication of research results
- Increase copublication

Rice data bases
- Improve data bases and data base services

Conferences and workshops
- Help focus meetings to support research program objectives

Public awareness
- Increase awareness of and support for rice research

The importance of communication to effective international research has been central to IRRI's mission from the very beginning. Three of the seven objectives set out in the Institute's founding mandate are explicit about its role:

• To publish and disseminate research findings and recommendations of the Institute;

• To establish, maintain, and operate an information center and library which will provide, among others, for interested scientists and scholars everywhere a collection of the world's literature on rice; and

• To organize or hold periodic conferences, forums, and seminars, whether international, regional, national, or otherwise, for the purpose of discussing current problems and for developing research strategies for elevating and stabilizing rice yields under different environments.

These responsibilities were reaffirmed in IRRI's objectives developed in the 1989 document *Toward 2000 and beyond*: "To generate and disseminate rice-related knowledge and technology . . ."

Activities in the Information and Knowledge Exchange Program blend to fulfill IRRI's obligation to provide current information to rice scientists, policymakers, research supporters, and scholars everywhere in the world. ■

An important means of scientific exchange involves scientists from many parts of the world, meeting together to evaluate current research and plan future collaboration.

Rice Literature Update **helps rice scientists stay current with research documentation.**

Library and documentation

Six times a year, *Rice Literature Update* listing the latest rice publications added to the IRRI Library and Documentation collection is mailed to nearly 12,000 scientists and libraries worldwide. The issues published in 1990 averaged 1,500 citations each. More than 300 requests for reprints from 39 countries were filled, with 23,300 duplicated pages of rice literature.

The Rice Literature Search System (LSS), essentially a computerized card catalog, now lists 170,000 original documents in the IRRI collection. We also acquired, and use, more than 2 million 1984-1989 abstracts of the U.K.-based CAB-International on CD-ROM (compact disc: read-only memory), along with LSS, AGRICOLA, and other data bases, for computerized literature searches. In 1990, 351 literature searches were done.

The IRRI Library monograph collection, the world's largest for rice, now totals more than 93,000 titles. Serial titles reached a maximum of 4,022, but 50 subscriptions were discontinued to cut costs.

Improving research commmunication

IRRI published 11 new books in English in 1990, and distributed almost 83,000 copies of major IRRI publications. About 34,000 were in English; the remainder were translations copublished by national system cooperators.

Four hundred key national rice libraries receive one complimentary copy of each new book written in English. Sales of earlier IRRI books finance publication of new titles in English. National programs and donors finance the printing and distribution of translations, through IRRI's copublication project.

Nearly 250,000 copies of IRRI periodicals were distributed to some 12,000 addresses in 146 countries in 1990.These included the *International Rice Research Newsletter*, the *IRRI Research Paper Series*, and *Rice Literature Update*.

IRRI's historical *Annual Report* was changed to an annual *Program Report* in 1990, with a new format to reflect the Institute's ecosystem-based program structure.

IRRI also published, on behalf of all centers, a 730-page 1989 catalog *Publications of the International Agricultural Research and Development Centers*, and a *1990 Supplement*. The catalogs are probably the largest compilation of titles on agricultural science and production in the developing countries. The combined catalogs will be made available on computer disc in 1991.

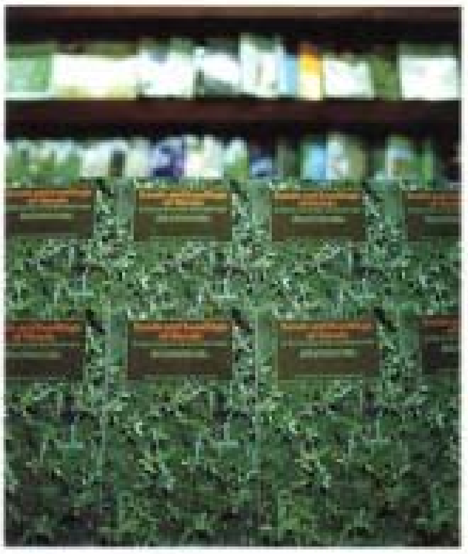
IRRI and the International Center for Living Aquatic Resources Management (ICLARM) organized the International Agricultural Research Center Book Exhibition at the 1990 Beijing Book Fair in China.

One new IRRI book designed for copublication was released: *Seeds and seedlings of weeds in rice in South and Southeast Asia*. Nine translations of IRRI books were copublished in 1990. *A Farmer's Primer on Growing Upland Rice* was published in Hindi, Vietnamese, and Spanish. *A Farmer's Primer on Growing Rice* is now available in 38 languages. At least 139 editions of 33 IRRI books have now been copublished in 44 languages in 29 countries.

Conferences and workshops

IRRI was host to or cosponsor of 32 international conferences, workshops, and meetings in 1990, with a total of 1,374 participants. The second International Rice Genetics Symposium attracted 300 participants. The 1990 International

Seeds and seedlings of weeds in rice in South and Southeast Asia is the latest IRRI book published in English, but designed for inexpensive translation and copublication.



A 1-hour public television feature—Seeds of Hope—produced by a U.S. public television studio is being distributed on Beta and VHS cassettes for airing by TV stations in rice-producing countries.

Rice Research Conference held in Seoul, Republic of Korea, had 200 participants. Other conferences and workshops covered diverse topics, such as rodent control in rice and gender analysis in farming systems research.

Improving public awareness

IRRI produced 37 news releases in 1990, and disseminated them to about 1,000 media worldwide. The releases were published in newspapers and magazines at least 200 times. We also assisted 108 visiting journalists.

One major cooperation was with WNET/Thirteen, a public television station in the U.S. that produces programs for national and international telecast on the Public Broadcasting Service. WNET produced a 1-hour feature, *Seeds of Hope*, for the series INNOVATION. It features IRRI's strategies for promoting sustainable agricultural productivity in developing countries, IRRI programs in Cambodia, and collaborative projects with Cornell University.

At least 26 U.S. public television stations are scheduled to air *Seeds of Hope* in 1991; Australian television will also air the program. WNET has given IRRI permission to share the film with TV stations in rice-producing countries with which we collaborate.

One new activity was publication of *IRRI 1989*, the first annual corporate report that replaced the *IRRI Research Highlights* series. We continue to publish the *IRRI Reporter* for donors, supporters, and friends of the Institute.

Rice data bases and computer services

Renovation of Computer Services facilities was completed in 1990, with funding from the Japanese Government. Installation of a headquarters-wide Local Area Network (LAN) began. That will enable 24 hour-a-day electronic communication within IRRI headquarters. A Wide Area Network (WAN) connection already allows IRRI scientists to communicate with colleagues around the globe. As soon as the local area network is complete, the WAN will enable IRRI staff and, later, national program collaborators to access information stored in IRRI data bases.

The *Rice Virus Data Base* was completed in 1990. The data model developed for this application is the basis for additional data bases being developed in other subject areas. Scientists enter their observations into a subject-specific table that links to other tables (for viruses, to the germplasm table of the genetic evaluation project). This allows a researcher to access, manipulate, and analyze relevant data from other disciplines.

The *Rice Workers Data Base* contains information about 10,000 people, IRRI's worldwide clients. The primary data were gathered through our computerized mailing-list access system. It can be merged with other data bases, such as the *International Bibliography of Rice Research*, to give a clearer picture of IRRI clients and their research interests and needs. ■

Networks

NETWORK Projects for 1990-1994

International Network for Genetic Evaluation of Rice (INGER)

- Exchange and evaluate improved cultivars from national programs and international agricultural research centers
- Exchange and evaluate sources of genetic resistance to biological, soil, and climatic stresses

Crop and resource management networks

- International network on soil fertility and sustainable rice farming (INSURF)
- Asian Rice Farming Systems Network (ARFSN)

Networks strengthen collaboration, not just between IRRI and other institutions, but among the national rice research programs and institutions themselves. The participating scientists plan network activities to expand and accelerate the effects of their contributions. The exchange of technologies, the development of practical methodologies, the exchange of data, and the interactive interpretations increase the productivity of their individual efforts.

The networks headquartered at IRRI include INGER, focused on genetic evaluation; INSURF, focused on alleviating soil problems; and ARFSN, focused on farming systems technology. A fourth network, focused on IPM for rice, was formed in 1990. ■

An IRTP (now INGER) advisory group visited the stem borer screening nursery at IRRI in 1976. More than 900 improved varieties with IR parentage have been released to farmers in 38 countries.

Screening nurseries for improved upland breeding lines help identify improved upland rice breeding lines that are adapted to acidic soils; yields can be 70 percent higher than those of traditional varieties.

International network for genetic evaluation of rice (INGER)

INGER links the rice improvement programs of national systems and international centers. It acts as a low-cost catalyst for germplasm evaluation and utilization and provides opportunities for rice scientists in different countries to work together on common concerns.

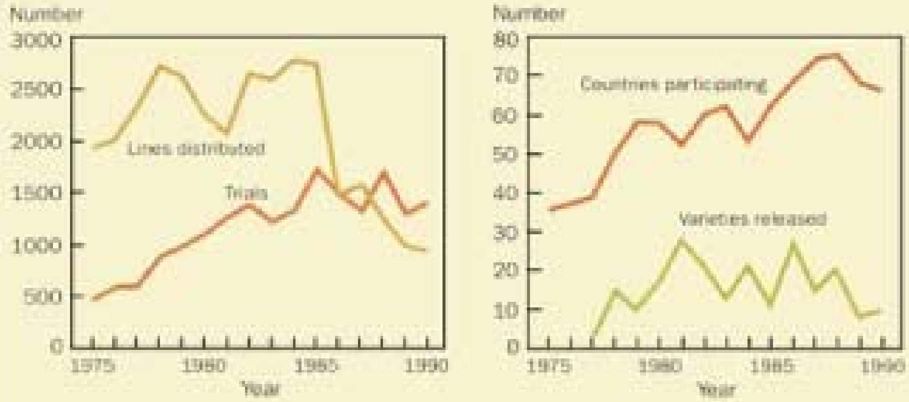
The network began in 1975 as the International Rice Testing Program (IRTP), with support from the United Nations Development Programme (UNDP). It was restructured into INGER in 1989. Throughout its evolution, it has been an effective mechanism for pooling efforts and resources to exchange and evaluate elite genetic breeding materials over a wide range of environments. Scientists in some 75 countries have participated in the network at some time; this year, about 60 countries are represented.

INGER has three regional components: in Asia, Africa, and Latin America. Overall coordination is at IRRI. Advisory committees with members selected from national programs guide global and regional activities. Groups of member scientists visit research sites in different countries every year. Those joint site visits provide stimulating forums for the interaction of national and international rice scientists.

Specific modules within different yield and genetic evaluation nurseries, preliminary hot-spot screening, and genetic donor kits increase the efficiency of the testing program. In-depth analysis of data from multilocation trials provides leads for follow-up research at national and international levels.

Since 1975, INGER entries originating from 21 countries and from international centers have been released to rice farmers in different agroecological regions in 50 countries. A total of 184 varieties have been named, although some are the same lines with different national labels. Most have contributed to significant

Dissemination of improved genetic materials from different sources for testing in the International Network for Genetic Evaluation of Rice.



increases in rice production. More than 4,500 entries have been used as donors of important traits in national hybridization programs.

This joint effort of national and international rice breeding programs should continue to be an efficient mechanism for transnational scientific cooperation, with strengthened multidisciplinary linkages. Exchange and evaluation of improved genetic materials help extend genetic diversity and minimize potential threats of pest epidemics.

An IRRI liaison scientist stationed at the International Center for Tropical Agriculture (CIAT) in Colombia coordinates the INGER regional program for Latin America. The pedigrees of 143 improved rice cultivars released by Latin American countries 1971-1989 have been traced to their original land race parents. IR8 was found in the pedigrees of 75 percent of the improved varieties released.

Coordination of INGER-West Africa has been transferred from the International Institute of Tropical Agriculture (IITA) to the West Africa Rice Development Association (WARDA).

Asian rice farming systems network (ARFSN)

ARFSN enables IRRI and national scientists to work together to identify more productive rice-based farming systems for different agroecologies. Member scientists are working in 17 national programs.

They use a collaboratively developed methodology for on-farm systems research. Activities at different participating sites are designed to improve components of the methodology and to identify appropriate environment-specific technologies.

ARFSN began in 1976, with cropping systems research at five sites in three countries. Livestock and aquaculture were added in 1983, refocusing the work toward increasing income through diversified farming systems. Now, research sites represent a full range of rice-growing ecologies. Collaborative research projects include cropping systems testing, rice-fish farming, crop-animal systems, women in rice farming, impact of farming system, varieties of upland crops grown before and after rice, rice - wheat cropping rotations, and establishing upland crops after rice.

Cropping pattern trials are conducted in 11 countries, at sites representing irrigated, rainfed lowland, upland, and deepwater ecosystems. These trials in collaboration with extension agents and farmers help identify cropping patterns that are agronomically and economically better than traditional farmer practices.

In most cases, the trials involve increasing cropping intensity by planting short-duration, high-yielding crops in the rice fallow season. The second or third crops are usually legumes. Some forage crops intercropped with food crops produce good grain yields, provide animal feed, and serve as green manure for the next rice crop.

Interest in rice-fish farming is picking up fast. Research activities are strong in China, Indonesia, and Thailand. The number of on-farm research sites has increased in Bangladesh, India, Indonesia, Korea, the Philippines, and Thailand.

Data from seven sites indicate higher net returns from rice-fish systems than from rice alone. In most cases, rice yields were higher with fish than without fish, and in Indonesia, rice with fish has lower stem borer and weed infestations.

The impact of farming systems research was studied at selected sites in six countries. In Indonesia, new rice-fish technology increased per capita farm income by about 34%. While expenditures for food did not change, purchase of non-food items increased.

In Nepal, both rainfed lowland and upland farmers who adopted recommended cropping patterns grew more vegetables, and that improved the nutrition of farm family members. In the Philippines, traditional rice-only farmers had higher average rice yields, but farmers who diversified had higher incomes.

Several rice-related technologies that directly concern women farmers are being tested in seven countries. In a Philippine integrated pest management survey, women in an irrigated rice farming area in Laguna Province were found to be more heavily involved in vegetable production and marketing than in ricefield operations. They participate in decisions about pesticide use, seed varieties, and hired labor for rice and provide the labor for weeding, harvesting, irrigating, and marketing of vegetables.

This led the IPM research team to include women in planning meetings, training activities, and farmers' field experiments. That has helped significantly reduce insecticide use in rice as well as in vegetables.

At a rice-animal farming system site in northeast Thailand, hybrid chickens were introduced to improve egg and broiler production. The additional labor required for improved poultry production led male family members to help in what was previously an all-female enterprise. Farm income was more evenly distributed across the year and family nutrition improved.

Most farm household women in Santa Barbara, Pangasinan, Philippines, are involved in processing glutinous rice for special rice delicacies. The crop is grown on a portion of the village's ricelands and processed for sale before the Christmas season.

In a 1987 survey, we found that women did most of the hard work of hand pounding and winnowing the rice. A centrifugal minihuller designed by IRRI appeared to be a suitable labor-saving tool. But the machine and the 5-hp gasoline engine cost about $400—too expensive for a single rice-farming family. The village farmers' association acquired a community machine with support from the provincial government.

This year, we went back to reassess work loads. The labor and time involved in processing are drastically reduced when the new machine is used. In 1987, it took five people nearly 4 hours to dehull and winnow 24 kg of rice by hand; in 1990, the machine did the task in less than an hour. This year, 66 percent of

Monitoring tours enable network collaborators to compare notes and harmonize testing and evaluation activities.

the 16 tons of rough glutinous rice processed in the village went through the new rice huller. Our economic analysis is that the mechanical huller will pay for itself in six years.

Income in a majority of the rice-farming families has increased, particularly that of the women processors. Gross value added for processing glutinous rice during September and October 1990 was 46% higher than in 1987.

The women also evaluated the varieties of glutinous rice grown. They found IR65, first introduced in 1986, comparable to traditional varieties in taste and texture, with much higher yields. The area planted to IR65 has quadrupled, and other villages have begun planting IR65. Some 80% of the rice that went through the new huller in 1990 was IR65.

International Network on Soil Fertility and Sustainable Rice Farming (INSURF)

An informal collaboration organized in 1974 to speed work that would increase the efficiency of fertilizers applied to rice became the International Network on Rice Fertilizer Efficiency in 1976. It was renamed the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) in 1980. INSFFER had a wider scope: fertilizer efficiency plus nitrogen fixation studies and concerns about long-term soil fertility.

In 1987, the network reoriented its thrusts toward work to achieve sustainable rice farming. That broadened focus is reflected in its third name, the International Network on Soil Fertility and Sustainable Rice Farming (INSURF). Participating scientists develop holistic technology for improved and sustainable soil fertility.

Major activities involve collaborative trials to evaluate integrated nutrient management. Long-term fertility studies continue. Special attention is given to managing fertility in adverse soils. A training program strengthens the research capabilities of scientists in participating countries. Site visits and planning meetings enable scientists from different countries to plan stronger research agenda.

The latest development in INSURF's continuing evolution to resolve newly visible concerns using newly available methodologies is the organization of sub-networks. Each sub-network has a lead center, which does more of the strategic and applied research, with satellite sites for testing and adapting new technology. This decentralization should improve intercountry collaboration and help synchronize priority research across national systems.

Five sub-networks went into operation this year, with a joint planning meeting at IRRI. High priority research includes using green manure and azolla, managing soil fertility in acid upland and infertile rainfed lowland soils, and using sulfur and other micronutrients efficiently.

Integrated Pest Management for Rice Network (IPM-R)

Integrated pest management uses the best mix of tactics to control crop pests at the least cost. Control measures are selected for their effectiveness, ecological soundness, economic feasibility, and social acceptability. A central aspect is reducing the use of chemical pesticides.

New pest control technologies must maximize natural biological balance mechanisms with minimal undesirable effects to beneficial organisms and to the environment. Specific ecological studies, research on pest populations, and development of new control technologies, tactics, and strategies are essential. Equally important is a better understanding of the biological, technical, social, economical, and political dimensions of pest problems.

Effective IPM involves farmers, extension specialists, and policymakers. Research must focus on developing tools for each decisionmaker, taking into account each sector's differing role in the complex process.

The IPM-R Network was initiated in 1990, with coordination at IRRI and participating scientists in China, India, Indonesia, Malaysia, the Philippines, and Thailand. They met in July to establish the initial network organization and to identify common research interests.

Each country has organized a research team of scientists and extension specialists. Interdisciplinary representation involves plant protection sciences, social sciences, and development communication. The first phase involves in-country workshops. IPM research team members are being trained in systems analysis techniques used to describe and analyze pest problems. Each workshop focuses on the important pests in the country, to identify related research, extension, and policy priorities relative to their control.

At the workshop in Thailand, the important pests identified are the brown planthopper and rice ragged stunt virus. In Indonesia, the priority pest is the white stem borer. Workshops in China, India, the Philippines, and Malaysia are scheduled in 1991. ■

Training

Training projects for 1990-1994

Degree and postdegree training
Group training courses

More than 6,000 scientists have been trained at IRRI so far, in degree programs, on-the-job internships, and short-term group training courses. In 1990, trainees included 169 scholars and nondegree interns, 282 short course trainees, and 51 postdoctoral fellows from all over the world (see list).

As universities in many countries strengthen their graduate training capabilities, especially for MS degrees, IRRI is beginning to reduce the number of full scholarship grants for degree candidates accepted from those countries. Priority is shifting to support more Ph D thesis research work at IRRI and to strengthen collaboration among national universities and IRRI .

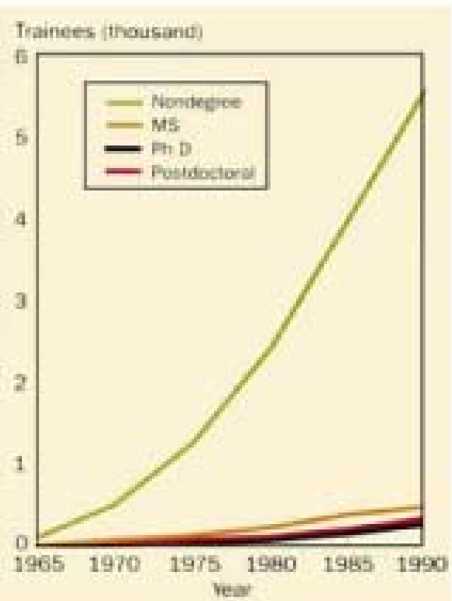
This is supported by collaborative agreements between IRRI and more than 30 universities worldwide. Course work is completed at one of these universities under the guidance of a faculty member there, thesis research is conducted at IRRI under the supervision and guidance of an IRRI scientist.

Development and implementation of group training courses are linked intrinsically to technology devèlopment: the technologies generated by IRRI and national rice research programs are reflected in the courses offered.

The first group training at IRRI, in 1964, was a six-month rice production course that focused on

practical skills. In 1969, a cropping systems course focused on growing other crops after rice. In 1975, three more courses were offered: Genetic Evaluation and Utilization (GEU), Agricultural Engineering, and Agricultural Economics. In 1978, Irrigation Water Management and Fertilizer Evaluation for Rice courses were added.

As national systems expand their research capacity, the demand for new skills is increasing. Recent courses include Rice Biotechnology, Biological Control in Rice-based Cropping Systems, and Simulation and Modelling. Concurrently, demand for the more basic courses continues from national systems in early stages of technological development. IRRI now has a dual responsibility, to offer training in both upstream and downstream research approaches at the same time.



Numbers of scientists and rice technicians trained at IRRI, 1960-1990.

Participants in IRRI training programs 1990

Thesis-only research scholars (8 MS, 32 Ph D)	40
Course work and thesis scholars (31 MS, 54 Ph D)	85
On-the-job research trainees	39
Collaborative research scholars (1 MS, 4 Ph D)	5
Postdoctoral fellows	51
Group course trainees (17 courses)	282

This is threatening to overtax the Institute's limited resources. To overcome this problem, we are developing an approach to decentralize training. As national systems strengthen their research capacity, they also increase their ability to conduct training in-country. IRRI assists national programs to mobilize training resources, involve IRRI training program alumni, and facilitate course development by sharing training materials and expertise. With IRRI support, these new training opportunities will be open to participants from countries lacking such programs.

Research consortia will be the pathway for linking training to IRRI's ecosystem-based research programs. Short-term training, knowledge sharing, in-service training, and refresher training are expected to be opportunities at selected key sites. ■

An important part of IRRI training activities is field work.

Country and regional projects

Country and Regional Projects for 1990-1994

In Asia
In Africa
In Latin America and the Caribbean

Responsibilities of IRRI's International Programs Management Office, established in 1990, include the following:

• Ensuring relevant and quality research and training activities in country and regional projects.
• Coordinating scientific and administrative support for country and regional projects from IRRI headquarters.
• Designing, appraising, and reviewing country and regional projects.
• Recruiting IRRI scientists and facilitating their work in the project to which they are assigned.
• Providing liaison with national program officials and scientists.
• Providing liaison with country and regional project donors and related international organizations, in coordination with IRRI's Liaison, Coordination, and Planning unit.

IRRI scientists are stationed in Bangladesh, Cambodia, Colombia (for Latin America), Egypt, India, Indonesia, Lao PDR, Madagascar, Myanmar, Nigeria (for Africa), and Thailand. We also collaborate through donor-funded projects with Bhutan, Sri Lanka, and Vietnam. ■

In Bangladesh, deepwater rice farming is an important part of the agricultural economy.

Bangladesh

Botanical pest control has been an important part of the collaboration between the Bangladesh Rice Research Institute (BRRI) and IRRI for 6 years. The research is supported by BRRI core funds and by the Asian Development Bank.

BRRI evaluated extracts of 14 local pesticidal plants, and found five that were highly effective in controlling eight major rice pests. In a follow-up, BRRI-IRRI collaborated to test derivatives of the neem tree *Azadirachta indica* against rice insect pests.In greenhouse experiments, spraying with 10-20% neem oil was highly effective against a number of foliage-feeding insects. In field trials, plots sprayed with 10% neem oil suffered significantly less damage from leaf rollers and tungro disease than did untreated plots.

Several commercial bioactive products from neem have been developed in several countries. BRRI-IRRI collaborating scientists now plan to evaluate those products against the major rice insect pests in farmers' fields.

Bhutan

Phase 1 of the Bhutan-IRRI Rice Farming Systems Project funded by IDRC was completed 31 March 1990, and phase 2 began in April. An important thrust is developing national ability to conduct baseline and diagnostic surveys. These surveys serve a dual purpose: as a basis for setting research priorities and for impact assessment. A survey in March-April in the low-altitude rice-growing zone of Gaylegphug District, southern Bhutan, identified causes of low rice yields and productivity that indicate a range of research needs.

Cambodia

Cambodia's traditional rice varieties have survived centuries of catastrophic droughts and floods. But 10 years ago, it appeared that they might have been lost to political upheaval. In the early 1970s, farmers and their families were abandoning their fields and fleeing ahead of advancing Khmer Rouge forces. By 1975, the area planted to rice had declined from 2.5 million hectares to only 500,000 hectares.

During the period of immense hardship and suffering that followed, human dislocation was severe. Refugee farm families ate their seed rice, and larger seed stocks were eaten by rats. In 1979, the first relief workers into Phnom Penh feared that the centuries of natural selection of traditional rices under Cambodia's harsh agricultural environment had disappeared.

In March 1981, a representative of the relief agency OXFAM asked IRRI if any Cambodian varieties were conserved in the International Rice Germplasm Center collection. IRGC offered seeds of 687 Cambodian varieties, mostly collected in the early 1970s.The Cambodian agricultural system, decimated by years of war, could not handle that many, and requested seeds of only 35 major cultivars. Since then, as the country's capacity to test, evaluate, and multiply varieties has increased, IRGC has provided the seeds of 562 traditional Cambodian varieties to the country where they evolved.

In 1989, traditional rice varieties, planted late and damaged by drought, still yielded about 1 ton per hectare. That helped the country avoid a new famine. That same year, a new joint Cambodia-IRRI collecting effort added new accessions.

Those rices were evaluated during 1990 wet season at Prey Pdhau Research Station for agronomic and grain quality characters and for resistance to pests and diseases. Cambodian and IRRI scientists found enormous genetic diversity that, along with the germplasm already preserved, will be valuable in rainfed lowland rice improvement programs in Cambodia and elsewhere.

Duplicate sets of the full Cambodian collection are stored in Cambodia and in the IRGC long-term preservation facilities at IRRI.

Since 1989, an agronomist, plant breeder, technology transfer specialist, and an administrative officer have been assigned in Cambodia, under a 3-year grant from the Australian International Development Assistance Bureau (AIDAB). The Cambodia-IRRI Project places special emphasis on developing low-cost means of improving soil fertility and identifying more productive rice varieties for Cambodia's major rice ecosystems.

During 1990, we surveyed Bhutanese farmers to identify the causes of low rice yield and to establish research priorities.

Egypt

The Egypt-IRRI project, supported by a grant from USAID, has for the last 3 years emphasized strengthening the Rice Research and Training Center (RRTC) at Sakha, Kafr El Sheikh. RRTC is now operational, training extension workers and demonstrating more productive rice technology in addition to conducting research. Yields of 1990 on-farm demonstration plots were 48 percent higher than national average yields.

India

The India-IRRI collaboration has a long history and is extensive. A major effort is to develop, evaluate, and refine a methodology for ecosystem analysis and farming systems research for rainfed environments in eastern India. This work is designed to strengthen the Ford Foundation-supported Farming Systems Research/Extension Network and the IFAD-supported Indian Council of Agricultural Resarch (ICAR)-IRRI collaboration.

In-depth analyses of ecosystem characteristics were completed at several sites. This enables extrapolation and crop adaptation studies across a number of agronomic environments. The basic framework for comparative analysis has been prepared and mapping has begun.

Representative farming systems at selected sites in rainfed lowland, upland, and deepwater rice ecosystems are being characterized in detail. The resulting data bases on land resources and use and on economic and social factors will be used in developing a method for predicting the best use of land. Data on social factors includes labor demand and supply during the cropping season, the role of women in the farming systems, and alternative income-generating opportunities.

Another major project in eastern India examines possibilities for improved pest management in deepwater rice, with support from the Asian Development Bank. Researchers are mapping deepwater rice areas, studying the population dynamics of major rice pests, testing rice-fish culture systems, surveying nematodes in ricefields, assessing crop losses to pests, and screening rice cultivars for resistance to important insects and diseases.

Indonesia

Indonesia-IRRI collaboration intensified in 1990, with the launching of a major new initiative on upland rice. An IRRI research fellow is assigned to Sitiung Station in West Sumatra, the area proposed as a key site in an upland rice research consortium to be organized in 1991. Collaborative trials in 1990 evaluated technologies for improving soil fertility and rice cultivars for tolerance for acid upland soils.Other scientist-to-scientist collaborative topics included nitrogen fertilizer use efficiency, phosphorus sources in lowland rice, soil and water management, biological control of rice diseases, development of hybrid rice technology, crop modeling, and collecting wild rice germplasm.

Lao PDR

About one-fourth of Lao PDR's 4 million people practice shifting cultivation, mainly of rice. Their plots in the uplands comprise one-third of the country's cropped area. Official government policy aims at eliminating shifting cultivation within the next 10 years.

The Lao-IRRI Rice Research and Training Project began in 1990, with support from the Swiss Development Cooperation. Two IRRI scientists arrived in Vientiane in late 1990 to work with national scientists under this project.

The first activity was diagnostic surveys of shifting cultivation in Luang Prabang and Oudomxay provinces in northern Laos. The data are enabling scientists to better understand farmers' perspectives, diagnose farmers' field production problems, and set research priorities.

Low and declining soil fertility, more frequent cropping cycles, and difficult pests (weeds, rats, birds, wild pigs) are affecting rice yields and system sustainability. Farmers cannot adopt innovations demanding more labor and more purchased inputs. The forest ecosystem has been degraded by logging, burning, and rice monocropping. The potential for environmental rehabilitation through natural succession is minimal.

Improved fallow could be an intermediate step leading to crop diversification, agroforestry, and settled agriculture. An IRRI agronomist stationed in Luang Prabang and Lao scientists will begin collaborative research on the system in 1991 wet season.

Madagascar

Phase 3 of the Madagascar-IRRI rice research project began in 1990, with support from USAID. High priority work in collaboration with FOFIFA is on alleviating the soil fertility constraints in the high plateau.

Cultivars with superior tolerance for iron toxicity have been identified in screening trials at Manjakandriana. The best management technology identified in cropping systems work includes using an improved variety, applying low rates of phosphorus by root dipping, shallow transplanting, and applying low rates of nitrogen through urea.

Work on rice diseases, particularly blast, show that rice straw left in the field or used as roofing material for farm structures are sources of pathogens that can infect rice crops in the next season.

Myanmar (Burma)

A February 1990 review of the Myanmar-IRRI Farming Systems Project supported by IDRC noted progress in identifying more efficient cropping systems, rice breeding, small-scale farm mechanization, and human resource development.

Areas for future collaboration include further development of cropping patterns and component technology; classifying the country's agro-ecosystems; farm-level diagnosis of production constraints; developing in-country training capacity; oeveloping improved rice cultivars for unfavorable rainfed lowland, deep water, and low temperature regions; and mechanization for dry seeding.

Sri Lanka

The Sri Lanka-IRRI collaboration is supported by the Swedish Agency for Research Cooperation with Developing Countries (SAREC). IRRI scientists consult with Sri Lankan scientists in areas of mutual interest. Opportunities for Sri Lankan scientists to undertake training under IRRI sponsorship have been increased, as has participation in international meetings.

In September 1990, the Department of Agriculture, Sri Lanka, hosted a major congress on rice research during which participants discussed strategies for rice research and development for the next 10 years.

Thailand

Testing integrated pest management technologies in farmers' fields is one of many Thai-IRRI collaborative research activities. In September 1990, a severe brown planthopper infestation devastated 250,000 hectares in central Thailand. The most damage was to rice variety Suphanburi 60. An IRRI entomologist worked with Thai scientists to devise an IPM strategy for dealing with the problem that affected 80,000 farms.

Vietnam

Research collaboration with Vietnam involves soil fertility improvement, varietal improvement, and agricultural economics with the support of AIDAB. IRRI and IFDC continued to collaborate with the Institute of Soils and Fertilizers (ISF) and Cantho University on ways to improve the effectiveness of urea for lowland rice. In the Red River Delta, researchers at ISF found that high floodwater temperature and pH in summer resulted in much higher partial pressure of ammonia in summer than in spring. This suggested a high potential for ammonia volatilization in summer. Future collaborative research with ISF will focus on examining alternative timings of urea application, integrated use of urea with farmyard manure, and climatic and soil constraints to effective use of N fertilizers.

Eastern, central, and southern Africa

A November 1990 regional workshop "Rice Research and Production in the SADCC Region and in Neighboring Countries" in Lusaka, Zambia, was jointly organized by the Southern Africa Coordinating Centre for Agricultural Research (SACCAR) and IRRI. Scientists from Burundi, Kenya, Madagascar, Swaziland, Tanzania, Zambia, and Zimbabwe participated.

They pointed out the rapidly increasing demand for rice in the eastern, central, and southern Africa region. Although current rice area and production are low throughout most of the region, the potential is large for developing hydromorphic depressions known as *dambo* or *vlei* for rice production.

Workshop participants recommended increasing collaborative research and training in the region, and asked SACCAR and IRRI for support in strengthening the scientific and technical capabilities of rice researchers. ■

classifications. In the short term, the new structure does not have substantial cost implications. Over the long term, Institute management hopes—depending on funding—to be able to increase IRRI nationally recruited staff salaries to the equivalent of the third quartile of the local professional job market.

New performance appraisal systems for internationally and nationally recruited staff implemented this year are providing a springboard for training staff in performance management systems. Workshops and other training programs are aimed at improving productivity and decisionmaking, and at helping staff members become better decisionmakers within their position levels.

Visitor and conference services

More than 30,000 persons from 59 countries visited IRRI headquarters in Los Baños, the Philippines, this year. Some 800 government officials , including one head of state and a number of ambassadors, were briefed on IRRI programs and toured laboratories, greenhouses, and the research farm.

The large majority of the visitors—more than 25,000—were students and teachers, and nearly 2,500 were farmers and agricultural technicians.

All visitors view a multiprojector slide show explaining IRRI's philosophy and work. Many tour the experimental farm. Those with special interests are briefed by selected IRRI scientists about work in progress. Most of these briefings must be fitted in and around that work: IRRI has no central exhibit area for visitor information.

In addition, more than 1,000 participants and observers attended 21 different meetings: conferences, workshops, planning meetings, program reviews. In May, three international conferences were in session during one 2-week period.

Operations

The major achievement of IRRI operations in 1990 was preparing the reorganization of IRRI's experimental plots into a centralized Research Farm. Three new IRRI Research Farm buildings sited in a central location are occupied by the Farm and Grounds superintendent and five unit officers.

These new buildings not only enabled us to rationalize Research Farm operations, but also freed up space and improved workingconditions in the old Service Building.

Physical renovation of the Research Farm is progressing. This year, we widened and straightened the main irrigation stream beds running through the farm, installed drainage and irrigation pipe in 70 percent of the wetland area, developed a 6-hectare plant quarantine screening block, set up a 2-hectare sprinkler irrigation system, and rebuilt the irrigation system for deepwater rice plots.

A Plant Protection Advisory Committee has established guidelines for those working with pesticides on the farm. ■

IRRI's work plan for 1990-1994 established a new management structure, one that called for major changes in finance, administration, and operations. Developments in 1990 include

- Decentralization of responsibilities within the research and international programs.
- Increased centralization of research farm operations, farm workshop services, physical plant services, transport and logistics, warehousing and stores.

Michael F. L. Goon, deputy director general for finance and administration, discusses human resource development with nationally recruited staff managers.

- Reorganization of human resources development, finance, materials management, and telecommunications.
- Computerization of program budgets, to provide financial feedback and monitoring.
- Stabilization of the computerized accounting and administration systems.
- Development of staff through training in decisionmaking, research management, productivity, performance appraisal, and job-related skills.
- Introduction of systems and procedures to enhance staff motivation and performance.
- Implementation of efficiency studies of activities in food and housing services.
- Implementation of cost-effective repair and maintenance programs.

We believe that our support system is now stronger and more capable of delivering the staff and resources needed to implement the work plan. With the new structure, our ability to provide cost-effective support services will continue to grow.

The challenges ahead include establishing more precise priorities and speeding up the decisionmaking process. Purchasing functions will be streamlined, and internal communication improved.

Greater delegation of authority will broaden leadership responsibilities and simplify staff work. New middle level managers will be trained in research management skills and in ways to foster team building. This will strengthen human resource development.

Improved financial reporting will increase efficiency and help reduce operating costs overall. Rehabilitating IRRI's aging facilities will improve safety and their usefulness. This is just part of the improved physical resources needed to support research.

The aftermath of the late 1989 separation program, which reduced by 720 the number of positions at IRRI, provided a new challenge: to do more with less. Our plans for the years ahead are geared toward meeting that goal. Despite being fewer in number, IRRI staff will strive to make the Institute a more cost-effective organization. All staff members are committed to making their contribution to attaining IRRI's objectives.

Michael F. L. Goon
Deputy Director General for Finance and Administration

Administration

Over the years, as IRRI's research grew in size and complexity, logistical support also increased. Now the focus is on increasing efficiency and improving service.

In 1990, 29 budgeted research and international program projects were launched and two major buildings were under construction. IRRI bought well over $5 million worth of goods and services, at an administrative cost of less than 3 percent of purchased value, using fewer personnel and much less staff time than before.

That performance will improve even more when purchasing and materials control merge into a Materials Management Unit. This will consolidate 10 scattered warehouses and reduce supply inventories.

To support the constant interactions necessary for smooth functioning, information systems at headquarters and in the Manila office were merged into one management unit. We are striving to eliminate defects in equipment and hardware and to improve personnel performance, to keep IRRI in touch with the world at lower cost.

Policies, procedures, and habitual practices are being codified into a central, ready-reference IRRI policy handbook, and appropriate manuals are being written. Special information stations throughout headquarters are helping improve internal communication.

Human resources development

IRRI is operating with a much leaner staff now, a consequence of the 1989 staff reduction program. As each staff member shouldered more responsibility in 1990, distortions in the job hierarchy were perceived. A job evaluation task force, with membership from both internationally recruited and nationally recruited staff, has been working to rationalize the structure of positions in the Institute.

Its basic recommendation was to establish a generic position framework for nationally recruited staff. Job classifications are being grouped into research and nonresearch categories, with the nonresearch group subdivided into supervisory and nonsupervisory.

A long-term staffing pattern is being designed to parallel reorganization. Job descriptions will match staff responsibilities to generic job

The new centralized Experimental Farm buildings.

classifications. In the short term, the new structure does not have substantial cost implications. Over the long term, Institute management hopes—depending on funding—to be able to increase IRRI nationally recruited staff salaries to the equivalent of the third quartile of the local professional job market.

New performance appraisal systems for internationally and nationally recruited staff implemented this year are providing a springboard for training staff in performance management systems. Workshops and other training programs are aimed at improving productivity and decision-making, and at helping staff members become better decisionmakers within their position levels.

Visitor and conference services

More than 30,000 persons from 59 countries visited IRRI headquarters in Los Baños, the Philippines, this year. Some 800 government officials, including one head of state and a number of ambassadors, were briefed on IRRI programs and toured laboratories, greenhouses, and the research farm.

The large majority of the visitors—more than 25,000—were students and teachers, and nearly 2,500 were farmers and agricultural technicians.

All visitors view a multiprojector slide show explaining IRRI's philosophy and work. Many tour the experimental farm. Those with special interests are briefed by selected IRRI scientists about work in progress. Most of these briefings must be fitted in and around that work: IRRI has no central exhibit area for visitor information.

In addition, more than 1,000 participants and observers attended 21 different meetings: conferences, workshops, planning meetings, program reviews. In May, three international conferences were in session during one 2-week period.

Operations

The major achievement of IRRI operations in 1990 was preparing the reorganization of IRRI's experimental plots into a centralized Research Farm. Three new IRRI Research Farm buildings sited in a central location are occupied by the Farm and Grounds superintendent and five unit officers.

These new buildings not only enabled us to rationalize Research Farm operations, but also freed up space and improved workingconditions in the old Service Building.

Physical renovation of the Research Farm is progressing. This year, we widened and straightened the main irrigation stream beds running through the farm, installed drainage and irrigation pipe in 70 percent of the wetland area, developed a 6-hectare plant quarantine screening block, set up a 2-hectare sprinkler irrigation system, and rebuilt the irrigation system for deepwater rice plots.

A Plant Protection Advisory Committee has established guidelines for those working with pesticides on the farm. ■

1990 financial statements

To the Board of Trustees of
The International Rice Research Institute

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, 1990, and the related statement of sources and applications of funds for the year then ended. Our examination was 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. The financial statements of the Institute for the year ended December 31, 1989 were examined by other independent accountants whose report dated April 21, 1990 expressed a qualified opinion on those statements in relation to the matter noted in the second paragraph of this report and subject to the effects on the 1989 financial statements of the deferral of a portion of the special separation benefits paid to certain employees in 1989. As described more fully in Note 4 to the financial statements, the special separation benefits deferred in 1989 was amortized in full in 1990.

As explained in Note 2 to the financial statements, 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, which practices differ in some respects from generally accepted accounting principles. Accordingly, the accompanying financial statements are not intended to present financial position and results of operations in conformity with generally accepted accounting principles.

In our opinion, the financial statements referred to above present fairly the assets, liabilities and fund balances of The International Rice Research Institute as at December 31, 1990 and its sources and applications of funds for the year then ended, on the basis of accounting practices described in Note 2 to the financial statements consistently applied, except for the recognition of cumulative translation adjustments in 1990, as explained in Note 2.

Our examination was made for the purpose of forming an opinion on the basic financial statements taken as a whole. The supplementary schedule of sources and applications of core operations, capital, working capital and complementary projects funds for the year ended December 31, 1990 are presented for purposes of additional analysis and are not a required part of the basic financial statements. The information in such supplementary schedule has been subjected to the auditing procedures applied in the examination of the basic financial statements and, in our opinion, is fairly stated in all material respects when considered in relation to the basic financial statements taken as a whole.

Joaquin Cunanan & Co.
Makati, Metro Manila
March 16, 1991

Statement of assets, liabilities, and fund balances

	1990	1989
Assets		
Cash and Short-term placements	$27,103,415	$16,676,778
Accounts Receivable - Donors (Note 3)	3,797,893	7,444,601
Receivables from officers and employees	145,609	194,069
Advances to projects and other receivables	1,260,254	1,147,151
Inventory of materials and supplies	1,544,635	1,245,476
Prepaid expenses (Note 4)	310,122	2,152,352
Property and equipment (Note 5)	42,424,841	35,737,942
	$76,586,769	$64,598,369
Liabilities and fund balances		
Liabilities		
Accounts payable and accrued expenses (Note 6)	$19,074,383	$13,957,053
Loan payable (Note 7)	2,200,000	2,200,000
Other liabilities (Note 8)	1,737,291	1,623,126
	23,011,674	17,780,179
Grants applicable to succeeding years (Note 9)	6,905,918	7,912,435
Fund balances		
Invested in property and equipment (Note 5)	42,424,841	35,737,942
Core operations	-	217
Working capital	2,718,501	2,202,000
Self-sustaining operations	428,769	404,837
Communication and publications	416,012	560,759
	3,563,282	3,167,813
Cumulative translation adjustments	681,054	-
	46,669,177	38,905,755
	$76,586,769	$64,598,369

Statement of sources and applications of funds for the year ended December 31, 1990

(With comparative figures for the year ended December 31, 1989)

	1990	1989
Sources of Funds		
Core operations		
Grants	$26,271,254	$25,869,313
Earned income	1,259,813	1,170,857
Foreign-currency transaction adjustments	9,756	196,597
Balance- previous year	217	35,363
	27,541,040	27,272,130
Capital - transfer from core operations	2,977,887	1,450,000
Working capital		
Provision from operations	516,501	-
Transfer to core operations	-	(100,000)
Balance - previous year	2,202,000	2,302,000
	2,718,501	2,202,000
Complementary projects - grants	9,123,392	6,721,218
Self-sustaining operations		
Revenue	1,455,162	1,643,129
Balance - previous year	404,837	455,166
	1,859,999	2,098,295
Communication and publications		
Revenue	229,458	335,330
Balance - previous year	560,759	456,095
	790,217	791,425
Cumulative translation adjustments	681,054	-
	$45,692,090	$40,535,068
Applications of Funds		
Core operations	$27,541,040	$27,271,913
Capital	2,977,887	1,450,000
Complementary projects	9,123,392	6,721,218
Self-sustaining operations	1,431,230	1,693,458
Communication and publications	374,205	230,666
	41,447,754	37,367,255
Fund balances		
Core operations	-	217
Working capital	2,718,501	2,202,000
Self-sustaining operations	428,769	404,837
Communication and publications	416,012	560,759
Cumulative translation adjustments	681,054	-
	4,244,336	3,167,813
	$45,692,090	$40,535,068

Notes to Financial Statements December 31, 1990

Note 1 - General

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

As a 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 privileges and prerogatives, the following tax exemptions:

a) exemption from the payment of gift, franchise, specific, percentage, real property, exchange, import, export, documentary stamp, value-added tax 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) all gifts, contributions and donations to the Institute are exempt from payment of gift tax and considered allowable deductions for purposes of determining the income tax of the donor; and

c) non-Filipino citizens serving on the Institute's technical and scientific staff are exempt from payment of income tax on salaries and stipends in United States dollars (US$) received solely from and by reason of service rendered to the Institute.

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

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

The accompanying financial statements, expressed in US$, are prepared on the basis of accounting practices prescribed for international agricultural research centers seeking assistance from the CGIAR.

Except as regard to property and equipment and commitments, the CGIAR-prescribed accounting practices do not deviate substantially from generally accepted accounting principles.

A summary of the Institute's significant accounting practices is set forth below:

Foreign currency transactions - The financial statements of the Institute are stated in US$. Philippine peso and other foreign currency transactions are translated to US$ 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 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-denominated accounts are carried in the "Cumulative Translation Adjustments" account in 1990.

Revenues - Revenues 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 special 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. Under these classifications, 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 Years", a liability account in the Statement of Assets, Liabilities and Fund Balances.

Expenditures/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.

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 are carried at cost and are acquired through a capital grant or grant designated by the Institute or donor for the purpose. Cost of acquisition and major modifications of or improvements on assets is charged to the appropriate fund source as period expense and subsequently capitalized at cost and accounted in the contra account "Invested in Property and Equipment" shown under the fund balances section in the Statement of Assets, Liabilities and Fund Balances.

In conformity with the accounting policy promulgated by CGIAR, depreciation is not provided on property and equipment.

Note 3 - Accounts receivable - donors

Accounts receivable from donors consist of unreleased balances of approved grants classified as follows:

	1990	1989
Core grants	$2,963,452	$4,311,981
Complementary projects grants	834,441	3,132,620
	$3,797,893	$7,444,601

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

Note 4 - Prepaid expenses

In 1989, the Institute deferred a major portion of benefits paid to employees who availed of the special separation program (a program for staff reduction). The amount deferred of about $2.0 million was amortized in full in 1990.

Note 5 - Property and equipment; leases

Property and equipment are classified under the following accounts:

	1990	1989
Buildings and improvements	$19,851,161	$19,851,161
Research, machinery and equipment	10,926,906	6,828,965
Transportation equipment	4,311,391	2,438,009
Site development	3,345,674	2,969,163
Furniture and fixtures	995,840	2,052,034
Library items	437,369	437,369
Jobs in progress and other projects	2,556,500	1,161,241
	$42,424,841	$35,737,942

The Institute also leases land and other properties 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 from the University of the Philippines for a nominal rent and is renewable upon the agreement of the parties. Pursuant to the Memorandum of Understanding between the Government 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 phased out.

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 properties under Presidential Decree No. 457.

Note 6 - Accounts payable and accrued expenses

The account consists of outstanding commitments and accrued liabilities as follows:

	1990	1989
Outstanding commitments for core and capital operations	$14,277,637	$9,158,546
Outstanding commitments for complementary projects	532,554	515,447
Accrued expenses	4,264,192	4,283,060
	$19,074,383	$13,957,053

The balance at December 31, 1990 includes obligations worth $6.4 million which are payable over a period of time in the future.

Accruals of unused sick leave and vacation leave represent about 75% and 58% of the accrued expenses in 1990 and 1989, respectively.

Note 7 - Loan payable

This represents an interest-free loan obtained from the World Bank to finance the special separation program which was implemented in 1989. The loan, $1.5 million of which was settled by the Institute in February 1991, is payable up to December 31, 1992.

Note 8 - Other liabilities

The balance of this account substantially represents 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 special program grants for trainees and special projects.

Note 9 - Grants applicable to succeeding years

Grants applicable to succeeding years consist of grants received in advance for the following:

	1990	1989
Special projects:		
Complementary (including grants received in advance of $32,112 in 1989)	$4,125,220	$5,282,835
Essential	556,502	-
Restricted core	2,224,196	2,479,600
Unrestricted core	-	150,000
	$6,905,918	$7,912,435

Note 10 - Staff benefit plan

The Institute maintains a 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 and is borne in full by the Institute. 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 about $471,000 in 1990 (1989 – $396,000).

Note 11 - Reclassifications

Certain accounts in the 1989 financial statements were reclassified to conform with the 1990 financial statements presentation.

SCHEDULE OF SOURCES AND APPLICATIONS OF CORE OPERATIONS, CAPITAL, WORKING CAPITAL, AND COMPLEMENTARY PROJECT FUNDS

	1990	1989
SOURCES OF FUNDS		
Core grants and earned income		
Unrestricted		
United States Agency for International Development	$5,285,000	$8,225,000
International Bank for Reconstruction and Development	3,400,000	2,049,000
European Economic Community	2,579,571	1,981,000
Overseas Development Administration – United Kingdom	1,557,812	1,454,031
Canadian International Development Agency	1,523,594	1,426,653
Swedish Agency for Research Cooperation	814,986	558,917
Australian Government	758,901	779,490
Federal Republic of Germany	590,715	542,319
Danish International Development Agency	587,929	424,911
Government of Finland	501,746	473,475
The Ford Foundation	150,000	150,000
Government of Norway	121,899	117,543
Philippine Government	103,961	94,774
Government of India	100,000	100,000
Government of Italy	85,583	181,719
People's Republic of China	50,000	50,000
Government of Spain	30,000	30,000
Earned income	1,259,813	1,170,857
Foreign-currency transaction adjustments	9,756	196,597
Stabilization Mechanism Fund - inflation/ exchange adjustments	-	2,081,000
	19,511,266	19,087,286
Restricted		
Government of Japan	6,350,332	5,611,612
United Nations Development Programme	1,695,300	1,721,900
The Rockefeller Foundation	400,000	326,279
The Swiss Development Cooperation	378,121	314,286
Government of France	234,445	-
Government of Italy	200,000	400,000
Government of the Netherlands	161,840	141,926
Government of Belgium	62,166	45,365
The Ford Foundation	60,500	9,388
International Centre of Insect Physiology and Ecology	22,169	87,482
Federal Republic of Germany	-	162,696
	9,564,873	8,820,934
Balance of grants - previous year	2,479,600	2,332,398
	12,044,473	11,153,332
Transfer to complementary projects	(467,867)	-
Funds applicable to succeeding years	(2,224,196)	(2,479,600)
	9,352,410	8,673,732
Fund balance - previous year	217	35,363
	28,863,893	27,796,381
Transfers (to) from		
Working capital fund	-	100,000
Capital fund	(2,977,887)	(1,450,000)
	(2,977,887)	(1,350,000)

	1990	1989
Essential projects		
Government of Japan	759,812	-
Asian Development Bank	403,466	161,031
The Rockefeller Foundation	284,043	97,347
Government of Belgium	282,766	-
Government of Netherlands	151,484	130,618
International Food Policy Research Institute	66,490	74,253
Federal Republic of Germany	41,367	17,775
Government of Australia	39,650	-
United States Agency for International Development	26,738	40,402
International Fertilizer Development Centre	26,206	38,735
The Swiss Development Cooperation	5,450	-
Others	-	265,588
	2,087,472	825,749
Balance of grants - previous year	124,064	124,064
	2,211,536	949,813
Funds applicable to succeeding year	(556,502)	(124,064)
	1,655,034	825,749
	27,541,040	27,272,130
Capital fund - transfer from core operations	2,977,887	1,450,000
Working capital funds		
Provision from operations	516,501	(100,000)
Fund balance - previous year	2,202,000	2,302,000
	2,718,501	2,202,000
Complementary grants		
United States Agency for International Development - reimbursable contracts	1,348,493	2,073,578
The Swiss Development Cooperation	1,000,954	116,203
Government of Australia	935,685	609,746
Government of France	709,420	-
Government of Netherlands	685,722	29,266
Federal Republic of Germany	644,201	292,499
The Rockefeller Foundation	504,707	212,796
Asian Development Bank	338,733	6,002
Canadian International Development Agency	291,070	326,725
International Development Research Centre	288,696	726,883
Government of Japan	212,900	1,133,239
Government of Sweden	193,737	-
The Ford Foundation	108,042	56,458
Philippine Government	105,505	28,151
Government of Belgium	51,514	88,017
Food and Agriculture Organization	45,975	6,367
Republic of Korea	10,138	205,938
Government of Denmark	5,398	-
International Fund for Agricultural Development	-	371,048
Government of Italy	-	200,000
Others	141,064	99,796
	7,621,974	6,582,712
Balance of grants - previous year	5,126,659	5,265,165
	12,748,633	11,847,877

	1990	1989
Transfer from restricted core	467,867	-
Grants received in advance in 1989	32,112	-
Funds applicable to succeeding years	(4,125,220)	(5,126,639)
	9,123,392	6,721,218
	42,360,820	37,645,348
Applications of funds		
Core operations		
Programs	19,374,278	21,460,240
General administration and operation	6,281,804	6,139,212
Provision for working capital	516,501	-
Special separation benefits	2,134,541	704,101
Overhead recovery	(766,084)	(1,031,640)
	27,541,040	27,271,913
Capital	2,977,887	1,450,000
Complementary projects	9,123,392	6,721,218
	39,642,319	35,443,131
Excess of sources over applications of funds		
Core operations	-	217
Working capital	2,718,501	2,202,000
	$2,718,501	$2,202,217

IRRI trustees 1990

IRRI international staff 1990

KLAUS LAMPE, Ph D, *director general*
FERNANDO A. BERNARDO, Ph D, *deputy director general for international programs*
MICHAEL F. L. GOON, MBA, *deputy director general for finance and administration*[1]
HUBERT G. ZANDSTRA, Ph D, *deputy director general for research programs*

ADMINISTRATIVE PERSONNEL

TIMOTHY L. BERTOTTI, MBA, *director, administration*
ERNEST W. NUNN, Ph D, *director, operations*
EDWARD N. SAYEGH, BBA, *director, finance*
PEDRO G. BANZON, LLB, *manager, security, safety, and shipping*
REBECCA C. PASCUAL, MS, *manager, food and housing services*
ZOSIMO Q. PIZARRO, LLB, *manager, legal office*
ORLANDO G. SANTOS, MPS, *senior farm and grounds superintendent*
DIOSCORO L. UMALI, Ph D, *IRRI liaison scientist, China (consultant)*
JOHN DOWLING, *consultant*[1]
KLAUS WAHL, *consultant*[1]
PHILIP WILLIAMS, Ph D, *consultant*[1]

SCIENTISTS POSTED TO NATIONAL AGRICULTURAL RESEARCH SYSTEMS

Bangladesh
JERRY L. McINTOSH, Ph D, *research systems specialist and IRRI representative*
NOEL P. MAGOR, M Agr, *agronomist-cropping systems*

Cambodia
HARRY J. NESBITT, Ph D, *agronomist and team leader*
RAM CHET CHAUDHARY, Ph D, *plant breeder*
RICHARD P. LANDO, Ph D, *technology transfer specialist*

Egypt
EDWARD D. SPRATT, Ph D, *project manager*[2]
ANKIREDDY P. K. REDDY, Ph D, *plant pathologist*

India
B. P. GHILDYAL, Ph D, *IRRI liaison scientist*
SUDHAMOY BISWAS, Ph D, *project director*

Indonesia/Malaysia/Brunei
CEZAR P. MAMARIL, Ph D, *agronomist and IRRI liaison scientist*

Japan
MASAMI HIMEDA, D Agr, *part-time IRRI liaison scientist*

Lao PDR
JOHN M. SCHILLER, Ph D, *agronomist and team leader*[1]
SUVIT PUSHPAVESA, MS, *plant breeder*[1]

Madagascar
JAMES R. HOOPPER III, Ph D, *agronomist*
B. B. SHAHI, Ph D, plant breeder[2]

Myanmar
ROSENDO K. PALIS, Ph D, *agronomist-farming systems*

Thailand
DONALD W. PUCKRIDGE, Ph D, *agronomist and program leader, deepwater and tidal wetlands rice ecosystem*

Africa
KRISHNA ALLURI, Ph D, *liaison scientist and regional coordinator, International Network for Genetic Evaluation of Rice (INGER)*

Latin America
FEDERICO E. CUEVAS-PEREZ, Ph D, *liaison scientist and regional coordinator, INGER*

STAFF AT HEADQUARTERS

Agricultural engineering division
GRAEME R. QUICK, Ph D, *agricultural engineer and head*
N. K. AWADHWAL, PhD, *project engineer*[1]
JAMES S. TOWNSEND, Ph D, *visiting scientist*[2]
ANTHONY J. RINGROSE-VOASE, Ph D, *consultant*[1]

Agronomy, physiology, and agroecology division
SURAJIT K. DE DATTA, Ph D, *principal agronomist and program leader, rainfed lowland rice ecosystem*
BENITO S. VERGARA, Ph D, *plant physiologist and acting head*
DENNIS P. GARRITY, Ph D, *agronomist*[4]
KEITH T. INGRAM, Ph D, *agronomist*
MARTIN J. KROPFF, Ph D, *agronomist/crop modeler*[1]
KEITH MOODY, Ph D, *agronomist*[1]
F. W. T. PENNING DE VRIES, Ph D, *agronomist/crop modeler*[2]
VIRENDRA PAL SINGH, Ph D, *associate agronomist*
MINORU YAMAUCHI, Ph D, *plant physiologist*[1]
ROLAND J. BURESH, Ph D, *visiting scientist*
H. DAVID CATLING, Ph D, *visiting scientist*[2]
ROMEO BRUCE, Ph D, *consultant*[1]
ALAN K. WATSON, Ph D, *consultant*[1]

Entomology division
DALE G. BOTTRELL, Ph D, *entomologist and head*[1]
KONG LUEN HEONG, Ph D, *associate entomologist*
JAMES A. LITSINGER, Ph D, *entomologist*
RAMESH C. SAXENA, Ph D, *entomologist*
Z. R. KHAN, Ph D, *associate entomologist*

Plant breeding, genetics, and biochemistry division
GURDEV S. KHUSH, Ph D, *principal plant breeder and head*
DERK HILLERISLAMBERS, Ph D, *plant breeder*
RYOICHI IKEDA, Ph D, *plant breeder*
BIENVENIDO O. JULIANO, Ph D, *chemist*
DAVID J. MACKILL, Ph D, *plant breeder*[2]
DHARMAWANSA SENADHIRA, Ph D, *plant breeder*
SANT S. VIRMANI, Ph D, *plant breeder*
FRANCISCO J. ZAPATA, Ph D, *tissue culture specialist*
DARSHAN S. BRAR, Ph D, *associate plant breeder*
SUSAN McCOUCH, Ph D, *associate geneticist*[1]
LESLEY A. SITCH, Ph D, *associate plant breeder*[2]
MICHEL A. ARRAUDEAU, MS, *visiting scientist and program leader, upland rice ecosystem*
JUN KYU PARK, Ph D, *visiting scientist*
GERARD SECOND, Ph D, *visiting scientist*[1]
BAIJ NATH SINGH, Ph D, *visiting scientist*[2]
N. PANDA, Ph D, *consultant*[1]

Plant pathology division
TWNG-WAH MEW, Ph D, *plant pathologist and head*
JOHN MICHAEL BONMAN, Ph D, *plant pathologist*
HIROKI KOGANEZAWA, Ph D, *plant pathologist*
PAUL S. TENG, Ph D, *plant pathologist and coordinator, integrated pest management*
REBECCA NELSON, Ph D, *associate plant pathologist*
JEAN-CLAUDE PROT, Ph D, *visiting scientist*

Social sciences division
JOHN C. FLINN, Ph D, *agricultural economist and program leader, irrigated rice ecosystem*
CRISTINA C. DAVID, Ph D, *agricultural economist and acting head*
J. BART DUFF, MS, *agricultural economist*[2]
J. SAMUEL FUJISAKA, Ph D, *social scientist*
LEONARDO A. GONZALES, Ph D, *agricultural economist*[2]
PRABHU L. PINGALI, Ph D, *agricultural economist*
YUJIRO HAYAMI, Ph D, *visiting scientist*[3]
ROBERT E. HUKE, Ph D, *visiting scientist*[3]
ELEANOR H. HUKE, BFA, *visiting scientist*[3]
KEIJIRO OTSUKA, Ph D, *visiting scientist*[3]

Soils and water management division
HEINZ-ULRICH NEUE, Ph D, *soil chemist and head*
TERENCE WOODHEAD, Ph D, *physicist and program leader, cross ecosystems research*
SADIQUL I. BHUIYAN, Ph D, *agricultural engineer*
GUY J. D. KIRK, Ph D, *associate soil chemist*
GASTON AMEDEE, Ph D, *visiting scientist*[3]

Soil microbiology division
IWAO WATANABE, D Agr, *soil microbiologist and head*
JAGDISH K. LADHA, Ph D, *soil microbiologist*
PIERRE A. ROGER, D Pedologie, *visiting scientist*

Project management services and biometrics
KWANCHAI A. GOMEZ, Ph D, *statistician and head*
V. A. SAMANARAYAKE, Ph D, *visiting scientist*[2]

International programs management office
GLENN L. DENNING, Ph D, *scientist, (international collaboration) and head*
JIT BHUKTAN, Ph D, *consultant*[1]
ALAN J. CARPENTER, BS, *consultant*[3]

Genetic resources center
TE-TZU CHANG, Ph D, *principal geneticist and head, International Rice Germplasm Center (IRGC)*
DUNCAN A. VAUGHAN, Ph D, *associate geneticist*

Information center
THOMAS R. HARGROVE, Ph D, *editor and head*
STEPHEN J. BANTA, Ed D, *editor*
GEORGE C. KRAJCSIK, Ph D, *software coordinator*[2]
M. LARUE POLLARD, Ph D, *editor*
WILLIAM H. SMITH, BS, *editor*
MARINUS CORNELIS VAN DEN BERG, BS, *hardware coordinator and network manager*
LINA M. VERGARA, MS, *librarian*

Network coordination
VIRGILIO R. CARANGAL, Ph D, *agronomist and coordinator, Asian Rice Farming Systems Network (ARFSN)*
V. SESHU DURVASULA, Ph D, *plant breeder and global coordinator, International Network for Genetic Evaluation of Rice (INGER)*
ERNESTO L. ARAGON, Ph D, *associate agronomist and coordinator, International Network on Soil Fertility and Sustainable Rice Farming (INSURF)*[1]
SANG-WON AHN, Ph D, *plant pathologist, INGER*
MUHAMMAD AKBAR, Ph D, *plant breeder, INGER*
FRANK J. VAN SCHOUBROECK, MS, *visiting scientist*[3]

Training center
DAN R. MINNICK, Ph D, *training specialist and head*[4]
ELLIS L. MATHENY, JR., Ph D, *visiting scientist*[1]
GINA M. ORDONEZ, MBA, *consultant*[1]

---

[1] Joined during the year.
[2] Left during the year.
[3] Joined and left during the year.
[4] On study leave.
[5] Returned from study leave.

Credits

WRITER / EDITOR
LaRue Pollard
GRAPHIC DESIGNER
Ramiro Cabrera
GRAPHIC ARTISTS
Pat Mamon
Ed Delfino

PHOTOGRAPHERS

cover	R. Cabrera (IRRI)
p2	S. Fujisaka (India)
p3	D. Vaughan (Cambodia)
p4	R. Guevarra (Philippines)
	R. Cabrera (Philippines)
p5	S. Fujisaka (India)
p6	D. Vaughan (Myanmar)
	S. Fujisaka (India)
p7	S. Fujisaka (India)
p8	L.R. Pollard (Philippines)
p9	A. Songco (Philippines)
p10	IRRI photo archive
p11	IRRI photo archive
p12	IRRI photo archive
p13	IRRI photo archive
p14	R. Huke (Philippines)
	R. Huke (Philippines)
p15	L. Sayo (IRRI)
	L. Sayo (IRRI)
p16	M. Dingkuhn (Senegal)
p18	S. Fujisaka (Indonesia)
	R. Cabrera (Philippines)
p19	R. Cabrera (IRRI)
p20	S. Fujisaka (IRRI)
p21	S. Fujisaka (Indonesia)
p22	G.S. Khush (IRRI)
	G.S. Khush (IRRI)
	G.S. Khush (IRRI)
p24	S. Bhuiyan
p26	S. Lapiz (IRRI)
	S. Lapiz (IRRI)
p27	A. Barrion (IRRI)
p30	S. Fujisaka (India)
p31	S. Bhuiyan (Philippines)
p32	S. Fujisaka (India)
	S. Fujisaka (India)
	S. Fujisaka (India)
p35	D. Mackill (Thailand)
p37	S. Fujisaka (Indonesia)
p39	S. Fujisaka (Bangladesh)
p41	D. Puckridge (Thailand)
p43	Thailand Remote Sensing Center
	L. Sayo/R. Cabrera
p45	O. Panaud (IRRI)
p46	M. Manza (IRRI)
p48	D. Vaughan (Cambodia)
p50	G. Denning (Bhutan)
p51	D. Vaughan (Myanmar)
p52	D. Vaughan (Papua New Guinea)
p54	S. Lapiz (IRRI)
p55	M. Manza (IRRI)
p56	R. Cabrera (IRRI)
p57	R. Cabrera (IRRI)
	R. Cabrera (IRRI)
p58	IRRI photo archive
p59	J. Bonman (Philippines)
p62	J. Bonman (China)
p64	E. Lozada (IRRI)
p65	S. Yabes (Philippines)
p66	S. Fujisaka (India)
p67	S. Fujisaka (Bangladesh)
p68	S. Fujisaka (Bhutan)
p71	R. Cabrera (IRRI)
p72	L. Sayo (IRRI)
p73	R. Cabrera (IRRI)

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of the 13 nonprofit international research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 50 donor countries, international and regional organizations, and private foundations.

IRRI receives support, through the CGIAR, from a number of donors including the Asian Development Bank, the European Economic Community, the Ford Foundation, the International Development Research Centre, the International Fund for Agricultural Development, the OPEC Special Fund, the Rockefeller Foundation, UNDP, the World Bank, and the international aid agencies of the following governments: Australia, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, India, Iran, Italy, Japan, Republic of Korea, Mexico, The Netherlands, New Zealand, Norway, the Philippines, Saudi Arabia, Spain, Sweden, Switzerland, United Kingdom, and United States.

The responsibility for this publication rests with the International Rice Research Institute.

International Rice Research Institute
P.O. Box 933, 1099 Manila
Philippines
FAX: (63-2) 817-8470; 818-2087
Telex: (ITT) 45365 RICE INST PM; (RCA) 22456 IRI PH;
(EASTERN) 67552 RICE PN

1991
ISBN 971-22-0019-1
International Rice Research Institute
P.O. Box 933, 1099 Manila, Philippines