IRRI 1989 Planning for the 1990's

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.

IRRI 1989 is the first in a new series of yearly corporate reports on the International Rice Research Institute. It replaces the *IRRI Research Highlights* series. Each issue will focus on current rice research concerns and will report contemporary IRRI accomplishments.

Contents

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.

Have you eaten rice today?

All over the world, every day, people greet each other. For many, the greeting seems casual. But for half of them, their greeting reflects what is most vital to their lives.

Rice is the world's most important food crop. More than 90% of the world's rice is grown and consumed in Asia, where more than half the world's population live and where nearly 80% of the world's poor are concentrated. With continuing population growth, the pressure to grow more and more rice accelerates.

From 80 to 100 million additional rice consumers must be fed each year. But in Asia, almost no more land is available to plant to rice. Environmentally fragile areas are being overrun. Hungry people are clearing highly erodible mountain slopes to harvest meager crops of rice. What choice do they have? Their families must be fed, today.

Landless families in Asia are being forced from the countryside into already overcrowded cities. They too must be fed. And cities are spreading outward, taking prime riceland out of production.

In 30 years, the earth will be home to 8 billion people. More than half—4.3 billion, almost as many as inhabit the earth today—will be rice consumers. Feeding them will require a massive increase in global rice production, from today's 470 million tons to 760 million tons. That 60% increase—if it can be achieved—will merely maintain current nutrition levels, which are already inadequate for hundreds of millions of people.

The impending food crisis that threatened South and Southeast Asia in the 1960s was averted by new rice technology. Today, half a billion people are being fed by the increased production it made possible. But that rice is already spoken for. Even more production will be needed to adequately feed the rice consumers who will be born during the next 30 years.

Rice market surpluses and low market prices in the late 1980s gave some supporters of international agricultural research a false impression, that the world's rice problems had been solved. They forgot just how precarious the line is between sufficient rice and potential famine.

Asia's population continues to grow, but almost no more land is available to plant to rice. Needy farm families are turning erodible hills into cropland that has very poor productivity.

Today's world rice situation

Rice production in Asia doubled in response to the adoption of modern varieties, increased investments in irrigation, and higher use of fertilizer. Several major rice-importing countries attained self-sufficiency in national production. Accumulated rice stocks rose to an unprecedented 18% of consumption. By the early 1980s, the main problem of a number of countries had shifted from coping with rice shortages to disposing of rice surpluses.

Many countries that traditionally imported rice had relatively high proportions of irrigated area, and were able to quickly adopt modern rice technology to in-

Growth in rice production has fallen behind growth in demand. Stocks are dangerously low in many countries whose people depend on rice as their staple food.

crease their domestic supplies. That weakened the demand for rice on the world market. Favorable weather and low world prices of nitrogen fertilizer also helped increase production.

The collapse of the world rice market between 1982 and 1987—when the world rice price in real terms dropped to its lowest level in this century—worsened the perception of global rice abundance.

Productivity gains in developing countries were only partly responsible for the low world rice price. At the same time, overall contraction of the world economy and the lack of foreign exchange in many developing countries with heavy debt burdens lowered their demand for rice imports. Strong agricultural protectionism in some industrialized countries reduced their grain imports and led to the dumping of grain surpluses onto the world market.

By the late 1980s, growth in rice production in Asia once more fell behind population-driven growth in demand. Increases in yield tapered off and area planted to rice ceased to expand. Rice stocks dwindled to their lowest level in the last decade, especially in three major rice-consuming countries: China, India, and Indonesia. Global stocks fell to 13% of consumption—the lowest ratio since the world food crisis of the early 1970s.

Now two consecutive years of poor harvests have driven world rice prices up. A few countries that had become self-sufficient only a few years ago (India, Indonesia, the Philippines) are again importing rice. This illustrates the narrow margin between self-sufficiency and potential famine in most of monsoon Asia.

Prospects for a rapid recovery of production are dim. Contraction of public investments in rice research and in irrigation in many countries, in response to budget constraints, perceived global rice surpluses, and depressed world rice prices, is impacting the growth rate of rice production. New major technological breakthroughs that would ensure abundant rice supplies for the next decade are yet to be found.

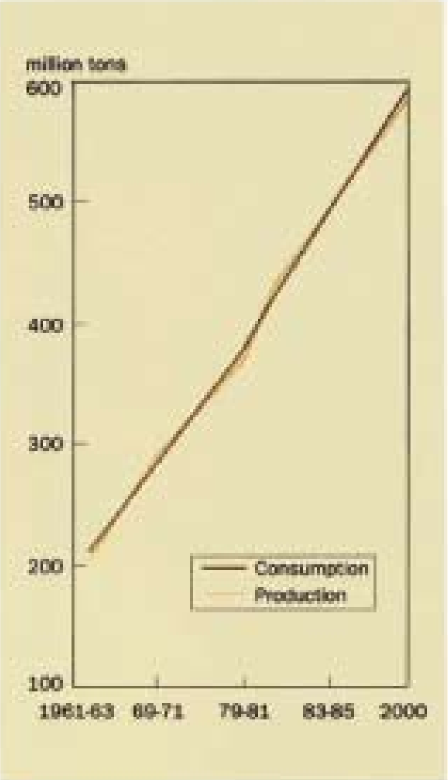
In fact, projections of future demand and supply into the 21st century predict global as well as Asian shortfalls in rice production relative to demand. That will tend to raise world rice prices.

The experience of the 1980s and the outlook for the 1990s highlight the basic problems of the world rice economy—instability of prices and markets, need for investments in production to meet increasing consumption, and need to maintain adequate carryover stocks.

Only about 4% of the world's rice production—12 million tons—enters the international market. The other 96%—460 million tons—is consumed within the country where it is grown. In most of Asia, more than half the rice produced is consumed at home, by the rice farming family.

In the face of population increases without parallel rice yield increases, efforts to sustain growth in production in developing countries—including investment in research—are critical. When public investments in irrigation and rice research are made

In 30 years, more than 8 billion people will live on earth. More than half of them will depend on rice.



Alternating rice shortages and oversupplies are a major problem developing countries face in meeting the demand of their growing populations for food. One causal factor is public investments made in response to short-term cycles rather than long-term social profitability.

Rice is probably the world's most versatile crop. It grows on mountain slopes and in water as deep as 4 meters.

in response to cyclical price changes instead of against long-term trends of social profitability, alternating shortages and over-supplies recur. Wide fluctuations in world rice prices are inevitable.

Meantime, rice-growing countries continue to try and reconcile conflicting responsibilities, that appear to be irreconcilable:

- To provide consumers with rice at low prices.
- To give a fair return to rice farmers.

RICE RESEARCH AND DEVELOPMENT

The challenge to rice scientists is awesome: to conduct research that will help developing countries grow more rice on limited land, in ways that do not harm the environment and that benefit both farmers and consumers.

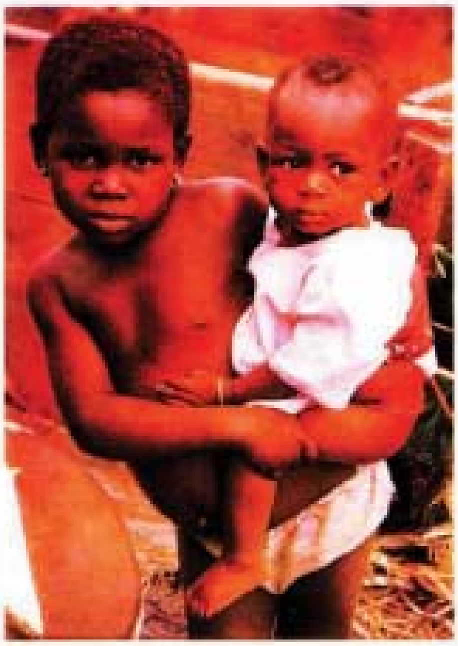
IRRI scientists and management have been involved in far-reaching thinking and planning to develop a strategy that will ensure enough rice production for the world in the 21st century. In 1988, we released the strategic plan *IRRI toward 2000 and beyond*. In 1989, we developed IRRI's *Work Plan for 1990-1994*. Both documents focus on how investments in rice science can contribute to increased rice production, with stability, sustainability, and equity.

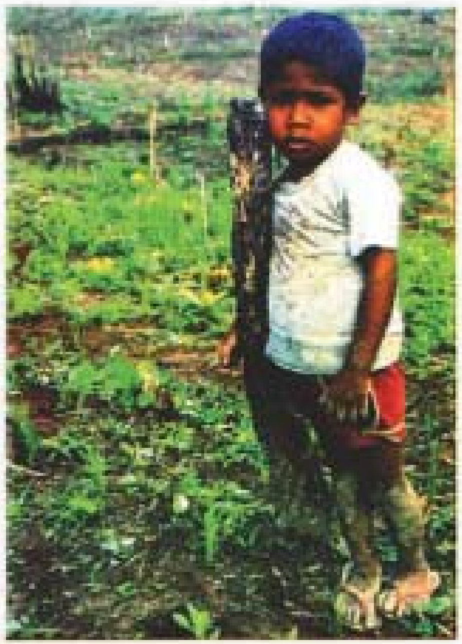
The strategy articulates IRRI's goal, establishes its objectives, and outlines the global approach. Within those guidelines, the work plan identifies IRRI programs, specifies priorities, and describes IRRI's research focus during the next five years.

Reorganization is integral to the strategy. IRRI has been restructured as three major units. The research programs are the core. International programs link IRRI research with scientists and national research systems in both developing and industrialized countries. Management and support services facilitate the serious business of rice research and help IRRI scientists focus their work on the vital problems.

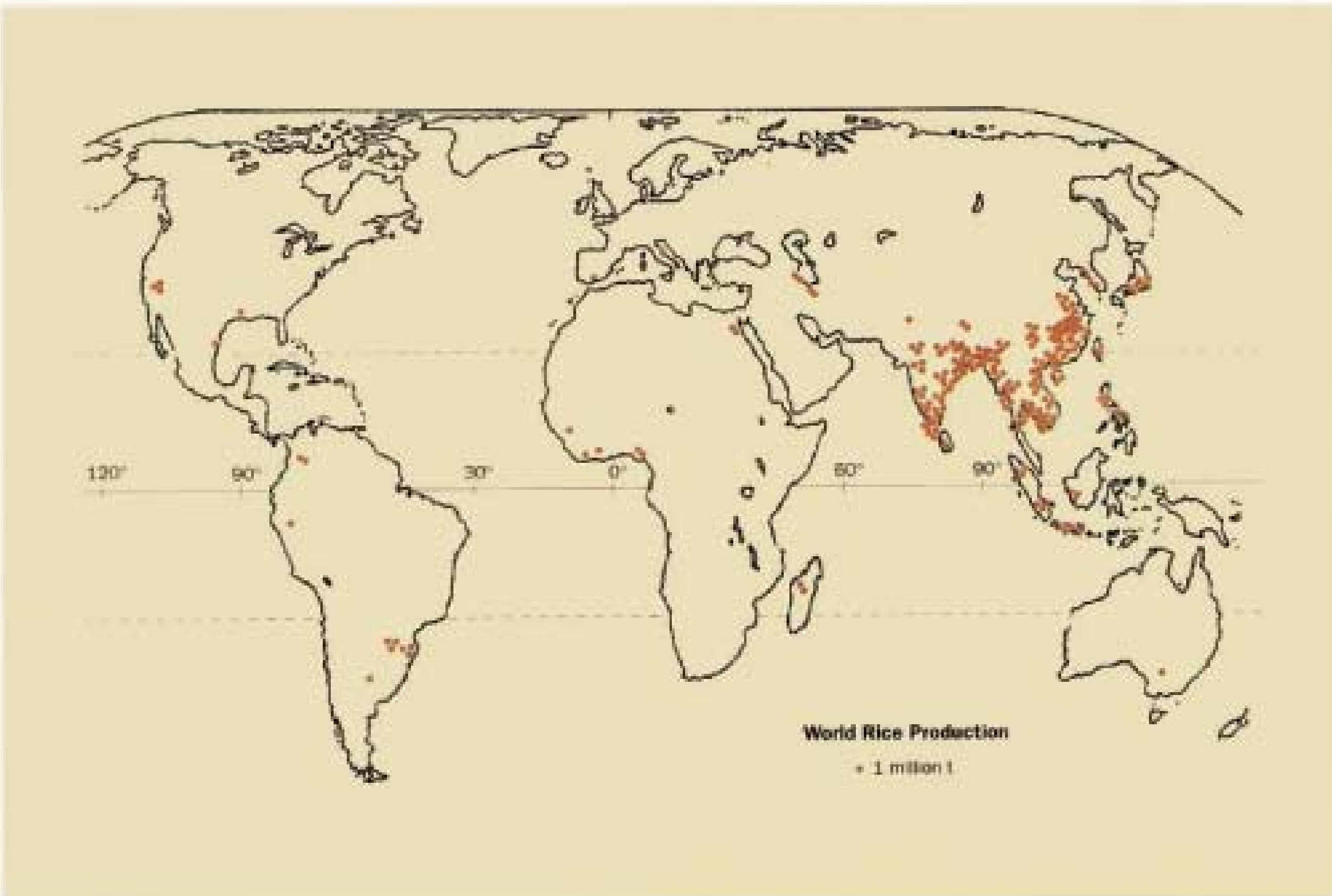
IRRI acquired a new look on 1 January 1990, that of a sharply focused institute dedicated to discovery and invention, to finding the knowledge and technology needed to enable rice-dependent people everywhere to live in dignity and in harmony with their environment.

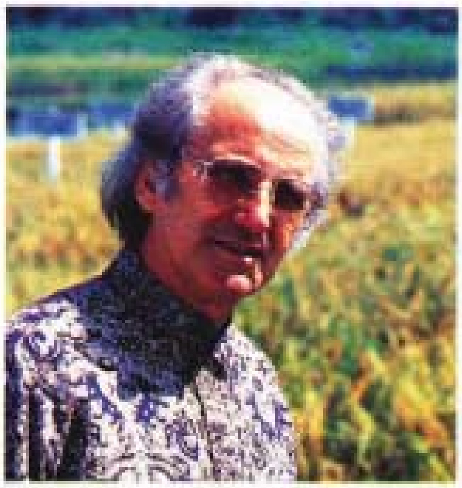
More than 90 percent of the world's rice is grown in Asia. Most of that rice is consumed within the country where it is grown, half of it by the rice farming family.





Only about 4% of the world's rice production enters the international market. Most is consumed within the country where it is grown, more than half by the rice farming family.





Klaus Lampe
Director General

This year—1989—has been a year of change, a turning point for much of the world. The rigidity of political systems seems to be softening. Thinking, in cold war terms, has shifted to a common "no war" goal. Political conflicts in Indochina, South Africa, and Europe suddenly seem to be problems that can be solved without bombs and bullets. *People power*, which changed the political environment in IRRI's host country the Philippines four years ago, is now changing the world.

This year has taught us that looking into the future is risky. Who would have predicted the political changes in Europe and in East-West relationships even one year ago?

We at IRRI are well aware of the risks linked to planning for the future. Our research strategy, developed in 1988 and 1989 for the next 10 years, is built on assumptions that reach far into the next century. It is full of uncertainties and risks. But we are convinced that not looking ahead, not facing the risk that some of our assumptions may be wrong, would almost certainly lead to unmanageable situations in the future.

What about, for example, global warming? We all hope that theory proves not to be true. Still, IRRI feels committed to analyze the role that rice plays in shaping the climate of the future, and to search for tools that will minimize any negative effects of that role on the global environment.

We at IRRI are neither alarmists nor dreamers. Research must deal with uncertainties, and we will face them. Research must anticipate the future, and we will prepare for it. Research must assume risks, and we are willing to take them.

It may be unpopular in these euphoric days to sound a note of caution. But it seems very clear that, within the time frame of IRRI's strategic planning horizon, the world will face new conflicts even more difficult to resolve than the political ones that seem to have been overcome.

If, by the beginning of the next century, we have failed to satisfy the very basic needs of the 2 billion very poor and 4 billion poor people who will occupy our globe, life for the rest of us could be extremely risky and uncomfortable.

IRRI's new goal and objectives leave no doubt about where our priorities lie. Social justice starts with an opportunity for income generation and access to food. IRRI will make every effort to contribute to that goal. Those who are serious about saving the tropical rain forests must realize that this cannot be done unless the basic needs of the people living at their borderlines are met.

We do not forget that, in many aspects, the IRRI mandate is global. While we will not neglect the Institute's role in Africa and Latin America, we must focus the use of our limited resources. In doing so, we will continue to concentrate most of our efforts on Asia, where more than 90% of the world's rice farmers live and where more than 90% of the rice produced is eaten.

The world seems to be overlooking the fact that Asia is on the move. Much of that movement is from rural to urban areas. Most countries are not prepared for that shift, nor for its dramatic consequences. The equivalent of Europe's present population, or the population of North America and Brazil combined—about 500 million people—will swell the present urban population in Asia within the next ten years.

How will governments provide for even their very basic needs—food, water, and shelter? What will happen if these basic necessities cannot be made available? We had better think of the problems the Asian continent will face while solutions can still be developed. Let us not ignore the fact that not much time is left.

Given that this is a realistic scenario, what has IRRI done in planning for the future?

Research direction

Reflecting the division of labor between national systems in the industrialized and tropical rice-growing countries, IRRI will try to build a bridge between basic research and applied rice research. We will look for new frontiers and new yield plateaus for the diverse rice-growing ecosystems, using all scientific tools currently available.

Quality and relevance

IRRI's place in the world of rice research has changed over the years. We are no longer the only one, but only one among many research institutes specializing in research on rice. We therefore are very selective in the work we do, and complementary to our partner institutes. We are searching for the best scientists we can find, and looking for the most promising partnerships with research centers at the cutting edge of the relevant disciplines. The highest possible quality and relevance of our research will lead to the needed results. That will instill confidence in IRRI's work among its clients and donors. Disciplinary depth guided by unquestionable leadership is the key to the quality research IRRI is pursuing. Ensuring the relevance of our work is the primary task of IRRI's newly established ecosystem-based programs. Balancing program and disciplinary interests will not be a problem, so long as we all keep our goal in sight and the ultimate beneficiaries of our research in mind.

Partnership and cooperation

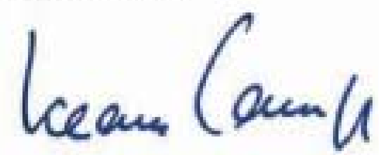
IRRI's new strategy and work plan have been developed by those who will implement the plans—the scientists of IRRI and their colleagues in national agricultural research systems. We are moving toward more team research and more interdisciplinary research in specific ecosystem-based programs. In a strong effort toward decentralization, we have paved the way for participatory management in all sectors of the Institute. Parts of our work will shift as soon as possible away from IRRI headquarters to centers of relevance for the different ecosystems. Research projects in the rainfed lowland, upland, and deepwater rice programs have high priority for such transfer.

Preparing for the future

Planning involves many factors. Our long-term and medium-term perspectives are set. Our relationship with our partners is defined. We know that with a high degree of flexibility, we will be able to meet the needs of the decade ahead. We must keep in mind that the Institute's target groups include nearly 60% of the world's population and that nearly 138 million hectares of riceland in the less-developed countries must benefit from the rice research with which IRRI deals.

Reducing IRRI's staff by about 600 positions over the last two years has helped us become a leaner institute. To implement our ambitious new research program, we also need to adjust and, if necessary, replace our wornout physical infrastructure. IRRI was planned and mostly built 30 years ago, with the perspective of a lifetime of about 25 years. Those years in the humid tropics have taken their toll on buildings, laboratories, and services.

IRRI is looking ahead, with confidence, optimism, and hope. During the next decade, we will strive with our partners in national agricultural research systems worldwide for a new rice yield plateau. Utmost care is guiding us in this endeavor. We know we must balance the environmental, social, and economic interests of present generations who depend on rice with our obligations to future generations.



Research programs

IRRI research focuses on ways to increase rice production, for the next decade and into the 21st century. Some of the work has a far horizon: knowledge gained in rice genetics will enable scientists to do more to increase future rice productivity, both through breeding even higher yielding rice varieties and through designing more efficient systems of crop management.

Some research results can be used immediately: improved methods of applying fertilizer increase yields and save input costs.

Work also is needed to ensure long-term stability of increased yields and sustainability of the environment. And we must keep both consumers and farmers firmly in view—all must benefit from increased productivity, now and into the future.

IRRI research programs center on the world's major rice-growing ecosystems, with a cross-ecosystems program for work that spans the environments. In each program, interdisciplinary scientific teams work to solve critical rice production problems.

Collaboration is an important research strategy. Many problem-focused research projects are carried out in partnership with scientists elsewhere, in advanced laboratories and in national system field experiments.

All the work will build on the results of IRRI's earlier research, in 1989 and the years before. Some recent results are highlighted here.

Women everywhere play key roles in rice farming, including most of the processing and marketing of the family harvest.

Hubert G. Zandstra
Deputy Director General
for Research

IRRI identified four important concerns in its strategy: sustainability, equity, research strengthening, and advanced approaches. Our new program structure and work plan, developed in 1989 in consultation with scientists, policymakers, collaborating research institutions, and development-oriented, nongovernmental organizations, reflect these concerns.

To emphasize the importance of environmental factors, we restructured our research into interdisciplinary programs focused on the major rice-growing ecosystems. Research teams are characterizing the ecosystems, diagnosing their constraints and potentials, and setting research priorities.

This process will ensure that IRRI work is relevant to the needs of users and beneficiaries of the research results. It also will help define the best locations for collaborative research with our national partners and the criteria for screening and evaluating technology. That will ensure that new technologies will at least maintain, and we hope improve, the natural resource base while meeting the objectives of efficiency and equity.

Intensive agricultural systems can produce more than 5 tons per hectare, per rice crop. Continuously-cropped irrigated ricelands often produce more than 12 tons per hectare a year. But such intensive cropping removes nutrients from the soil faster than they can be replaced. Thus, sustainability of production is of highest priority.

The efficiency of input use, particularly nitrogen, must be improved dramatically. We plan to do this by developing biological sources of nitrogen, by improving application methods to increase the efficiency of fertilizer use, and by matching nutrient release to crop demand. We will stress development of integrated pest management technologies that will minimize pesticide use.

Our concern for equity is explicit in IRRI's objective to improve returns to farmers while keeping production costs low enough to protect the rapidly increasing number of urban consumers. In the interest of equity, we are giving special attention to the less-favorable ecosystems. We also seek to increase employment in postharvest processing and using rice by-products.

The role of women in rice production and the impact of new technologies on female employment and income have been evaluated. Special efforts are being made to ensure that data collected on-farm to design new technology are gender differentiated. Affirmative action in recruitment and in selecting candidates for IRRI training programs will include more women.

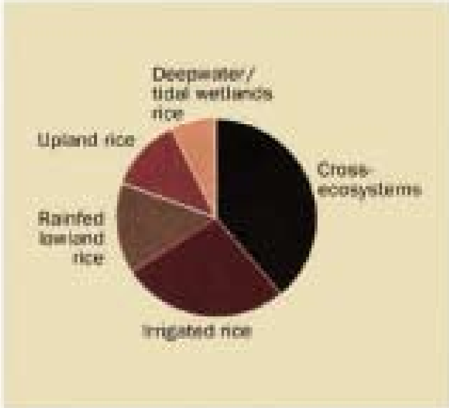
IRRI's research is enhanced by and contributes to strong national rice research systems. We will continue our shift to stronger research collaboration with national programs, and to knowledge exchange with our partners in a global rice research system.

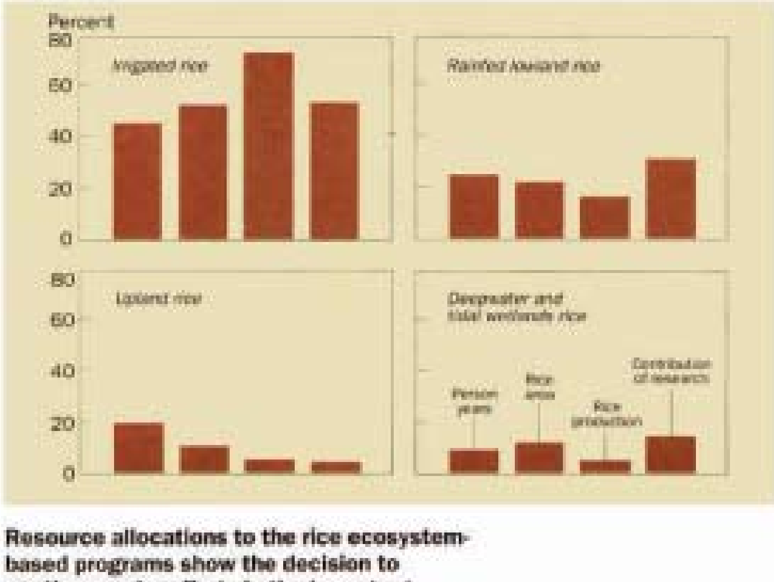
One IRRI initiative toward this objective is the research consortium model. We are developing consortia with national program scientists in locations that have particular advantages for a particular research focus.

Effective agricultural research occurs along a continuum of research level: adaptive - applied - strategic - basic. Adaptive research is carried out on-farm, to tailor new technology to particular situations. Basic research seeks knowledge about fundamental processes.

IRRI is oriented to rice problems, and does not conduct basic research as such. We are increasing our collaboration and communication with advanced institutions that are conducting basic research, to enable us to rapidly apply results from the cutting edge of science in our own strategic and applied work. That work seeks the particular knowledge that helps in designing technology to meet our objectives. As more national programs increase their research capacity, we will increase the proportion of IRRI resources devoted to strategic research and to sharing newly available research tools with national program collaborators.

Resources were allocated to the research programs after weighing the priorities of sustainability, equity, research strengthening, and advanced approaches. IRRI research time is apportioned 27% to irrigated rice, 15% to rainfed lowland rice, 12% to upland rice, 7% to deepwater and tidal wetlands rice, and 39% to cross-ecosystems research.





Resource allocations to the rice ecosystem-based programs show the decision to continue major efforts in the important irrigated system, while paying additional attention to the less-favorable systems with large needs for increased rice production.

PROGRAM PRIORITIES

We developed a planning matrix to guide allocation of IRRI's limited resources to a multitude of research projects and activities.

The first important task was to identify the most promising entry points for research to achieve the strategic objectives. For this, we used a goal-oriented process of project planning, based on Logical Framework Analysis.

That started with analysis of the core problems, objectives, targeted research outputs, and IRRI's research strengths. From that, we developed a research planning matrix. It established a hierarchy of goals, objectives, outputs, and activities for each program, with corresponding sets of progress indicators, means of verification, assumptions, critical additional requirements, and opportunities for collaboration.

Each project was reviewed in terms of priorities, staff requirements, and the hard reality of limited resources. Priority research will focus on

• Maintaining yield gains already made.
• Increasing rice yield potential.
• Anticipating effects on the environment.
• Contributing to production sustainability.
• Addressing the needs of the urban and rural poor.
• Opening options for crop diversification.

We also considered opportunities that each project offers to

• Increase yield, cropping area, and cropping intensity.
• Reduce production costs.
• Create jobs.
• Alleviate gender inequities.

• Complement the capabilities of national systems.
• Exploit IRRI's comparative advantages.

These considerations gave us a relative weighting of resource allocations to the four major rice ecosystems.

We gave special emphasis to the upland rice and deepwater/tidal wetlands rice ecosystems, even though they have relatively limited current and potential land area and production. Our reason: poverty and hunger are greatest there, and these ecologically fragile ecosystems face the most severe threats of soil erosion and loss of sustainability.

Simultaneously, we decided to continue concentrating the most scientific resources on the favorable irrigated environments, because we must maintain earlier gains in productivity. Irrigated lands also show the most promise for a new, higher yield potential. This is where, for example, research investments in hybrid rice or in developing a new plant type for direct seeding are expected to pay off most.

The high productivity of irrigated regions must also be maintained to keep desperate farmers from damaging new lands that are not fit for agriculture. The lack of new yield increases in irrigated rice may be a major contributor to soil loss and environmental deterioration in marginal areas.

Some activities, such as work on new research techniques and tools, will support the objectives of all or several ecosystem programs. To increase efficiency and avoid duplication, we combined these into a separate cross-ecosystems program. It will provide our primary link to advanced research institutions.

Its activities will focus on germplasm evaluation; genome manipulation; and physical and biological processes of the rice plant, its pests, and the soil and water that sustain it. The program also includes work on grain quality, by-product utilization, techniques for ecosystem characterization, and analysis of the impact of new technology on people and societies.

Increasing the productivity of irrigated ricelands may be the best protection against environmental deterioration of marginal areas.

Irrigated rice research

Irrigated Rice Research Projects for 1990-1994

Germplasm improvement
- High yield potential
- Multiple resistance
- Abiotic stress tolerance

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
- Intensified rice-based farming

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

Half the world's 144 million hectares of rice is irrigated, but this ecosystem produces nearly 75% of the world's harvest. Less than 40% of the rice area in tropical South and Southeast Asia is irrigated, but it supplies well over half the region's rice.

The dominance of the irrigated rice ecosystem, and its remarkable production increases in the 1970s, could be the Achilles' heel of global rice security. The yield gap is closing: farm yields have increased steadily, but yield potential—the maximum possible yields on research stations—has not.

Meanwhile, the sustainability of large tracts of irrigated ricelands is being degraded by salt buildup, waterlogging, and siltation of irrigation reservoirs.

Increasing production, productivity, and profitability of irrigated rice is just as great a challenge now as it was when IRRI was founded. If the 2.5% a year growth rate in rice supplies needed to meet increasing demand in South and Southeast Asia is to be realized, irrigated riceland productivity must be increased and sustained.

The irrigated rice research program designed to address the challenge has these objectives:

- To raise irrigated rice yield potential from the current 10 tons per hectare to 15 tons within the next 20 years.
- To develop crop and resource management techniques that will

Half the world's ricelands are irrigated. That hectarage produces almost 75% of the world's harvest.

increase input efficiency, reduce production costs, increase yields, sustain land productivity, avoid gender-based inequities, and not be harmful to human health.

- To secure yield gains.
- To reduce the gap between actual farm yields and potentially attainable yields.

The challenge is to confront the problems involved in increasing and sustaining riceland productivity in a manner that is safe to both humans and the environment. This implies that we will be concerned more explicitly with health and environmental impacts. It means that IRRI's irrigated rice research will involve upstream strategic work and both applied and adaptive studies.

Work in germplasm improvement has three major concerns: to increase the yield potential of irrigated rice, to continue to ensure that new cultivars possess multiple resistance to rice pests and tolerance for environmental stresses, and to breed for high efficiency in nutrient use.

Work to improve management technology focuses on increasing the efficiency of major and minor nutrient use in intensified cropping systems, on integrated pest management strategies, and on increasing the efficiency of water use and labor.

Studies of livelihood, production, and environmental impacts will help integrate improvements

Breaking the yield barrier

Changing the tropical rice plant's architecture doubled yield potential in the 1960s. IR8 was the prototype for modern high-yielding rice varieties: short stature, high tillering, sturdy stems, and erect leaves. More than 60% of the world's riceland is now planted to semidwarfs.

But maximum yield potential has increased only slightly since the 1966 release of IR8. Increases in productivity have been through the incorporation of disease and insect resistance, shortened growth duration, and increased cropping efficiency.

Our strategies to raise the yield plateau of irrigated rice are

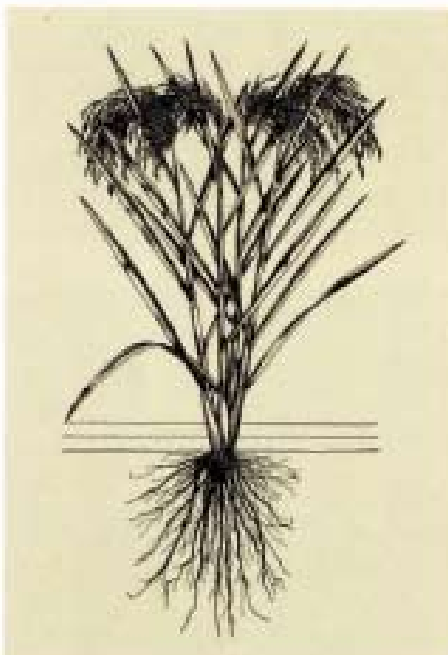
- To modify, once again, the rice plant type, and
- To develop hybrid rices for the tropics.

New plant type for increased yield potential

Centuries ago, maize and sorghum produced many tillers but only a few small cobs and grain heads. Their plant types have been altered, and now they produce only one shoot that bears large ears. That change raised their yield potential significantly.

Modern rice varieties tiller profusely, but not all tillers produce panicles. Elimination of the nonproductive tillers could direct more nutrients to grain production.

Our vision is of a new rice plant type, a rice plant with only four or five tillers—all productive—that support large, heavy panicles. Its stems must be sturdy; its leaves, dark and erect; its root system, vigorous.



High-yielding irrigated rice plant of the future

- 13-15 tons per hectare yield potential
- 3-4 panicles per plant
- 200 - 250 grains per panicle
- no unproductive tillers
- very sturdy stems
- 90-100 centimeters tall
- vigorous root system
- multiple disease and insect resistance
- 100-130 days growth duration
- harvest index 0.6

In 1989, we planted 1,600 cultivars from Indonesia and identified donors for low tillering, large panicles, and sturdy stems. We have begun a crossing program to exploit these traits.

Changes in plant type will dictate changes in crop management. To fully exploit its yield potential, the new rice plant will probably be densely seeded directly, not transplanted. That will require changes in timing and methods of applying fertilizer.

into profitable, sustainable rice-based systems. This work is directly concerned with the impact of rice technology and production on people and the environment.

The ultimate concern is to develop technology (such as new rice varieties), knowledge, and practices for national rice research programs to adapt for the best use by their farmers—technology that is profitable and productive, safe to humans and the environment, and within reach of the irrigated rice farmer in the tropics.

Hybrid rice

Hybrid rice offers another potential to break the yield plateau for irrigated rice in the tropics. In China, hybrid rices yield up to 20% higher than the best improved semidwarfs. Hybrid rices also have been released for commercial cultivation in the Democratic People's Republic of Korea. But development of hybrid rices for the Asian tropics is taking longer than in the temperate zones.

We are finding that hybrid rice combinations perform differently in tropical and temperate climates, in cooperative research with the Republic of Korea. The problem for the tropics is finding adaptable lines with male-sterile cytoplasm and the effective maintainer lines needed to produce hybrids. In 1989, we identified several hybrid combinations that yield up to 30% more than the best true-breeding lines.

Hybrid seed production is labor-intensive, so a hybrid rice industry also would generate rural employment.

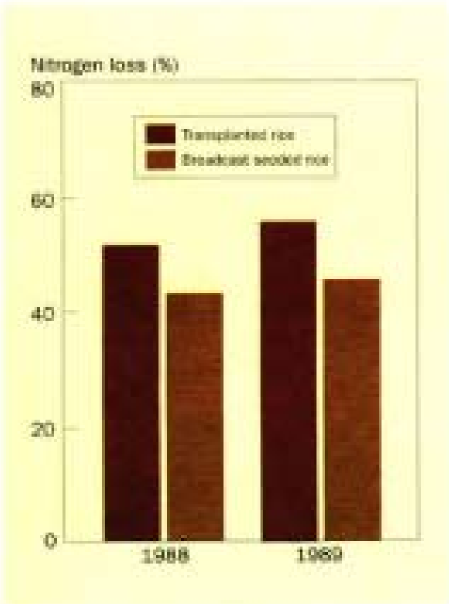
On-farm production stability

A major tool in our efforts to maintain yield stability is genetic resistance, the rice plant's inherent ability to ward off disease. No improved rice variety has adequate resistance to tungro, the most devastating disease in the tropics. But most modern varieties have resistance to the green leafhopper that transmits tungro. That can allow a rice crop to escape infection.

We crossed several traditional varieties with high tungro resistance to IR1561, a high-yielding line susceptible to both tungro and green leafhopper.

Research into livelihood, production, and environmental impacts helps develop profitable, sustainable, rice farming systems.

Progeny lines from backcrosses have improved plant type and, for the first time, tungro resistance. The next backcrosses will be to green leafhopper-resistant lines. We hope that will lead to high-yielding rices that resist both tungro and its vector.



Nitrogen loss in broadcast seeded and transplanted irrigated rice.

Rice grain quality

We continue to develop rice germplasm with the easy cooking traits that consumers prefer: rices with intermediate amylose content, intermediate gelatinization temperature, and translucent grain. IR64 is widely grown because it has this desirable combination of grain characters. We are evaluating new lines that match IR64's grain quality.

Aromatic rices are preferred in much of Asia, but that character is hard to incorporate into modern varieties. We have transferred aroma from the Thai variety Khao Dawk Mali into promising lines that have intermediate amylose content and gelatinization temperature, with translucent grain.

Nitrogen use efficiency by direct seeded rice

Much of the fertilizer nitrogen farmers apply on irrigated ricefields is lost to the atmosphere. We compared that loss in weed-free irrigated fields where rice crops had been transplanted and broadcast seeded. The process is ammonia volatilization and denitrification, through which nitrogen as gas escapes to the atmosphere and is not used by the rice crop. The big loss is through volatilization—close to half the ammonia from applied nitrogen was lost in transplanted rice, but the broadcast crop lost only 20-30%. When fertilizer was topdressed 2-3 weeks after crop establishment (the common farmer practice), total nitrogen loss was about 10% less with broadcast seeding. That could mean large savings in the fertilizer needed to reach rice yield potentials.

Most rainfed lowland rice farmers continue to use traditional rice varieties that give low but stable yields.

Rainfed lowland rice research

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

Farmers who grow rainfed lowland rice bund their fields (like irrigated ricefields) to capture water. But without reliable water, the 40 million hectares of rainfed lowland rice—almost 30% of the world's total—contribute only 20% of the global rice supply. Some 100 million hectares of wetlands in Africa, and about the same hectarage in Latin America, are not cropped or are underutilized. New rainfed rice technology could bring much of that land into production.

Five major subecosystems have been identified within the rainfed lowlands: drought-prone, both drought- and submergence-prone, submergence-prone, medium-deep water, and favorable. All but the favorable areas are characterized by erratic water regimes: both drought and flooding can occur during the same cropping season.

Most rainfed lowland rice farmers continue to use traditional, photoperiod-sensitive rice cultivars that give low but stable yields. A major limitation to

increased productivity is the lack of varieties that respond to increased nitrogen and better management, but with the tolerance of traditional varieties for drought, floods, and soil stresses. Such rices would yield bountifully when farmers are blessed with good weather, and at least as much as traditional varieties in less favorable years.

Earlier research did not greatly benefit the resource-poor rice farmers of the rainfed lowlands. Our new research plan specifically targets these disadvantaged people and areas.

The first breeding priority is to develop and test lines for drought-prone and waterlogged areas. New breeding lines are

Alternative tillage methods

Puddling, or working the flooded field intensively before transplanting or broadcast-seeding rice, is a hard, time-consuming task for rainfed lowland farmers. In the Asian tropics, puddling is done by plowing and harrowing to 25-centimeters soil depth, using animal-drawn implements.

We compared yields and labor requirements of traditional deep puddling, shallow puddling, and zero tillage.

On zero-tillage plots, we sprayed a herbicide on the fallow field before the rains came, to speed the biological breakdown of stubble and to control weeds. For shallow puddling, we used a hand-guided IRRI power tiller to plow and harrow to 15 centimeters. Rainfall was abundant throughout crop growth in test plots at three Philippine sites and yields were similar, averaging 3.8 tons per hectare.

Minimum tillage appears most feasible for rainfed transplanted rice farmers. Shallow puddling using the power tiller was six times faster than deep puddling with a water buffalo. In the zero-tillage plots, labor costs doubled because transplanters found it hard to insert the tender rice seedlings into the hard topsoil. Weed populations also were high.

Shallow puddling using a hand-guided power tiller prepared a flooded field for planting rice six times faster than deep puddling using a water buffalo.

Rainfed lowland ricefields can suffer both flooding and drought within the same cropping season. New breeding lines are being tested for tolerance of these conditions.

needed that combine drought and submergence tolerance with appropriate photoperiod (daylength) sensitivity, seedling vigor (for dry seeding), lodging resistance, disease and insect pest resistance, and tolerance for salinity and phosphorus deficiency. This demands work in stress-prone testing sites away from IRRI: Bangladesh, Cambodia, India, Nepal, northern and central Philippines, and Thailand. A consortium of national programs with key sites representing the subecosystems is planned.

Because rainfed farmers rarely have the cash to buy chemical inputs, our emphasis in crop management is on developing on-farm resources to improve yields. We are working on techniques of soil, nutrient, and water management that allow improved varieties to realize more of their yield potential.

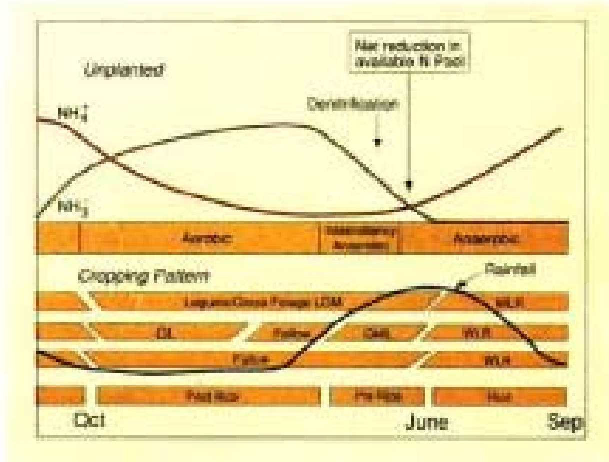
Role of legumes in biological nitrogen fixation and soil nitrogen dynamics

Erratic weather makes rainfed rice farmers reluctant to buy inputs such as fertilizer, and their yields are low and fluctuate widely. Farmers need the ability to increase productivity without increasing costs.

We are exploring ways to improve the efficiency of non-chemical sources of nitrogen, in collaboration with the Nitrogen Fixation in Tropical Agriculture Legumes project at the University of Hawaii, International Fertilizer Development Center, the Australian Council for International Agricultural Research, and concerned national program scientists.

Rainfall patterns are governed by tropical monsoons and typically result in soils that cycle from aerobic (exposed to air) to anaerobic (flooded). Such conditions strongly influence the dynamics of nitrogen in the soil. The dry season favors mineralization and nitrate accumulation. But in the wet season, denitrification in flooded soils can reduce the pool of available soil nitrogen.

We think soil and crop management practices can be improved to offset this nitrogen loss. Growing legumes after rice, in the dry season, could capture some of the available nitrogen through biological fixation. Incorporating the crop residues would recycle that nitrogen for use by the wet season rice crop.



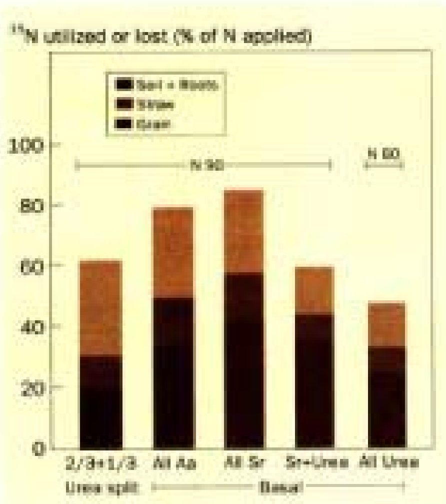
Conceptualized dynamics of available soil nitrogen (measured in unplanted fields) and a cropping sequence that could contribute nitrogen to the soil nitrogen pool.

We have identified legumes and grass forages that are suitable pre-rice and post-rice crops. *Indigofera tinctoria*, a Philippine legume, can be intercropped with short-duration mungbean or long-duration maize. The indigo continues to grow after the main crop harvest. Its incorporation during land preparation for wet season rice has increased yields as much as 1.6 tons per hectare.

The legume *Siratro* sp. and grass forage *Setaria sphacelata* can be clipped for livestock forage several times during the dry season. The last regrowth is incorporated during land preparation for rice.

The legumes *Sesbania rostrata* and *Aeschynomene afraspera* grow rapidly and have nitrogen-fixing nodes on their stems, which makes them uniquely suited for green manure production during the pre-rice period when short-term floods are common. *S. rostrata* is possibly the fastest nitrogen-fixing plant known: 100 to 285 kilograms of nitrogen per hectare in 45 to 55 days.

We know the potential for legumes to increase the nitrogen available to rice, but lack adequate understanding of the soil and biological nitrogen fixation relationships to exploit it. The cultural and moisture conditions involved in rice-based cropping systems mean unique soil conditions. We are mapping how legume-fixed nitrogen fits into the dynamics of the system.



Effect of ^{15}N-labeled urea, *Aeschynomene afraspera* (Aa), and *Sesbania rostrata* (Sr) in single or combined application on IR64 in lowland soil on ^{15}N recovery in soil, straw, and grain. Nueva Ecija, Philippines, 1988 dry season. N rate in kg/ha.

Utilization of biofertilizer nitrogen

We compared recovery by rice of nitrogen fixed by *S. rostrata* and *A. afraspera* legumes with that from urea fertilizer. The green manures could substitute completely for 90 kilograms of nitrogen as urea per hectare.

Nitrogen recovery was higher when green manures were combined with urea than with urea alone. That suggests that combination with organic matter reduces the loss of non-organic nitrogen. Also, more nitrogen remained in the system as green manure than as urea. The residual nitrogen gave higher yields from an unfertilized second crop of rice.

Conserving and using rainwater for a second crop

Many rainfed lowland rice farmers in the tropics would benefit if they could grow a second cash crop after wet season rice. Some rainfed farmers already construct on-farm reservoirs to collect rainfall and runoff to grow a small dry season rice crop. Return for the water is low.

We developed a computer simulation model to evaluate cropping patterns. It is based on optimal use of available water in the dry season, and takes into account agroclimatic and market factors plus land, capital, and family labor.

In a 1989 dry season field test of model outputs using a farm in Tarlac, Philippines, a minimum area was set aside to grow rice for family consumption. The model predicted that cash crop returns would be highest from a rice - mungbean combination. Actual returns were close to those predicted, with a net return of about US$225 using $86-worth of family labor.

Incorporating a green manure crop before planting rice reduces the amount of inorganic fertilizer needed and nitrogen recovery by rice is higher.

Rainfed farmers need ways to improve their soil, nutrient, and water management practices to reap the most benefit from improved rice varieties.

Germplasm improvement for rainfed environments

In work to improve the adaptability of rice breeding lines, we tested 435 recent crosses and 48 advanced lines in three drought-prone sites in the Philippines. Another 76 lines were screened in medium-deep water conditions. The advanced lines were also grown under favorable conditions to establish yield potential and pest resistance.

Three lines with average yield potential of 5.5 tons per hectare appear well-adapted to both water deficit and medium-deep water. The lines mature in about 130 days and have intermediate plant height and sturdy stems plus resistance to major insects and diseases. Other lines with specific tolerance for either drought or medium-deep water were identified.

Promising lines also were identified at sites in Thailand, Eastern India, Nepal, Bangladesh, and Cambodia.

Rainfed lowland rice plant of the future

- **5-7 tons per hectare yield potential**
- **6-10 panicles per plant**
- **no unproductive tillers**
- **150-200 grains per panicle**
- **very sturdy stems**
- **dark green, erect or moderately droopy leaves**
- **130 centimeters tall**
- **extensive root system**
- **multiple disease and insect resistance**
- **strong submergence tolerance**
- **strong grain dormancy**
- **120-150 days growth duration**

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

Upland rice farmers use traditional cropping methods to grow rice in scattered fields.

Upland rice research

Upland or dryland rice is grown in rainfed fields with naturally well-drained soils and no surface water accumulation, much like wheat or maize. The upland topography ranges from sloping terraces to well-drained flatlands.

Upland rice is produced on about 12 million hectares in South and Southeast Asia. Yields average only about 1 ton per hectare, and are very unstable. Constraints to increased production include acidic soils, uncertain rainfall, weeds, diseases, and low inputs.

Upland ricefields are cultivated by poor farmers using traditional methods (predominantly slash-and-burn) in scattered fields. Environmental degradation, erosion, and destruction of forests are serious concerns. Few farmers have ready access to markets, or the capital to purchase inputs. Varieties planted and cropping practices vary.

Biological control of rice blast disease

Rice blast is a severe disease problem in upland and rainfed lowland ricefields. In the tropics, control is mainly by varietal resistance, but resistance is unstable because new races of the fungus evolve rapidly. Most temperate regions use chemical control, but pesticides are environmentally disruptive and too expensive for most tropical rice farmers.

Initial tests show that some bacteria found naturally in ricefields are antagonistic to pathogens, suppressing sheath blight and other fungal diseases. The pathogens also are effective against seed-borne diseases.

We screened more than 400 strains of bacteria for antagonism toward the blast fungus *Pyricularia oryzae*. Two fluorescent pseudomonas strains and two bacillus strains effectively inhibited this foliar disease. On upland rice, seed bacterization and spraying the foliage with these bacteria reduced leaf blast as much as 50% and neck blast up to 25%.

Rice blast is a severe disease problem in upland fields. Using naturally occurring bacteria shows promise for inhibiting blast.

Improved rice cultivars for the upland ecosystem need to have tolerance for drought and for problem soils.

Another problem is the limited work done so far. Only a few national program scientists work on the problems of upland rice farming systems.

IRRI program activities focus on two components: integrated farming systems research and strategic work to improve knowledge about the major upland cropping constraints. Farming systems work will identify alternate practices within a whole-farm enterprise involving food and cash crops and livestock. The objectives are to increase incomes, stabilize the ecosystem, and sustain overall productivity. Ecosystem characterization is part of this effort.

Strategic research is needed on weeds, drought, diseases, and phosphorus and calcium-magnesium soil dynamics, as well as the effects of soil chemical and physical properties on rice and other crops. Improved rice cultivars with drought and problem soil tolerance and disease resistance also are needed.

Upland rice ecosystem work will be done in sites selected to represent the diversity of upland environments, through a consortium of relevant national program researchers. Sites identified in Indonesia, Philippines, Thailand, and India have differing degrees of the major constraints—land degradation, drought, weeds, and blast. They vary in altitude and length of rainy season.

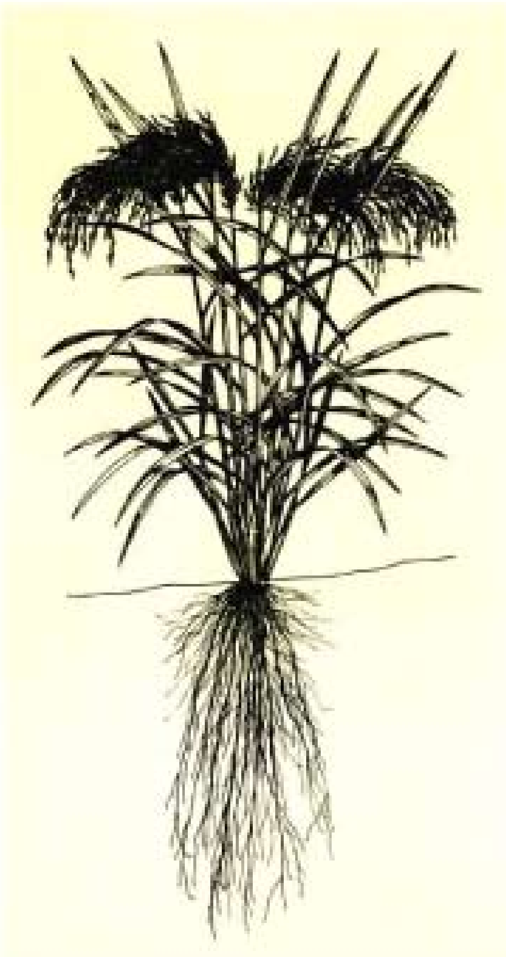
Contour hedgerows hold the soil on sloping land. Rice can be grown between the hedges.

Contour hedgerows for sustainable upland systems

Much of the upland rice grown in the tropics is planted on moderate to steeply sloping fields with strongly acidic, infertile soils. With continuous cropping, topsoil is lost and productivity goes down fast.

Small-scale farmers need practical, affordable soil conservation techniques. Using permanent contour hedgerows to hold the soil may be one answer. Rice and other food crops can be grown in the alleys.

Hedgerows of the non-nodulating tree legume *Cassia spectabilis* look promising. When trimmings were incorporated as a green manure for the rice crop, yields increased slightly. But the rice plants nearest the hedge didn't grow very well. We are looking for ways to ease this interspecies competition, and studying the impacts of hedgerows on insects and weeds in the ricefield and on labor and total farm income.



Upland rice plant of the future
- **3-5 tons per hectare yield potential**
- **5-8 panicles per plant**
- **very sturdy stems**
- **erect upper leaves, droopy lower leaves**
- **130 centimeters tall**
- **deep, thick roots**
- **multiple disease and insect resistance**
- **100-day growth duration**

Breeding stable, high-yielding upland rices

We analyzed the results of 4 years of trials of nearly 2,000 rices at 18 upland sites across the Philippines. The trials were mostly on acidic soils representative of the poor croplands in sloping hill regions. Nitrogen and phosphorus application ranged from none to moderate levels. Yields ranged from 0 to nearly 6 tons per hectare. Maximum yields across sites averaged more than 3 tons.

A few entries, including improved cultivars from Brazil, France, and IRRI, showed yield potentials of twice the trial average, with good adaptation to the poor environments.

Deepwater and tidal wetlands rice research

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 grows for 1-3 months in rainfed fields subject to drought or shallow flooding, then is flooded to depths of more than half a meter for a month or longer. Where flooding is deeper than 1 meter, the crop is usually called floating rice. In tidal wetlands, the water levels in coastal ricefields fluctuate as tides rise and fall. Harsh soils—saline or acid or peat—are common in these ecosystems.

About 13 million hectares of deepwater and tidal wetlands rice are harvested annually, mostly in South and Southeast Asia. Several million hectares of land suitable for deepwater or tidal wetland rice in Asia are not being farmed. In West Africa, floating rices similar to those of Asia are grown in some riverine areas of deep-flooded land and mangrove swamps. Several million hectares of unused deep-flooded lands in South America could be planted to deepwater rice.

Farmers in deepwater and tidal wetland areas can grow little other than rice in the wet season. Varying flooding patterns in different seasons give highly variable stresses. Most farmers are barely self-sufficient in food

In tidal wetlands, water levels fluctuate as the tides rise and fall. Rice varieties must be tolerant of salinity.

grains and live with the constant threat that their basic food supply will be destroyed.

With only one crop a year, the development of improved varieties for deepwater areas is slow. Each new rice variety may have only a limited number of ecological niches. Fitting improved rices into the wide range of environments is difficult. Plants must be selected for submergence and drought tolerance, for saline conditions, and for pest resistance. The inheritance and mechanisms of expression of these traits are not well understood.

For tidal wetland rices, we lack both progenitors and improved germplasm for withstanding the stresses associated with problem soils. Increased understanding of the soil characteristics and processes that cause mineral toxicities and deficiencies will help in developing improved soil management techniques.

Breeding for deepwater rice improvement

Wild floating rices tend to elongate rapidly. We crossed the wild rice *Oryza rufipogon* from Bangladesh with promising deepwater rice breeding lines, to capture and combine rapid elongation ability with a better plant type and more productive panicles. Lines from the crosses were selected for rapid elongation in 110 centimeter-deep water.

Growing large breeding nurseries at the Prachinburi Rice Research Center in Thailand is helping to accelerate our breeding work for 50-100 centimeter-deep water. In one breeding nursery of 11,000 experimental lines, 5% had desirable traits and were selected for further evaluation.

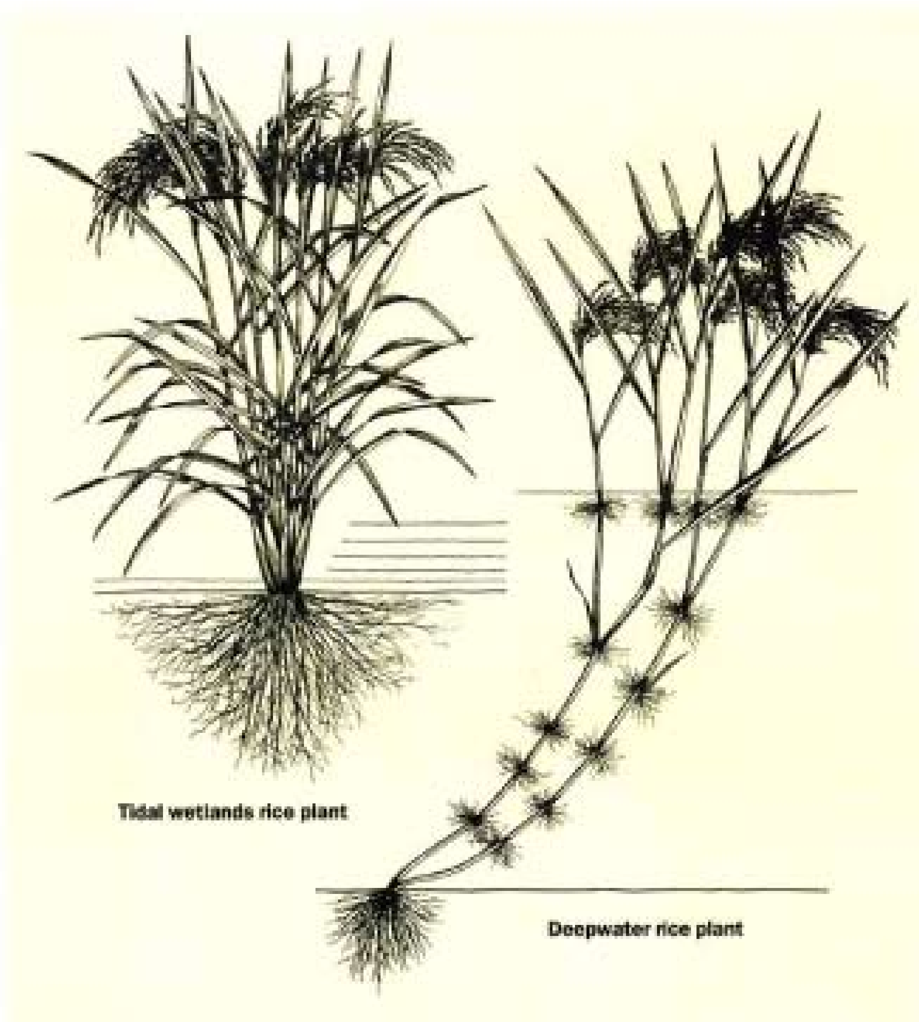
Special efforts are made to test breeding lines in representative farmer fields early in their development, in collaboration with national deepwater rice centers in Thailand, India, Bangladesh, and Vietnam.

Using upland rices in tidal wetlands

Breeders seldom use traditional bulu-type upland rices because they have many undesirable traits and are difficult to cross with indica rices. But many bulus carry genetic tolerance for problem soils.

Tidal wetlands rice plant of the future
- 3-4 tons per hectare yield potential
- 5-7 panicles per plant
- very sturdy stems
- erect to moderately droopy leaves
- 130 centimeters tall
- wide, relatively shallow rooting
- multiple disease and insect resistance
- submergence tolerance
- problem soils tolerance
- photoperiod sensitivity

Deepwater rice plant of the future
- 4-5 tons per hectare yield potential
- 5-7 panicles per plant
- 150-200 grains per panicle
- dark green, long, erect leaves
- internode elongation for 100 centimeters flood
- upper nodal rooting and tillering ability
- early root development
- multiple disease and insect resistance
- photoperiod sensitivity
- grain dormancy



Farmers in both ecosystems will benefit from work to increase the productivity of the whole system, not just the rice crop. Cropping systems must be adapted to specific combinations of a wide range of soil, climate, and flooding conditions.

Much of the work on problem soils is done through a 4-year-old consortium of IRRI, India, Indonesia, Thailand, and Sri Lanka. 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.

We successfully crossed a few bulus with indicas, and selected for high-yielding plant type, grain fertility, and problem soil tolerance in the segregating populations. Six advanced lines show remarkable adaptability to acid, saline, acid-saline, and acid sulfate soils in farmers' fields.

Stem borer problems in deepwater rice

Yellow stem borers are the main insect pest of deepwater rice. All known varieties are susceptible, so we must look for mechanical control methods.

Silica accumulated in rice leaves and stems appears to repel stem borers. We grew a stem borer-susceptible floating rice in cultural solutions with different levels of silica. The higher the silica content of the growth solution, the more silica in the stem and leaves, and the less yellow stem borer infestation. Silica also appears to retard blast disease.

Ufra nematodes endemic in Brahmaputra floodplains

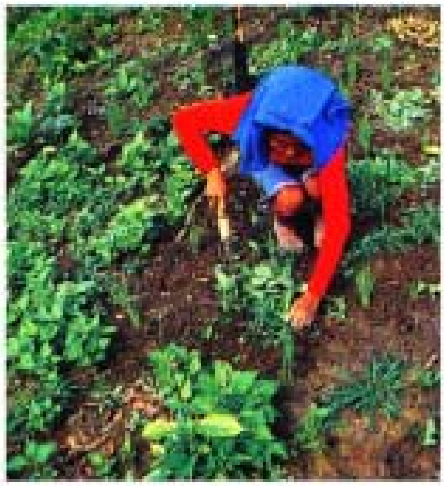
Several thousand random assessments across 4 years in Assam, India, confirm that ufra disease is a serious endemic problem in the floodplains of the Brahmaputra River. Ryadha, a variety from Bangladesh tolerant of the root nematodes that cause ufra, is being used in breeding for ufra resistance.

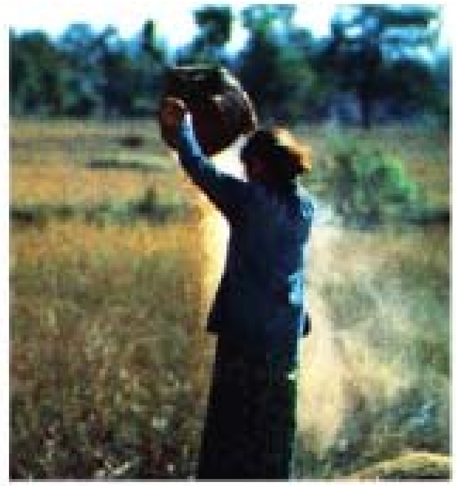
Deepwater rice - fish culture to increase farmer incomes

Fields stocked with fingerlings have produced more than a half ton of fish per hectare, without reducing rice yields, in trials on fish culture in deepwater ricefields in eastern India.

An Indian deepwater rice farmer and his family can harvest more than a half ton of fish from one hectare, without affecting the rice yield.

IRRI research is developing methods to classify factors that distinguish rice-growing ecosystems.





Cross-ecosystems Research Projects for 1990-1994

Germplasm evaluation
- Methods for [illegible] germplasm

Genetic manipulation
- [illegible] 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

Cross-ecosystems research

IRRI's cross-ecosystems program is a "scientific bridge" planned to generate knowledge applicable to more than one ecosystem and techniques to speed research in all ecosystem-specific projects. A flexible research agenda allows us to respond quickly to problems not yet identified. Projects bridge basic research done at other advanced institutions and strategic and applied research done in the ecosystem-specific programs and in national programs for rice research.

A rice ecosystem classification system

We are developing methodology to define the range of farmers' problems and opportunities. The system will classify information on the physical, climatic, biological, and socioeconomic factors of each ecosystem.

The information will be consolidated into a geographic database. Defining the extent of an ecosystem's features will help us identify priorities for varietal

Ecosystem characterization

IRRI has used maps of climate, soils, crop data, and socioeconomic variables for years to help set research priorities. New computer simulation techniques and Geographic Information Systems now make it possible to analyze determinants of rice production in a range of environments, including climate changes projected for the future.

We used a simulation model to predict rice yields using current technology under the weather conditions anticipated in 2020. Predicted yields were about 10% lower than today's yields.

We have developed methodologies to analyze variability in the physical properties of rice soils. The objective is to indicate the measurement precision and sampling densities needed for reliability in ecosystem characterization and production simulations.

Processes at the root-soil interface

Research in the rhizosphere—the narrow zone of soil near the roots where chemical and biological characteristics differ markedly from those of the surrounding soil—is difficult because it extends less than one millimeter from the root surface. We are complementing direct experimental observations with simulation models and now have a model of the reaction of oxygen released by rice roots to ferrous iron present in the soil.

Understanding the rhizosphere could lead to major advances in breeding rices for efficient nutrient uptake and with tolerance for soil stresses, and will help in developing more efficient agronomic practices.

New techniques are enabling direct study of the rhizosphere—the narrow zone of soil near the rice roots. That will help in developing new varieties and more efficient agronomic practices.

improvement and for research on crop and resource management. This database will help us extrapolate the potential spread of successful technologies. We are developing crop simulation methodologies to quantify options for increasing crop production and land management.

Research into the effects of world rice supply and demand on national policies will link with studies on the social and economic impacts of new technologies.

Crucial processes must be mapped if we are to predict the applicability of new technologies. One example is the soil-water-nutrient processes in flooded soils and during the transition from flooded to nonflooded. Better understanding of the processes at the root-soil interface in submerged soils will help in selecting varieties that use nutrients efficiently and those that tolerate soil stresses such as salinity and alkalinity.

Kairomones in rice plant volatiles

As part of our work to understand the processes of insect resistance in rice, we examined naturally occurring compounds in volatiles of rice varieties susceptible and resistant to yellow stem borer and leaffolder. And we found differences among the varieties.

Of the 36 compounds found, limonene was the major component in volatiles of susceptible Rexoro and resistant IR36. But its level was 16 times higher in Rexoro. Rexoro also yielded the highest amount of kairomones. E-(2)-hexanal and Z-(3)-hesen-1-ol were major constituents in the volatiles of IR36; their levels were much lower in other varieties. Cineole was found only in the wild rice *Oryza perennis*.

Plant volatiles and insect resistance

We used electroantennography (EAG), which involves attaching electrodes to insect antennae, to screen 97 plant volatiles—including the 36 identified from rice plants—for sensory responses by rice leaffolders. Some volatile compounds elicited extremely negative EAG potential, indicating attractors. The volatile compounds thymol and carvacrol elicited highly positive EAG potential, indicating that they strongly repel leaffolder feeding. Rices that produce repellant could be valuable in breeding for resistance.

Insect resistance in wild rices

Recently, planthopper and leafhopper resistance was successfully transferred from the wild rice *Oryza officinalis* to cultivated rice. In our search for additional donors of genetic resistances, we evaluated wide hybrid progeny of *O. brachyantha* and domestic rice *O. sativa* and backcrossed plants for resistance to yellow stem borer and rice leaffolder.

Defining the extent of each ecosystem's features will help in identifying priorities for varietal improvement and for research on crop and resource management.

Establishing economic thresholds (the pest levels that cause economic crop loss) helps in making management decisions and provides data for simulations that can predict pest dynamics and epidemics.

Determining the physical and biochemical mechanisms of resistance in rice will help in developing biologically and economically sound pest management for all rice ecosystems.

Seed health is important for farmers and consumers in all ecosystems, and is a major concern of quarantine procedures in germplasm exchange and in international marketing. Pests damage not only stored grain, but also crops grown from infected seed. We are developing taxonomic identifiers, evaluating the relative effects of specific pathogens on seeds, and measuring how seedborne pathogens affect growth of the rice crop.

Yellow stem borer larvae removed 14 days after plants with *O. brachyantha* genes were infested with first-instar larvae were small and underweight. This indicates that resistance had been successfully transferred.

Molecular analyses of rice pathogen populations

Better understanding of variation in rice pathogens would allow development of improved methods to manage diseases in rice crops. We used DNA analysis techniques to study variation in populations of three rice pathogens.

In one study, we cloned several transposable genetic elements from the bacterial blight pathogen and used one of them as a probe to analyze a collection of blight isolates.

Rice blight pathogen populations infecting weeds appear to be genetically different from those infecting rice. This indicates that diseased weeds do not provide inocula to threaten a rice crop.

DNA analyses also are being used to identify new resistance genes in conserved germplasm.

Transferring disease resistance genes from *Oryza minuta* to rice

The wild rice species *O. minuta* is resistant to several diseases and insect pests. But it is only distantly related to rice, so the cross to capture the resistance genes requires special techniques. This year, we obtained derivative lines with the proper number of chromosomes for rice. One line is resistant to blast, another to bacterial blight.

The blast pathogen apparently has difficulty adhering to and penetrating the leaves of the wild species. If the fungus does enter the leaf, it cannot establish itself. For bacterial blight, at least three different resistance factors appear to be segregating in one line.

Molecular analysis of rice pathogens will lead to the development of improved methods of managing diseases.

Rice quality

Delays in harvesting can cause losses in the field and at the rice mill. We plan to improve varietal resistance to shattering losses at harvest and to grain cracking during drying and milling. We can also reduce postharvest losses by improving the design of threshers, winnowers, grain dryers, on-farm storage facilities, and small mills and dehullers.

Technology that would make use of rice by-products, such as hulls as fuel (directly or processed into briquettes) or machines to chop straw for easy incorporation into the soil, are needed.

We need information to apply in rice markets: better methodology for identifying cultivars from seed and milled rice, methods to evaluate and classify cooked rice texture and aroma, and information on the inheritance of grain protein content.

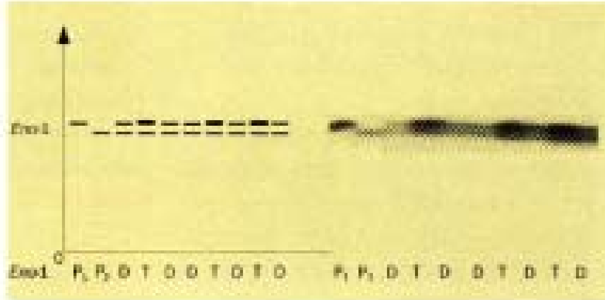
Screening the germplasm collection

We are setting priorities for the important agronomic traits needed in each ecosystem and developing procedures to accelerate screening of unimproved rices and their wild relatives for those traits. Genetic sources of important traits will be available as seeds and a database to breeding programs everywhere.

Genetic and molecular maps of rice

The search to saturate the genetic linkage map of rice continues. Four morphological markers have been located through trisomic analysis: one zebra each on chromosomes 1 and 5, chlorotic tigrina on chromosome 2, and brittle culm on chromosome 5.

Three isozyme loci have been located through gene dosage and segregation analysis: *Enp-1* on chromosome 3, *Est-1* on chromosome 7, and *Fdp-1* on chromosome 11. The two loci *Amp-1* and *Got-3* on chromosome 2 are independent of each other.



Starch gel zymogram and diagrammatic interpretation of *Eno-1* showing disomic (D) and critical trisomic (T) banding patterns.

Polymorphism for four new isozyme loci—*Dia-2*', *Sud-1*', *Sud-3*', and *Tpi-1*'—have been detected. One, for the cross IR36/Ma Hae, shows polymorphism for 13 isozyme loci.

We have generated segregating rice plant generations for determining linkage relationships among morphological, isozyme, and RFLP markers.

Tissue culture to speed plant breeding

Anther culture is a laboratory technique that encourages the asexual development of rice plants from grain heads. It allows rapid production of pure breeding lines with desirable characteristics (such as drought tolerance or blast resistance) in two generations instead of the six or seven needed in conventional breeding. But the procedure needs to be refined and stabilized.

We evaluated 26 IR varieties for their plant regeneration ability in anther culture. This provides a database for future studies. High anther response and plant regeneration ability have been achieved in 12 lines, and some poor responders identified. High responders may be good parents for wide crosses of incompatible species.

We also developed a new medium for anther culture of recalcitrant indica rices. The quality and quantity of nitrogen is the critical factor. We will use this medium in the anther culture of indica/indica crosses.

Pollen culture progress

We obtained successful plant regeneration from isolated pollen culture in indica variety IR43 (in 1988, we were successful with japonica variety Taipei 309). Now we are improving the culture conditions to increase pollen plant formation efficiency.

APPLICATIONS OF BIOTECHNOLOGY FOR CULTIVAR IMPROVEMENT

Current activities in biotechnology involve four thrusts:

- Production of novel germplasm by breeding desirable traits from wild relatives of rice into cultivated rice, or by "gene splicing" from rice or even from other plants.
- Identifying isozyme and RFLP markers closely linked to genes that control specific traits.
- Rapid production through anther culture of pure breeding lines with desirable characters.
- Use of nucleic acid probes to characterize and distinguish strains of bacterial, fungal, and viral diseases.

The knowledge biotechnological procedures develop can be used across the ecosystems and will support an International Biotechnology Network sponsored by the Rockefeller Foundation.

Biotechnology is expanding knowledge about the genetics of rice and leading to the production of novel germplasm with many desirable traits.

International programs

IRRI's international programs facilitate the dissemination of new knowledge and useful technology to national programs around the world.

IRRI's Research and International Programs are interactive. Activities designed to share knowledge and strengthen national agricultural research systems also strengthen IRRI's own research. The International Programs

- House the world's major rice germplasm collection and provide the evaluation, preservation, and dissemination services that this responsibility demands.
- Gather and disseminate information on rice and rice-related science.
- Organize conferences to facilitate the exchange of knowledge and direct its application to resolving emerging problems.
- Promote the exchange of technologies and their evaluation by national programs.
- Provide short-term training and degree training in collaboration with universities all over the world.
- Extend technical services to strengthen the capacity of different national agricultural research systems to conduct rice research.

Resource allocation

Continuing dialogue guides the nature and scope of the Institute's international programs and their close integration with its research programs. The increasing number of research activities at key ecosystem sites outside IRRI headquarters are managed through the research programs, in collaboration with the relevant national programs and with cooperation from international program projects.

Some important work is carried out in tandem with research programs: documenting the germplasm collection and screening it for desirable genetic traits, designing needed training courses, organizing relevant conferences and workshops, collaborating in country and regional projects. And some research is integrated into the international programs: surveys on the research capacity and training needs of national programs, studies on seed storage problems, ways to improve database management, and analysis of network data.

Estimated budgets for specific international programs during 1990-1994 are based on the senior staff time needed in each program and on historical costs of program activities.

Fernando A. Bernardo
Deputy Director General
for International Programs

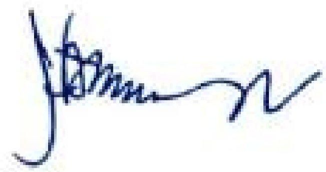
The benefits of IRRI research would be only IRRI's hopes and dreams if they were not made available to the rice farmers of the world. The Institute's International Programs enable us to disseminate useful information and knowledge to national rice improvement programs around the world. We make new rice technologies available for national systems to test, adapt, and apply; they, in turn, feed their research results and information about actual field problems back to IRRI. That process is vital in keeping IRRI's research relevant and rigorous.

Rice genetic resources are the lifeblood of rice breeding programs. The International Rice Germplasm Center gives all countries, regardless of their political system, free access to an enormous gene pool, to enrich the genetic base of their national programs. Similarly, the IRRI Information Center and international networks facilitate worldwide exchange of rice knowledge and technologies.

IRRI's research would be of limited value without our work with strong partners in the national rice programs. Thus, training and collaborative country projects are the keystone of our program to strengthen national rice research systems. IRRI alumni—now about 6,000 strong—comprise the most important human resource in global rice research. Many of them hold key positions in national systems and help formulate the national policies that promote the application of science to increasing rice production and to improving the welfare of rice-farming families.

The need for training continues and changes as national programs evolve and as we jointly address production, socioeconomic, and environmental sustainability problems in the rice ecosystems. Our new approach is to transfer some responsibility for regional training to more advanced national programs. We plan to contribute to the strengthening of the infrastructure for training in those countries—increasing the relevance of the training and enhancing the linkages among rice-growing countries with similar interests.

IRRI's collaborative country projects also strengthen national rice research systems, especially in countries where production cannot meet the needs of rapidly increasing populations. We are committed to the long-term task of helping them build their capacity to undertake their own rice research and training programs. We believe that a populous rice-growing and rice-consuming country can face the future with confidence only with a strong capability for rice research and development.



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

The rapid erosion of rice germplasm in farmers' fields, in seed banks, and in unprotected areas demands multiagency cooperation for energetic collection and conservation. IRRI shares its experience in genetic conservation and gene bank management with national and regional rice conservation agencies.

The world's total rice gene pool is about 130,000 varieties and wild species. Seeds of some 85,000 of them are preserved in the International Rice Germplasm Center (IRGC) at IRRI. IRRI has the global responsibility to help national partners collect, conserve, and share this irreplaceable biological heritage. The survival of future generations may depend on it.

Seeds of rare and endangered rices and wild relatives of rices are collected for conservation in IRRI's genebank.

Collecting native and wild rices in Vietnam, Laos, Cambodia

We traveled with colleagues from the National Institute of Agricultural Sciences over high mountain passes to isolated villages in northwestern Vietnam whose rice varieties had never been documented. There, we collected traditional varieties and previously unknown populations of wild relatives of rice. Farmers grow only glutinous rices in Muong Pon; we collected 10 varieties. We also took samples of both glutinous and nonglutinous varieties at 1,200 m altitude in Sothan village.

Traditional rice varieties and previously unknown populations of wild rices were collected this year in Vietnam, Laos, and Cambodia.

Exploration for wild rices in the forested mountains that surround the ancient Laotian capital of Luang Prabang yielded *Oryza granulata*, a small shade-loving perennial relative of rice that had never been reported in Laos. Villagers call it *khao not pet*, bird rice.

Wild rice is a dominant grass along the roadside in areas of the lower Mekong river in Cambodia, where we collected samples of 6 wild species and 167 traditional varieties. One Kompong Chhang farmer recalled a favorite deepwater variety whose seeds he lost when growing deepwater rices was prohibited in central Cambodia. The IRGC holds accessions of 902 Cambodian varieties, including 25 deepwater rices collected in 1973. Since 1981, we have returned seeds of many traditional varieties to Cambodian rice scientists. This year's shipment was the largest—172 varieties.

New wild rice species

A new wild rice—*Oryza rhizomatis*—was identified from a 1988 collection in Sri Lanka. It may be a good source of genetic tolerance for drought.

In 1988, we collected several types of wild rices in collaboration with Sri Lankan colleagues. When we grew the collected germplasm side by side at IRRI, we realized we had found a new species. We named it *Oryza rhizomatis* because, unlike other species, it produces rhizomes—adventitious plantlets from the parent roots.

Now we are evaluating its genetic base. The new wild rice grows in Sri Lanka's dry zone and has many thick, deep roots, so it may be a good source of drought tolerance. Sri Lanka is also a region of brown planthopper diversity, and we are examining the resistance of *O. rhizomatis* to this important pest.

Stocking new genebanks

Years of field collection had led to a near-complete collection of the native rices of Sri Lanka. The IRGC provided seeds of 1,862 accessions—the entire national collection—when a modern genetic conservation facility opened at the Central Agricultural Institute at Peradeniya.

The IRGC has also restocked or revived entire national collections in Cambodia, Nepal, Pakistan, the Philippines, Senegal, and three states of India.

Data on special traits of the seeds that we send—duration; grain quality; tolerances for cold temperature, drought, and excess water; resistances to insect pests and diseases—help national scientists find and use specific genetic traits needed for their breeding programs.

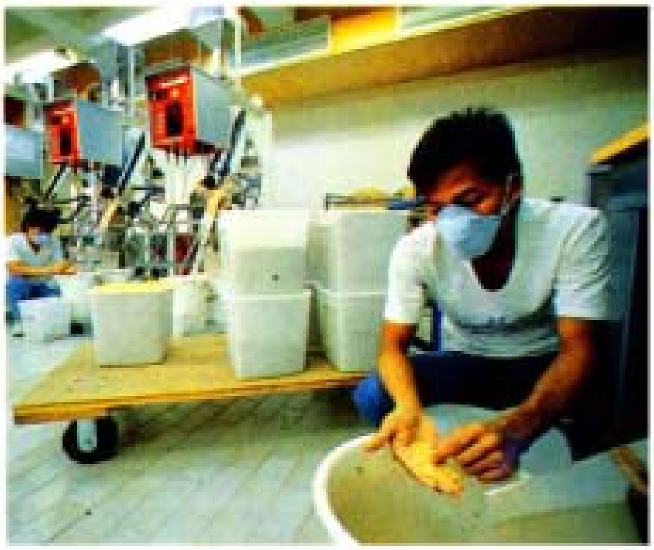
Seed health for germplasm exchange

IRRI sends seeds of wild rice species, early generation crosses, advanced breeding lines, and traditional rice varieties around the world. This massive flow of seeds means the obvious risk of also moving exotic insects and diseases.

The need for seed health is not restricted to international seed exchange. Pure, clean seed is essential for disease management in farmers' crops. Crop losses caused by seedborne diseases have not been quantified, but they are estimated to be substantial.

IRRI strives to meet, and exceed, the plant quarantine standards of our collaborating countries and to find new ways to ensure seed health for international exchange and in-country storage and movement.

A massive number of rice seeds are sent from IRRI to scientists around the world. Strict precautions ensure the health of such seeds.



Information and knowledge exchange

Information and Knowledge Exchange Projects for 1990-1994

Library
- Improve services and expand international access

Scientific publication
- Publish research results
- Increase copublication

Rice databases
- Improve databases and database information services

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

Public awareness
- Increase awareness of and support for rice research

IRRI plays an increasingly important role as the major facilitator of the worldwide flow of rice information. The library, communication and publications, and computer services are the main units concerned with gathering, processing, and disseminating information on rice science.

LIBRARY AND DOCUMENTATION

We initiated a new library service, *Rice literature update*, in June 1989. Essentially, it is a 2-month edition of the *International bibliography of rice research*. *Update* goes to the 15,000 libraries and individuals who receive the *International Rice Research Newsletter*. The *1988 Supplement* to the bibliography released this year contained 8,468 rice literature citations.

CD-ROM is increasing the accessibility of electronic references and databases to IRRI staff and scholars. Already available are the prototype disk of CGIAR literature, AGRICOLA, and an electronic encyclopedia.

We reached agreement with Universite Catholique de Louvain, Belgium, to computerize the IRRI collection of azolla literature, dating from 1783 to 1989, and consolidate it with the literature in Belgium. The new database will be published jointly.

Funds are sought to preserve the entire library collection

Computerization is expanding the accessibility of IRRI's extensive databases. CD-ROM is facilitating use of electronic references in the library. The computer services unit is harmonizing all databases to facilitate information searches.

(89,000 books and 3,800 serial titles) on CD-ROM or optical disk, and to replace labor-intensive cataloging and circulation procedures with an integrated library system, accessible on-line to IRRI staff.

Selected IRRI publications are designed to be easy to translate and copublish in the languages of national rice development programs.

IMPROVING RESEARCH COMMUNICATION

IRRI is one of the largest publishers of agricultural science in the developing countries. Our book publishing is self-sustaining: new titles are financed from income generated by sales of earlier books. In 1989, we published 11 new books in English and distributed about 70,000 copies of major IRRI publications. Almost 37,000 were in English; the others were translations generated through IRRI's copublication program.

Four issues of the *IRRI reporter*, six issues of the *International rice research newsletter* (IRRN), and the two *IRRN indexes* went to 12,000 rice workers and 3,050 libraries in 151 countries. Also distributed were two issues of the *IRRI research paper series*; international newsletters on azolla, deepwater rice, hybrid rice, and rice genetics; and the *IRRI alumni newsletter*.

Since 1986, CAB International and IRRI have jointly published *Rice abstracts* six times a year and distributed 1,100 subscriptions to key agricultural libraries in developing countries, with support from the Asian Development Bank. We are now trying to make *Rice abstracts* self-sustaining.

During 1990-1994, we will concentrate on publishing works that reflect IRRI's research priorities and will categorize our publications list by ecosystem.

We design selected publications to make them easy and inexpensive for cooperators in NARS to translate and copublish. Eight such translations were issued in 1989, making a total of 131 editions of 33 IRRI books copublished in 44 languages in 29 countries.

A farmer's primer on growing rice is undoubtedly the world's most widely published agricultural text; this year, the 45th edition in the 37th language was published. *A farmer's primer on growing soybean on riceland*, and a companion volume for cowpea, had been published in four languages by late 1989. *A farmer's primer on growing upland rice* was published in Hindi. The 1988 English edition was published jointly by IRRI and the French Institute for Tropical Food Crops Research (IRAT); a French edition is being produced by IRAT.

Field problems of tropical rice is available in 23 languages and *Helpful insects, spiders, and pathogens* in 10.

Two more books designed for copublication are in production: *A primer on organic-based rice farming* and *Seeds and seedlings of weeds in rice in South and Southeast Asia*. By 1995, we hope to have published a primer and a field guide for each rice ecosystem.

RICE DATABASES

A new genebank information system has been developed using the ORACLE database management system, and we are harmonizing other IRRI databases. If, for example, a scientist requests information on a specific rice variety, the database search might include the International Rice Bibliography, the genebank database, the History of IR Crosses database (which is expanding to include genealogies of varieties and lines from national programs) and the International Network for Genetic Evaluation of Rice database.

Data generated by research in the rice ecosystems programs will be processed into easily accessible databases that we hope to share worldwide, via improved telecommunication.

Conferences and workshops

The drive to exchange knowledge that led to the formation of the earliest scientific societies is especially relevant to IRRI's mission. Scientific conferences and workshops have fostered the interaction of rice researchers since the early 1960s. That knowledge and cultural exchange is crucial to strengthening collaborative research partnerships and to building consortia.

Increasingly, we are using scientific meetings to set priorities, monitor programs, and discuss institutional and policy issues in a politically neutral, noncommercial setting. Topics of the 14 conferences held at IRRI in 1989 ranged from global climate change, to differential impacts of modern rice technology, to appropriate technology for rural women.

Improving public awareness

We have increased IRRI's print and electronic media exposure, to support creation of a better understanding of rice research among donors, policymakers, and the general public. In 1989, 33 news releases and 19 earlier releases were published at least 220 times in Philippine and foreign newspapers and magazines. Now we are translating selected releases into German, Spanish, and Japanese.

About 75 print and broadcast journalists attended three IRRI press days, and another 46 journalists visited IRRI; 26 were from international media.

IRRI work was featured on two nationwide Philippine TV programs in 1989 and was filmed by TV crews from Canada and Australia. We are preparing video programs showing rice and IRRI activities to help increase television coverage.

Almost 32,000 persons registered with IRRI Visitors Services in 1989. Two new audiovisual shows are being prepared: an update of the current show and a special presentation for schoolchildren.

Service to research

The Communication and Publications unit also provides in-house communication support to IRRI programs and administration. These include editing, typesetting, graphic art and design, printing, photography, and audiovisual services.

In the Computer Services unit, facilities were remodelled and relocated. Electricity is erratic in the Philippines, but our new uninterruptible power supply "conditions" raw electric power to allow proper shutdown when IRRI's power supply fails.

An additional direct-access storage device is helping us cope with the burgeoning data of the new personnel and administrative recordkeeping system. A computer laboratory and a Geographic Information System laboratory are in progress.

Networks link scientists across geographic regions and across continents. INGER distributes rice nursery materials for target environments and physical and biological stresses.

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 link people and organizations involved in rice research and technology evaluation, within geographic regions and across continents. They facilitate spillover use of new technologies among regions with similar agroecosystems. The networks coordinated by IRRI, once mainly vehicles to disseminate IRRI-developed technologies, have evolved into true networks, with significant inputs from national program participants.

International Network for Genetic Evaluation of Rice (INGER)

Genetic diversity is important to stable rice production. INGER promotes the worldwide exchange, evaluation, and use of genetically diverse breeding lines. National programs entered nearly two-thirds of the breeding material tested in INGER nurseries in 41 countries in 1989. Other materials were from CIAT, IITA, IRRI, and WARDA.

INGER came into being in July 1989, replacing the International Rice Testing Program (IRTP) established in 1975. The network is a component of the new International Cooperative Rice Improvement Project for Sustainable Rice Farming funded by the United Nations Development Programme (UNDP). It is the world's largest network for agricultural science, with the participation of scientists in more than 70 countries.

We distributed 959 types of nursery materials for different target environments and physical and biological stresses. Observational nurseries include a collection of breeding lines with genes for resistance to rice blast, bacterial blight, tungro, brown planthopper, and stem borer.

So far, 177 INGER test entries originating from 17 national breeding programs and international centers have been released as varieties in 50 countries in Asia, Africa, and Latin America. Some varieties bred in Bangladesh do well in Burma or Nepal. Varieties from Korea have been adapted in Bhutan. Entries from CIAT in Colombia and from Brazil are being used in Africa. Breeding lines from IRRI have been widely used.

INGER also helps link IRRI's ecosystem-based genetic research with national varietal improvement activities, giving feedback on how cultivars perform in different environments. Accumulated data help identify diverse sources of tolerance for low temperature and problem soils and of resistance to pests. They provide information on differentiation of pathogen races and insect biotypes across rice-growing areas.

International Network on Soil Fertility and Sustainable Rice Farming (INSURF)
INSURF focuses on developing improved soil fertility management practices and technologies for sustainable rice-based cropping systems in the major rice ecosystems. About 20 national rice research programs collaborate to test integrated nutrient management technology, manage long-term fertility studies, and study ways to manage adverse soils. Research is strengthened by training and monitoring tours.

Sub-networks initiated in 1989 will lead priority research on using green manure and azolla, managing soil fertility in acid upland and rainfed lowland soils, and applying sulfur and other micronutrients. We have identified satellite sites and are refining the mechanisms for implementing the sub-networks.

INSURF activities are funded by the Swiss Development Cooperation.

Asian Rice Farming Systems Network (ARFSN)
Scientists in 16 Asian countries and Madagascar collaborate through ARFSN to develop and evaluate productive rice-based farming systems. They design, refine, and test research methodologies and improved technologies for local use and their adaptation to other environments.

The work ranges across rice ecosystems, with more than 240 research sites in 14 countries. At most sites, cropping patterns such as rice - wheat rotation are evaluated, plus crop - animal systems and rice - fish farming.

Evaluating the impact of improved technology on agricultural production and household income is under way in six countries. We are studying the effect of new rice technology on nutrition in key sites where adoption took place long enough ago to measure its impact.

Cropping patterns that are agronomically and economically better than traditional farmer practices have been identified. The patterns usually revolve around short-duration varieties of high-yielding crops, to increase cropping intensity. In nine key sites, net returns have been higher with improved systems.

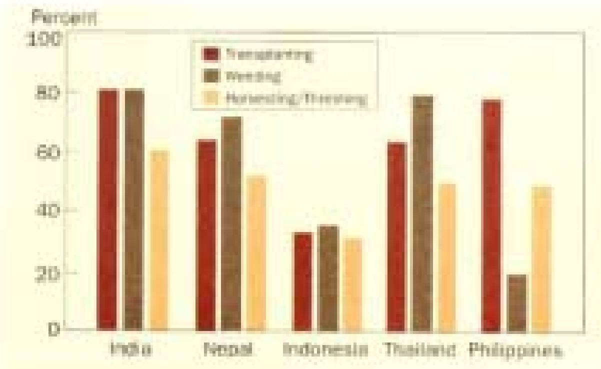
Work on women's roles integrates gender issues into research within ARFSN.

Women in rice farming

Although there are differences by country, culture, and rice-growing environment, women everywhere play a key role in rice farming. In addition to managing the domestic affairs of the farm family, they provide much of the labor used in rice production—about 75% on irrigated farms in India. They participate in making key decisions, particularly decisions about allocating farm resources, and they process and market the family harvest.

Yet much of the agricultural technology introduced so far has been conceived and developed without recognizing that women will probably be its primary users. IRRI's agricultural engineering division is leading by modifying and testing grain handling machinery with women users.

In Asia, nearly all rice farming households select and save seed from one crop to plant the next crop. Only about 8% buy certified seed. Women play an important role in seed management decisions about variety and about methods of drying and storing. We surveyed two rice-farming villages in the Philippines. Women were responsible for almost all the drying and, 75% of the time, for seed storage.



Contribution of women to rice farming labor.

INSURF focuses on developing improved soil fertility management, including work on using organic sources of nitrogen.

Women in Rice Farming Systems (WIRFS)

The Women in Rice Farming Systems project operates at key sites in seven ARFSN member countries. The aim is not separate research on women, but integration of gender issues into the agricultural research process.

WIRFS has quantified and documented distinctions in the types of tasks that rural women perform. The data help raise rice scientists' awareness of the critical roles that women play in rice farming—the first step toward technology development targeted for rural women. Developments are promising in seed and integrated pest management, design of agricultural machinery, and utilization of rice by-products.

The goal is to clearly define the target beneficiaries of new technology and to narrow the gap between men and women in access to production resources, including training and capital.

Work in seed and integrated pest management illustrates the range of innovations that result from incorporating gender analysis into technology development. In seed management, women do almost all the selecting, cleaning, preservation, and preparation for planting. When women are trained in improved methods of seed handling, seedling vigor improves. That translates into higher yields. INGER has published a brochure outlining aspects of seed quality, as a training tool.

Women also have been trained to monitor ricefields for rice pests. The information they generate helps target the needed crop protection measures.

Training

Training projects for 1990-1994
- Degree and postdegree training
- Group training courses

IRRI's training program assists national research systems in developing critical masses of professionals working to advance rice science. Training efforts focus primarily on the national systems that cooperate in research consortia and networks, and on countries whose rice production problems are of serious concern.

Program thrusts are degree and research scholarships and group training, including courseware development and course transfer.

Scientists in national programs take coursework for MS and Ph D degrees at one of 26 cooperating universities worldwide, and conduct thesis research at IRRI. In 1989, IRRI had 102 scholars from 13 countries in Asia, 5 in Africa, 1 in the Middle East, 1 in Latin America, and 6 in North America and Europe.

Through group training, usually 2- to 4-month courses, cooperators develop special research expertise to apply in their own programs and to share with colleagues. The strategy of small groups taking hands-on, problem-solving training is a model for training programs in national systems.

Courses usually involve 20 to 35 trainees, who spend about half

Short-term training involves classroom and applied field projects.

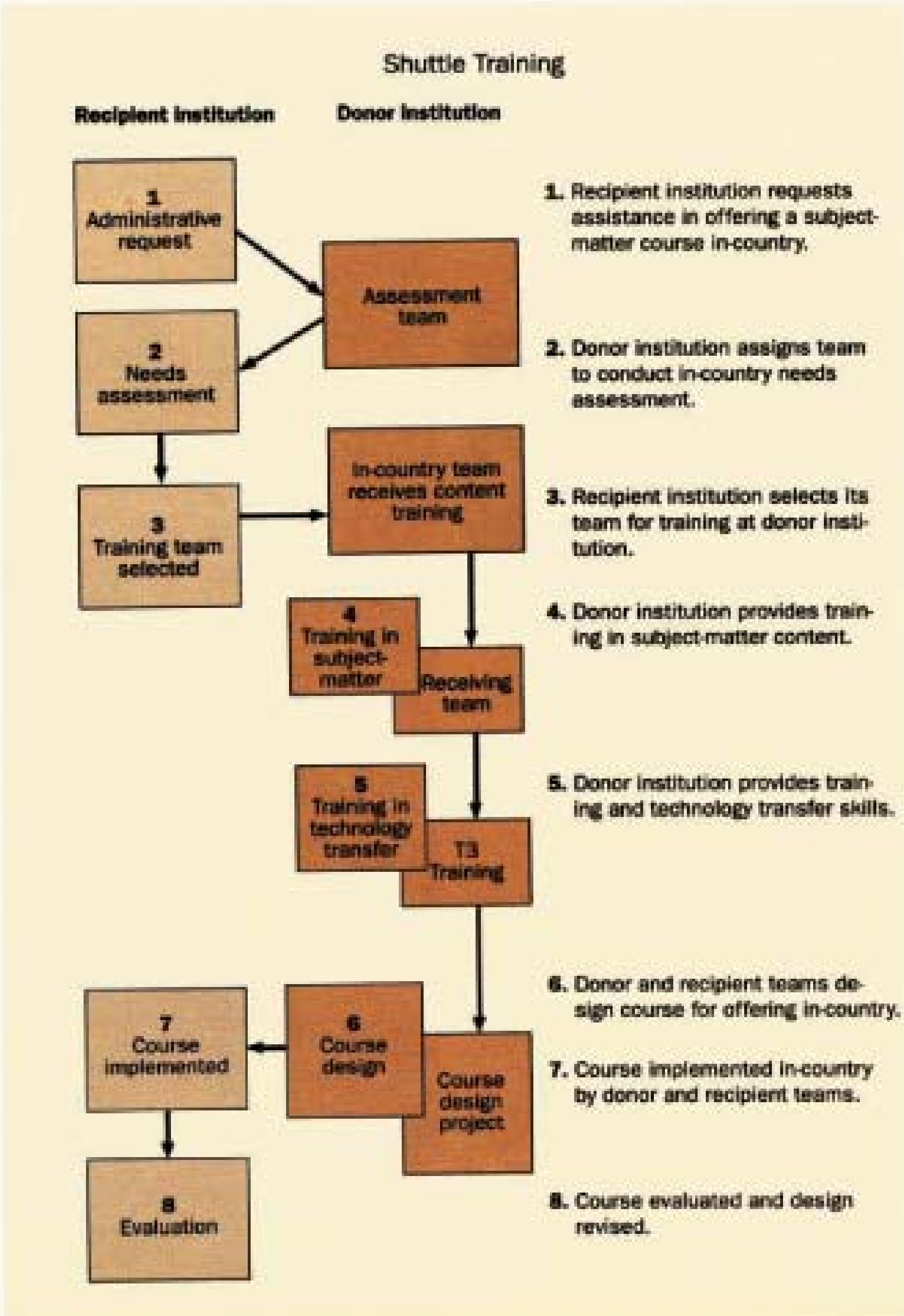
their time learning basic principles, the other half in applied work and team projects. In 1989, 174 trainees participated in 11 courses on aspects of Genetic Evaluation and Utilization, Integrated Pest Management, Irrigation Water Management, Statistical Procedures and Computer Applications in Agricultural Research, and Cropping Systems.

Adult education research shows the value of learner-oriented training whereby the learner himself plays a greater role in the training process. We design, produce, and manage instructional materials for self-learning, including self-instructional publications, slide/tape modules, video, computer-aided interactive tutorial programs, and test materials.

That instructional resources base helps implement distance learning. We use two approaches: sending IRRI training teams to conduct short courses in collaborating countries and assisting national systems to set up their own training programs.

A "shuttle training" scheme helps overcome in-country constraints and increase the training competency in national systems. We also offer a special short course on Training and Technology Transfer.

The Training Center parallels its programs with research on learning styles, training methodologies, visual literacy, distance learning, courseware development, and testing and measurement. We are analyzing our alumni information to document IRRI's impact on affirmative action in developing country agricultural research centers.



A shuttle training scheme is making courses available in countries away from IRRI headquarters.

Country and Regional Projects for 1990-1994

In Asia
In Africa
In Latin America and the Caribbean

Country projects help strengthen national rice research systems. Some programs help establish or rehabilitate a national program; others aim to increase skills in specific disciplines or problem areas.

Country and regional projects

Strong national rice research systems are important for the following reasons:

- Countries with less viable agricultural research systems have difficulty improving rice production enough to feed their populations without food imports.
- Improved rice technologies developed at IRRI and elsewhere are of limited value unless national research programs have the capability to adapt them to local conditions.
- Strengthened national rice research systems can more easily address their own domestic rice production problems, through their own research and through collaboration with IRRI and other agricultural centers.
- IRRI can help solve regional problems more easily and in relatively less time through collaboration with strong national rice research systems.

Country projects are undertaken primarily to strengthen national rice research capacity and effectiveness. Their scope varies greatly, from comprehensive programs to help establish or rehabilitate a national rice research system to smaller, sharply focused projects aimed at increasing the capability of a national institution in a specific discipline or problem area.

Bangladesh

Funding for phase 3 of the Bangladesh Rice Research Institute (BRRI)/IRRI Rice Research Training Project through June 1992 has been agreed to by the U.S. Agency for International Development (USAID) and the Canadian International Development Agency (CIDA). Funds from the International Fund for Agricultural Development (IFAD) also have been released for a Rainfed Rice Project. Exchange of germplasm and screening of rainfed rice cultivars have been under way for two years. Other collaborative projects include farming systems, fertilizer use efficiency, integrated pest management, and differential impact of rice technologies.

The BRRI/IRRI/International Irrigation Management Institute (IIMI) Irrigation Water Management Project selected a third site, in the Rajshahi area, for collaborative research on tubewell irrigation. Specific water use recommendations are being developed based on research results in the Ganges-Kobadak and North Bangladesh areas. In North Bangladesh, farmers prefer to plant winter season rice (boro) rather than wheat, in addition to main season rice (aman). The project has demonstrated techniques of using only supplemental irrigation water for both crops.

A study of the impact of cropping systems technologies is being carried out in one upland and five rainfed lowland rice villages. Whole-farm enterprise studies focus on farmers who own less than half a hectare and those who own from a half to one hectare. These land ownership categories are expected to dominate by the year 2000. The research includes gender studies and data on noncrop enterprises. An economic mobility study is providing the context for understanding changes taking place.

Bhutan

The IRRI-Bhutan Rice Farming Systems Project, supported by IDRC, demonstrates the potential for increasing rice yields through varietal improvement, improved soil fertility, and better weed control methods. The greatest potential appears to be in the mid-altitudes (1000-1500 meters above sea level). More than 40 Bhutanese scientists and technicians have been trained at IRRI and more than 200 have been trained in-country.

Cambodia

Three IRRI scientists began work in a Cambodia-IRRI project supported by Australia in 1989. In yield trials at 87 sites in 11 provinces, many plots were transplanted late because of an extended dry period. Even so, preliminary results indicate some modern cultivars have the potential to significantly increase yields.

Regional projects provide assistance to countries with relatively small but important rice production areas. Funding for country and regional projects is provided through grants from bilateral and multilateral donors.

Current country projects (and their donors) are Bangladesh (USAID, CIDA), Bhutan (IDRC), Cambodia (AIDAB), Egypt (USAID), Madagascar (USAID), Myanmar (CIDA, IDRC), and Vietnam (AIDAB). A project for Laos is being developed.

Country and Regional Liaison Offices facilitate collaborative research and training activities. Collaboration between national programs and IRRI in areas of common interest helps to solve problems. IRRI currently has liaison offices in India, Indonesia, Japan, and Thailand. A Liaison Office for China is located at IRRI; liaison with Korea is handled by a national scientist seconded to IRRI with Korean funding. IRRI also maintains a Regional Liaison Office for Africa at IITA and one for Latin America at CIAT.

The International Programs Management Office is responsible for managing country projects and coordinating liaison offices.

In studies on soil improvement, nitrogen and phosphorus needs were reevaluated; the value of native rock phosphate, green manure legumes, and cash crop legumes investigated; and cropping systems experiments begun. Two IRRI trainers conducted two 1-week integrated pest management courses for 60 Department of Agronomy employees.

China

The China National Rice Research Institute (CNRRI) was inaugurated on 9 Oct 1989 at Hangzhou, Zhejiang Province. IRRI assisted in many stages of this World Bank-supported project that began in 1975. CNRRI answers China's need for a center of excellence in relevant rice research. The complex includes a main laboratory building, biotechnology building, information building, phytotron, guesthouse for visiting scientists and trainees, and a 19-story building housing offices and staff apartments.

CNRRI has 12 well-equipped research departments with a staff of 206 persons, 64% of them senior and middle-level scientists. A medium-term genebank will be completed soon, to contain the 30,000 accessions in the rice germplasm collection.

Egypt

The Nile Delta is one of the best places in the world to demonstrate the yield potential of improved medium-duration irrigated rice varieties. Farmers fertilize the clay loam alluvial soils through a time-honored system of organic manuring that includes incorporating a winter crop of Egyptian clover. Solar radiation is high during the May to September/October growing season, with no temperature stress. The national average rice yield is 6.5 tons per hectare.

The Egypt-IRRI project plants more than 50 farmers' field plots a year to demonstrate performance under optimal management of new blast-resistant varieties. These plots yield 28% higher than good farmer yields and 62% higher than average yields.

India

In the farming systems project supported by IFAD, considerable attention was given this year to planning how to apply site characterization in identifying areas where new farming systems technology could be applied (these are called extrapolation domains). IRRI scientists and Ford Foundation Farming Systems research and extension scientists visited on-farm research sites in Orissa, reviewed the research and technology transfer program, and examined problems in developing appropriate on-farm research for the rainfed lowlands.

Lao PDR

The Swiss Development Cooperation approved in principle the Lao-IRRI Project and committed support for 1990-1992. The project will focus on development of low-cost technologies for the uplands and rainfed lowlands. Three IRRI scientists—a rainfed lowland agronomist, an upland agronomist, and a plant breeder—will be stationed in-country.

Countries need viable agricultural research systems to help improve their capability to feed their populations without costly food imports.

Madagascar

Cropping systems and component technology research is under way in four target regions, 80% of it applied work in farmers' fields. Phase 2 of the Madagascar-IRRI Rice Research Project supported by USAID was completed in 1989. Phase 3 will identify soil fertility constraints (particularly on the High Plateau) and strengthen research-extension linkages. On-farm research will increase farmer participation. A new team of IRRI scientists—soil scientist, agro-economist, cropping systems agronomist, and plant breeder—will be stationed in Madagascar.

Myanmar (Burma)

CIDA support for the Myanmar-IRRI Farming Systems Project ended; technical support by IDRC will continue into 1991. We began a study of tillage methods to achieve better crop establishment of upland crops planted after rice. It involves deep sowing with a slit-seeder and pointed blade, to take advantage of cracks that develop in drying soil and enable roots of an upland crop to overcome the hardpan that develops during puddling for the preceding rice crop.

IRRI and the Myanmar Agricultural Service have agreed to begin collection of traditional Myanmar cultivars in 1990. We expect to collect as many as 3,000 local varieties.

Thirty years of rainfall data in five rice-growing townships is being analyzed to determine the onset and termination of the monsoon. This will help in planning cropping patterns and better crop establishment.

Vietnam

Representatives of the Ministry of Agriculture and Food Industry, the Ministry of Higher Education, and IRRI began planning an expanded program for 1990-1994. The collaboration will involve nine priority projects, with a national scientist coordinating cooperation on the Vietnamese side.

IRRI management

IRRI's challenge now is to do more, with less. We reduced the IRRI staff by more than 20% in 1989. The Institute entered 1990 with about 1,700 scientific and support staff.

More than 400 nationally recruited staff positions were eliminated through a special separation program (it included a termination package financed with a special credit). Another 200 positions vacated by normal turnover 1988-1989 were abolished. The staff reduction, recommended by external management and program review panels and anticipated in the Work Plan, will streamline IRRI operations and allow us to use physical, financial, and manpower resources more efficiently. Skills of core staff are being reoriented to fit the work plan and to minimize adding staff. We anticipate that no more than 50 new positions will be needed to provide the particular skills needed for IRRI's program.

New structure

IRRI's new strategy and work plan impel far-reaching changes in the Institute's organization and management. The new research programs serving the main rice ecosystems are positioned to

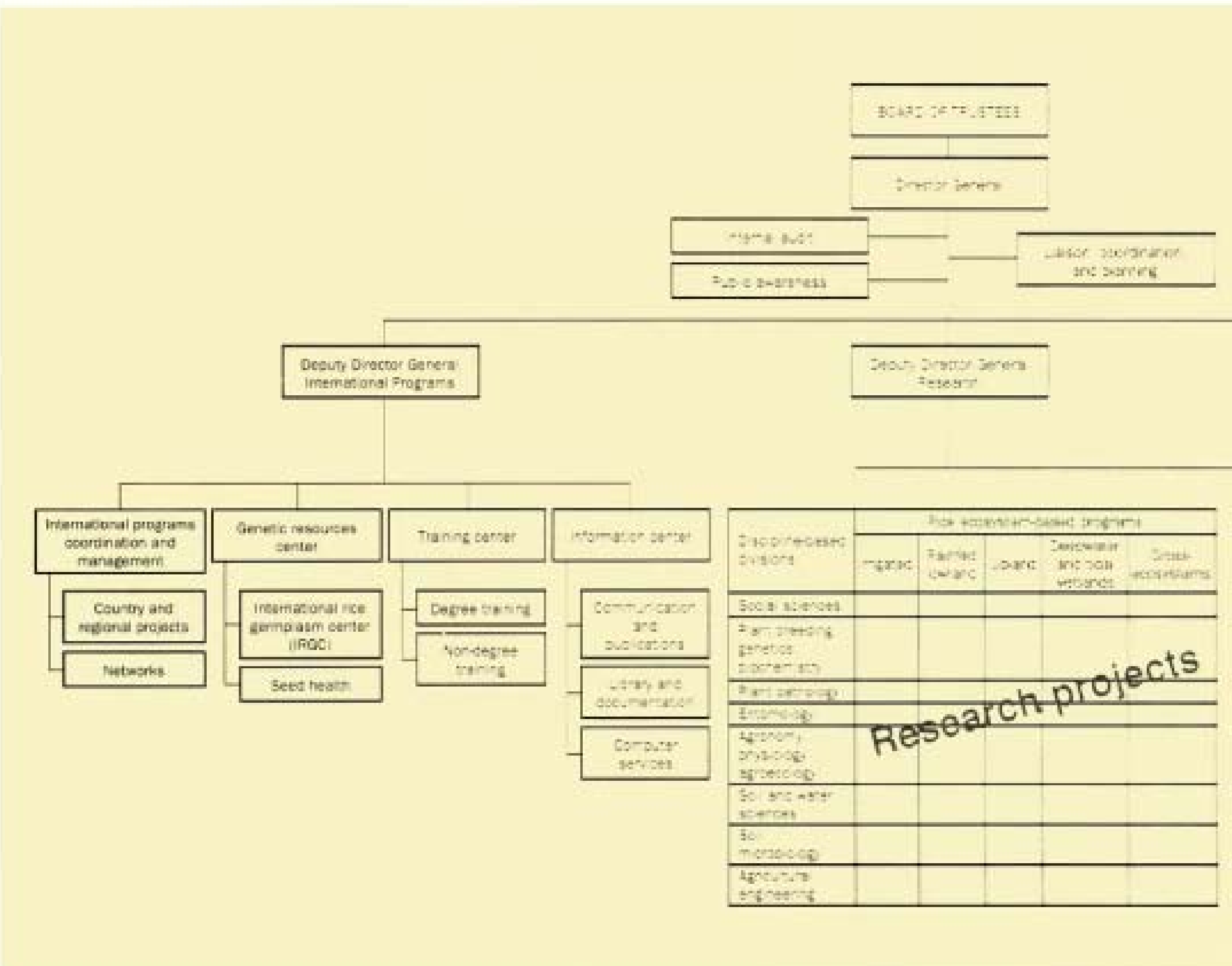
A new biofertilizer building is scheduled for completion in 1991. IRRI research headquarters and experimental farm are located in Los Baños, Laguna, Philippines. Much of the physical plant was built 20 or more years ago.

IRRI has been reorganized into three major units. The new ecosystem-based research programs are central to the structure. Interdisciplinary teams work on priority research projects.

drive all planning, monitoring, evaluating, and revising activities and to set priorities for management and services.

The newly structured discipline-based divisions (formed by merging existing research departments) provide scientific depth and leadership. Interactive management, within a matrix structure, enables program leaders and division heads to meet the objectives of the ecosystem-specific programs with appropriate disciplinary balance. With this interaction, IRRI can focus sharply on critical rice science issues and react quickly to emerging scientific opportunities.

International programs are carried out by center staff, who coordinate with the research programs. Related units were merged into centers of critical mass to streamline and focus activities. Many staff members of centers also are part of research teams, and members of research



divisions participate in international program activities. This provides the strong link for research partnerships with scientists in the national rice research systems, via research consortia, networks, and country programs.

A third dimension coordinates related activities across all programs. Biotechnology work is part of a number of research projects and involves a number of disciplines. The Biotechnology Group synergizes scientific sharing at that level of research. Integrated Pest Management also is a concept applicable in all ecosystems and involving several disciplines. The IPM Group ensures efficiency of those activities.

Budgeting is project based. Within Research Programs, 49 projects are planned; in International Programs, 17 projects. Each project team estimates the resources it needs (in terms of personnel time, general operating costs, and equipment) to carry out the work planned. Program leaders and division/center heads balance these estimates against resources. In the third step, program leaders and administrators reconcile needs and resources, and adjust all budgets against the Institute's overall resources.

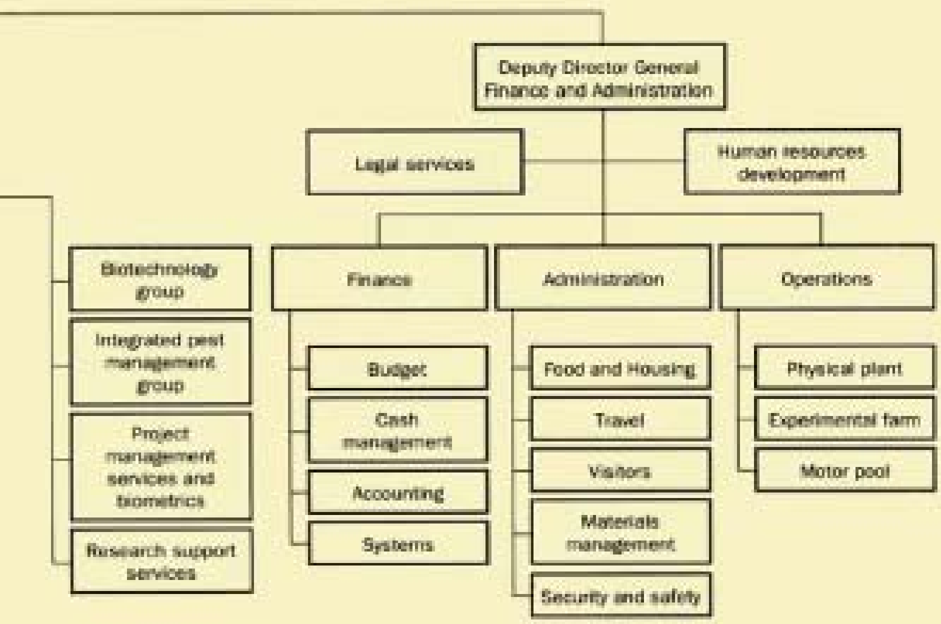
A new computerized accounting system will provide project coordinators with up-to-date information for continuous budget control.

Research services

We are economizing by centralizing research services. A Central Services Laboratory will provide common facilities, where possible, for the grain quality, analytical service, pesticide residue, and soils laboratories. The central laboratory will be housed in the Biofertilizer Building to be completed in 1991.

We have started to centralize IRRI Experimental Farm services, under the Director for Operations. A Farm Steering Committee guides farm use and reviews requests for land and services. The farm building complex begun in 1989 will ensure safe handling of agrochemicals and will centralize threshing and labor management.

Computerization of the system for accounting, payroll, purchasing, and inventory is under way.



IRRI 1990 budget (US$ millions)

	Approved		Estimated funding	
	Amount	%	Amount	%
Operations				
Research programs	18.4	48	15.5	49
International programs	8.6	22	7.2	23
General administration	4.2	11	4.1	13
General operations	2.2	6	1.7	5
Total	33.4	87	28.5	90
Capital				
New	1.6	4	0.7	2
Replacements	2.5	7	1.1	4
Total	4.1	11	1.8	6
Working Capital	1.0	2	0.0	0
Special Separation Program			1.3	4
Grand total	**38.5**		**31.6**	

We are preparing documents to guide IRRI policy implementation at all levels. So far, these include a guide for performance appraisal of both internationally and nationally recruited staff; training procedures; general information for residents of IRRI staff housing; handbooks for safety and security; an emergency plan; an institute-wide filing scheme; procedures for IRRI contracts; and a purchasing manual.

IRRI's AGING INFRASTRUCTURE

Our strategy calls for a shift in emphasis toward the less-favorable rice ecosystems and for doing more "upstream" research. But much of IRRI's US$24 million physical plant was built 20 to 30 years ago, when IRRI focused primarily on irrigated rice.

The projected life span of those laboratories and training facilities was 25 years. Three decades of use in the humid tropics has led to serious deterioration of laboratories, power plant, water supply system, and other essential support facilities.

Institute-wide renovation is badly needed, given both program shifts and aging facilities. But a 20% shortfall in the 1990 budget makes extensive renovation unlikely.

Research on the cutting edge of science is difficult or impossible with outdated facilities. Work with genetically engineered organisms, for example, offers great opportunity to stabilize rice production. This work requires the highest standards of biosafety. IRRI's work now meets those standards, and research will expand as containment facilities are improved.

Plans are under way to improve facilities for information management. The Library and Documentation Center holds the world's most complete collection of rice literature. As the holdings increase, expansion will need to include state-of-the-art fire prevention and protection technologies.

We continue to explain the importance of rice to growing numbers of visitors (more than 30,000 last year). The auditorium for viewing audiovisual presentations and films needs renovation, and more convenient display and demonstration space would expand our ability to tell the story.

We have developed a comprehensive master plan of the physical plant needed to support the new program and management structure. It takes into account the plans for decentralizing some research activities.

Adequate resources and appropriate facilities will help IRRI face the challenge of research that will increase the food security of the billions of rural and urban rice consumers by the year 2000 . . . and beyond.

IRRI is facing the challenge of seeking the knowledge needed to increase food security for billions of rural and urban rice consumers.

1989-88 financial statements

The Board of Trustees
International Rice Research Institute

We have examined the statements of assets, liabilities and fund balances of the International Rice Research Institute (a nonstock, nonprofit organization) as at December 31, 1989 and 1988, and the related statements of sources and applications of funds for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records in the circumstances.

As described in Note 2, the Institute's financial statements are prepared mainly on the basis of accounting practices prescribed for the 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. In addition, the Institute deferred for future amortization, a portion of special separation benefits paid to certain employees in 1989 as mentioned in Note 4. 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, except for the effect on the 1989 financial statements of the deferral of the employees special separation benefits mentioned in the preceding paragraph, the financial statements referred to above present fairly the assets, liabilities and fund balances of the International Rice Research Institute as at December 31, 1989 and 1988, and its sources and applications of funds for the years then ended, on the basis described in Note 2 to the financial statements, which basis, except for the changes, with which we concur, in the accounting treatment of core restricted and special project grants and of property and equipment as described in the same note, has been applied consistently.

Our examinations were made for the purpose of forming an opinion on the basic financial statements taken as a whole. The supplementary schedules of sources and applications of core operations, capital, working capital and special projects funds for the years ended December 31, 1989 and 1988 are presented for purposes of additional analysis and are not a required part of the basic financial statements. The information in such supplementary schedules has been subjected to the auditing procedures applied in the examination of the basic financial statements and, in our opinion, except for the effect on the 1989 supplementary schedule of the deferral of the employees special separation benefits mentioned in the second paragraph, is fairly stated in all material respects when considered in relation to the basic financial statements taken as a whole.

Sycip, Gorres, Velayo & Co.
Manila, Philippines
April 21, 1990

Statements of assets, liabilities, and fund balances

	1989	1988
Assets		
Cash (including short-term time deposits of $8,629,275 in 1989 and $11,175,119 in 1988)	$16,676,778	$15,963,226
Accounts receivable—donors (Note 3)	7,444,601	4,597,449
Receivables from officers and employees	194,069	287,920
Advances to projects and other receivables	1,164,149	957,363
Inventory of materials and supplies	1,245,476	1,101,135
Prepaid expenses (Note 4)	2,135,354	161,575
Property and equipment (Notes 2 and 5)	35,737,942	34,345,531
	$64,598,369	$57,414,199
Liabilities and fund balances		
Liabilities		
Accounts payable (Note 6)	$13,957,053	$10,455,197
Loan payable (Note 7)	2,200,000	-
Other liabilities (Note 8)	1,623,126	1,493,220
	17,780,179	11,948,417
Grants applicable to succeeding years (Notes 2 and 9)	7,912,435	2,482,398
Fund balances		
Invested in property and equipment	35,737,942	34,345,531
Working capital	2,202,000	2,302,000
Core operations	217	35,363
Special projects (Note 2)	-	5,389,229
Self-sustaining operations	548,371	455,166
Communication and publications	417,225	456,095
	3,167,813	8,637,853
	38,905,755	42,983,384
	$64,598,369	$57,414,199

Statements of Sources and Applications of Funds

	1989	1988
Sources of funds		
Core operations:		
Grants	$25,043,564	$24,960,501
Earned income	2,202,497	1,659,069
Translation adjustments	196,597	104,740
Balance - previous year	35,363	33,175
	27,478,021	26,757,485
Capital - transfer from core operations	1,450,000	950,000
Working capital:		
Balance - previous year	2,302,000	2,182,000
Transfer from core operations	-	120,000
Transfer to core operations	(100,000)	-
	2,202,000	2,302,000
Special projects:		
Grants	2,157,738	7,197,950
Balance - previous year	5,389,229	3,755,132
	7,546,967	10,953,082
Self - sustaining operations:		
Revenue	1,660,217	1,613,766
Balance - previous year	455,166	549,579
	2,115,383	2,163,345
Communication and publications:		
Revenue	318,242	323,467
Balance - previous year	456,095	463,402
	774,337	786,869
	$41,566,708	$43,912,781
Application of funds		
Core operations	$27,477,804	$26,722,122
Capital	1,450,000	950,000
Special projects	7,546,967	5,563,853
Self-sustaining operations	1,567,012	1,708,179
Communication and publications	357,112	330,774
	38,398,895	35,274,928
Fund balances		
Core operations	217	35,363
Working capital	2,202,000	2,302,000
Special projects	-	5,389,229
Self-sustaining operations	548,371	455,166
Communication and publications	417,225	456,095
	3,167,813	**8,637,853**
	$41,566,708	**$43,912,781**

See accompanying Notes to Financial Statements.

Notes to Financial Statements

1. General

The Institute was established in 1960 under the laws of the Republic of the Philippines as an autonomous, philanthropic, tax exempt organization. Its principal purpose is to undertake basic research on the rice plant and applied research on all phases of rice production, management, distribution and utilization with the view of attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas.

Under Presidential Decree No. 1620, which became effective on April 19, 1979, the Government of the Republic of the Philippines recognized the Institute as an international organization in the Philippines. As an international organization, the Institute can avail itself of certain legal immunities, tax exemptions and other privileges normally accorded to international organizations of a universal character.

2. Basis of financial statements

The accompanying financial statements (expressed in United States Dollars) are prepared mainly on the basis of accounting practices prescribed for international agricultural research centers seeking assistance from the Consultative Group on International Agricultural Research (CGIAR) in obtaining financial support from various donors. A summary of the Institute's significant accounting practices is set forth below:

Philippine Peso Transactions - Grants received are mostly in U.S. dollars or in other foreign currencies converted into U.S. dollars. During the year, conversions of U.S dollars to Philippines pesos are actually made to settle obligations denominated in Philippine pesos.

Philippine peso transactions are translated at standard bookkeeping rates which approximate the exchange rates prevailing at the dates of transaction (averaging P21.45 to US$1.00 in 1989 and P20.92 to US$1.00 in 1988). Peso balances of assets and liabilities included in the financial statements were translated into U.S. dollars at the year-end exchange rates (P22.428 to US$1.00 in 1989 and P21.335 to US$1.00 in 1988). The translation into U.S. dollars should not be construed as a representation that actual conversion of Philippine pesos to U.S. dollars had been, could have or could, in the future, be made at the same exchange rates.

Recognition of Grants - Core unrestricted grants are pledged on an annual basis and are recognized as funds available in the year the grant is pledged.

Core restricted and special projects grants had been recognized up to December 31,1988 as funds available when these became due for remittance based on the donors schedule of payment or approved budget. Under this method, grants were identified with specific periods and were taken up in the financial statements without regard to the date on which these were actually received. Starting 1989, these grants are recognized as funds available only to the extent of expenses incurred. Excess of grants received over expenses are shown as Grants applicable to succeeding years, a liability account in the Statements of Assets, Liabilities and Fund Balances. The change decreased the Institute's funds available for special projects by about $5.2 million and increased grants applicable to succeeding years by the same amount in 1989.

Expenditures - These are taken up in the accounts as incurred and/or as obligated, along with the assets acquired, without regard to the payment of cash. Obligated expenditures 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 - The inventory of materials and supplies is stated at cost, principally using the moving average method.

Property and Equipment - Property and equipment acquired through a capital grant or grant designated by the Institute or donor as being for capital are charged to the appropriate fund source as period expense and subsequently capitalized at cost (contra account of which is "Invested in Property and Equipment" shown under the fund balances section in the Statements of Assets, Liabilities and Fund Balances).

Replacement of assets, addition of nominal amounts and major modification or improvement of assets had been treated as expenditures up to December 31, 1988. However, starting 1989, replacements and major modification or improvement of assets are expensed and also subsequently capitalized. Cost of replaced asset is removed from the property and equipment account and the cost of the new asset is recorded in its place. The effect of the change in 1989 is not considered material.

No depreciation is provided on the property and equipment.

3. Accounts receivable—donors

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

	1989	1988
Core grants	$4,311,981	$3,332,171
Special projects grants	3,132,620	1,265,278
	$7,444,601	$4,597,449

The Secretariat of the 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 have been obligated for expenditures.

4. Prepaid expenses

In 1989, the Institute deferred a major portion of benefits paid to employees who availed of the special separation program. The account deferred as at December 31,1989 amounted to about $2.0 million and is being amortized up to 1992.

5. Property and equipment

Property and equipment are classified under the following accounts:

	1989	1988
Research Center:		
Buildings	$15,762,276	$15,762,276
Site development	2,969,163	2,862,267
Staffhouses	4,088,885	4,088,167
Phytotron	1,156,420	1,122,026
Research, machinery and equipment	5,672,545	4,817,300
Furniture and fixtures	2,052,034	2,052,034
Library items	437,369	437,369
Transportation equipment	2,438,009	2,434,559
Jobs in progress and other projects	1,161,241	769,533
	$35,737,942	$34,345,531

The land used as site for research activities is leased from the University of the Philippines at a nominal rent. 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 existence is terminated.

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

6. Accounts payable

Accounts payable consists of outstanding commitments and accrued liabilities as follows:

	1989	1988
Outstanding commitments for core and capital operations	$9,158,546	$7,046,441
Outstanding commitments for special projects	515,447	146,364
Accrued expenses	4,283,060	3,262,392
	$13,957,053	$10,455,197

Accruals of unused sick leave and vacation leave represent about 58% and 68% of the accrued expenses in 1989 and 1988, respectively.

7. Loan payable

This loan, which was obtained from the World Bank, is noninterest bearing and is payable annually up to December 31,1992.

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 trainees' stipends, board and lodging, other direct expenses and reimbursable overhead cost to be incurred by the Institute. Funding for these reserves is derived from charges against special program grants for trainees and special projects.

9. Grants applicable to succeeding years

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

	1989	1988
Unrestricted core	$150,000	$150,000
Special projects	5,282,835	-
Ongoing special projects transferred to restricted core	2,479,600	2,332,398
	$7,912,435	$2,482,398

10. Staff benefit plans

Separate noncontributory retirement plans have been adopted for regular junior staff and for senior staff. Contributions to these plans amounted to about $1,200,000 in 1989 and $1,180,000 in 1988. The Institute also maintains an insurance plan for senior staff to provide benefits for medical care, permanent and total disability, life insurance, and accidental death and dismemberment.

11. Exemptions

Under Republic Act No. 2707 and Presidential Decree No. 1620, the Institute was granted the following tax exemptions:

a. Exemption from the payment of gift, franchise, specific, percentage, real property, exchange, import, export, 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 payments of gift tax and considered allowable deductions for purposes of determining the income tax of the donor.

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 received solely from and by reason of service rendered to the Institute.

Schedules of sources and applications of core operations, capital, working capital, and special projects funds

	1989	1988
Sources of funds		
Core grants and earned income		
Unrestricted		
International Bank for Reconstruction and Development/International Development Association	$2,049,000	$1,950,000
Overseas Development Administration - United Kingdom	1,454,031	1,546,396
Canadian International Development Agency	1,426,653	1,482,421
Australian Government	779,490	629,644
Swedish Agency for Research Cooperation	558,917	552,787
Federal Republic of Germany	542,319	564,462
Government of Finland	473,475	249,180
Danish International Development Agency	424,911	405,175
Government of Italy	181,719	180,320
Ford Foundation	150,000	150,000
Government of Norway	117,543	127,684
Government of India	100,000	125,000
Philippine Government	94,774	112,933
People's Republic of China	50,000	50,000
Government of Spain	30,000	29,990
Stabilization Mechanism Fund - inflation/exchange adjustments	2,081,000	1,150,000
Earned income	2,202,497	1,659,069
Translation adjustments	196,597	104,740
	12,912,926	11,069,801
Restricted		
Government of Japan	5,611,612	5,691,104
United States Agency for International Development	5,225,000	5,250,000
European Economic Community	1,981,000	2,050,830
United Nations Development Programme	1,721,900	2,420,400
Government of the Netherlands	141,926	150,756
	14,681,438	15,563,090
Transferred special projects:		
Government of Italy	$400,000	$450,000
Rockefeller Foundation	326,279	136,600
Swiss Development Cooperation	314,286	671,282
Federal Republic of Germany	162,696	186,839
International Centre of Insect Physiology and Ecology	87,482	61,406
Government of Belgium	45,365	-
Ford Foundation	9,388	-
Government of France	-	206,120
International Development Research Centre	-	70,039
	1,345,496	1,782,286
Balance - previous year	2,332,398	1,714,475
	3,677,894	3,496,761
Transfer to special projects	-	(2,944)
Funds applicable to succeeding years	(2,479,600)	(2,332,398)
	1,198,294	1,161,419
Balance - previous year	35,363	33,175
	28,828,021	27,827,485
Transfers (to) from:		
Working capital funds	100,000	(120,000)
Capital funds	(1,450,000)	(950,000)
	(1,350,000)	(1,070,000)
	27,478,000	26,757,485

	1989	1988
Capital funds - transfer from core operations	1,450,000	950,000
Working capital funds:		
Transfer from (to) core operations funds	(100,000)	120,000
Balance - previous year	2,302,000	2,182,000
	2,202,000	**2,302,000**
Special projects grants:		
United States Agency for International Development - reimbursable contracts	2,113,980	1,641,350
Government of Japan	1,133,239	2,049,564
International Development Research Centre	726,883	358,303
Government of Australia	609,746	966,378
International Fund for Agricultural Development	371,048	-
Canadian International Development Agency	326,725	280,825
Federal Republic of Germany	310,274	123,692
Rockefeller Foundation	310,143	252,127
Republic of Korea	205,938	98,000
Government of Italy	200,000	220,000
Asian Development Bank	167,033	442,628
Government of the Netherlands	159,884	110,974
United Nations Development Programme	125,219	52,536
Swiss Development Cooperation	116,203	-
Government of Belgium	88,017	135,235
International Food Policy Research Institute	74,253	89,962
Ford Foundation	56,458	-
International Fertilizer Development Centre	38,735	35,055
Food and Agriculture Organization	6,367	23,000
Danish International Development Agency	1,364	142,092
Islamic Republic of Iran	-	83,065
Others	266,952	93,164
	7,408,461	7,197,950
Balance - previous year	5,389,229	3,755,132
	12,797,690	10,953,082
Funds applicable to succeeding years	(5,250,723)	-
	7,546,967	10,953,082
	$38,676,988	$40,962,567
APPLICATIONS OF FUNDS		
Core operations		
Research	$14,652,769	$14,456,978
Research support	2,666,562	2,650,188
Training, communication information and library	3,323,591	3,344,751
General administration - operation:		
Administration	2,877,248	2,303,462
Operation	3,261,964	3,151,299
Others	695,670	815,444
	27,477,804	26,722,122
Capital	1,450,000	950,000
Special projects	7,546,967	5,563,853
FUND BALANCES		
Core operations	217	35,363
Working capital	2,202,000	2,302,000
Special projects	-	5,389,229
	2,202,217	7,726,592
	$38,676,988	$40,962,567

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