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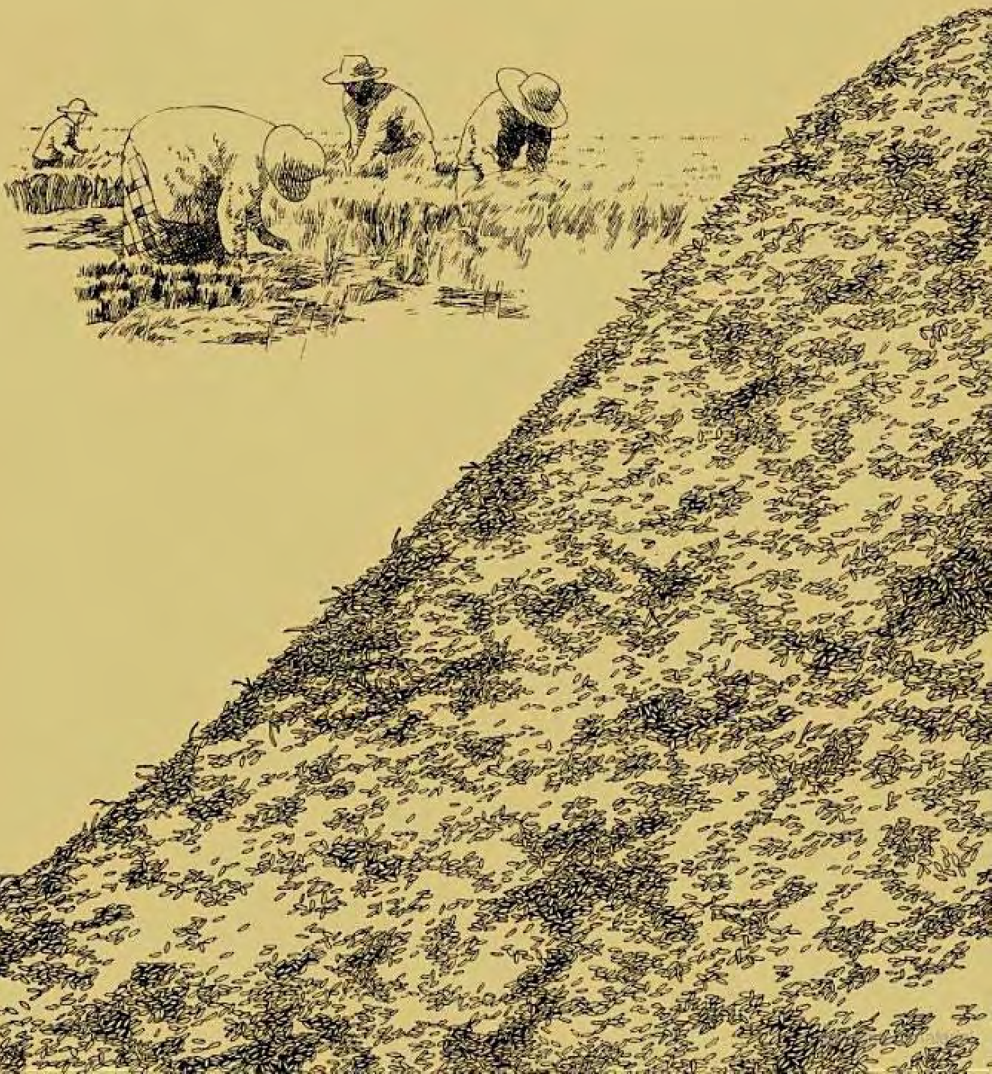

IMPACT
OF SCIENCE
ON RICE

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OF SCIENCE ON RICE

1985
INTERNATIONAL RICE RESEARCH INSTITUTE
P.O. Box 933, Manila, Philippines

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

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

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

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M. S. SWAMINATHAN
Director General, IRRI

FOREWORD

In 1960 the Ford and Rockefeller Foundations, in cooperation with the Government of the Philippines, established the International Rice Research Institute (IRRI) on the campus of the University of the Philippines at Los Baños (UPLB) with the goal to improve the productivity, profitability, stability, and sustainability of rice farming systems. More than 90% of the world‘s rice is produced and consumed in Asia and hence IRRI’s focus has been mainly on Asian countries with particular reference to indica rice.

Since 1971, IRRI has been supported by the Consultative Group on International Agricultural Research (CGIAR), a consortium of donor agencies and developing countries, all of which are committed to harnessing science for the advancement of agriculture in the developing world. The three cosponsors of the CGIAR are the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme, and the Food and Agriculture Organization of the United Nations. The U.S. Agency for International Development (USAID) provides 25% of the core budget of CGIAR.

Since the CGIAR was founded, IRRI has been able to assist African countries by working with the International Institute of Tropical Agriculture in Nigeria, the West Africa Rice Development Association, and multilateral and bilateral agencies. Similarly, in Latin America and the Carribean, IRRI works with the International Center for Tropical Agriculture in Colombia. Above all, the strength of IRRI’s research programs lies in its symbiotic bonds of cooperative endeavor with national research systems. The power of such cooperative research in accelerating the progress of rice production is described in a recent IRRI publication *International rice research: 25 years of partnership.*

In addition to problem-solving research, IRRI's program includes global research service functions such as the collection and conservation of rice genetic resources, organization of cooperative research networks, and dissemination of information through publications and bibliographic services. In addition, the Institute started almost from its inception a program of training of scientists and scholars from the national research systems of rice-growing countries. The history of IRRI and the evolution of its research and training programs were described by founding director R. F. Chandler, Jr., in *An adventure in applied science.*

On the occasion of its 25th anniversary, IRRI organized the following scientific meetings to review the progress made in different aspects of rice research and development and to set guidelines for future work:

- International Rice Genetics Symposium, 27-31 May 1985;
- International Rice Research Conference, 1-5 June 1985;
- Multilevel Symposium on Rice Research: Accomplishments and Challenges, 5-8 June 1985; and
- FAO International Rice Research Commission, 10-14 June 1985.

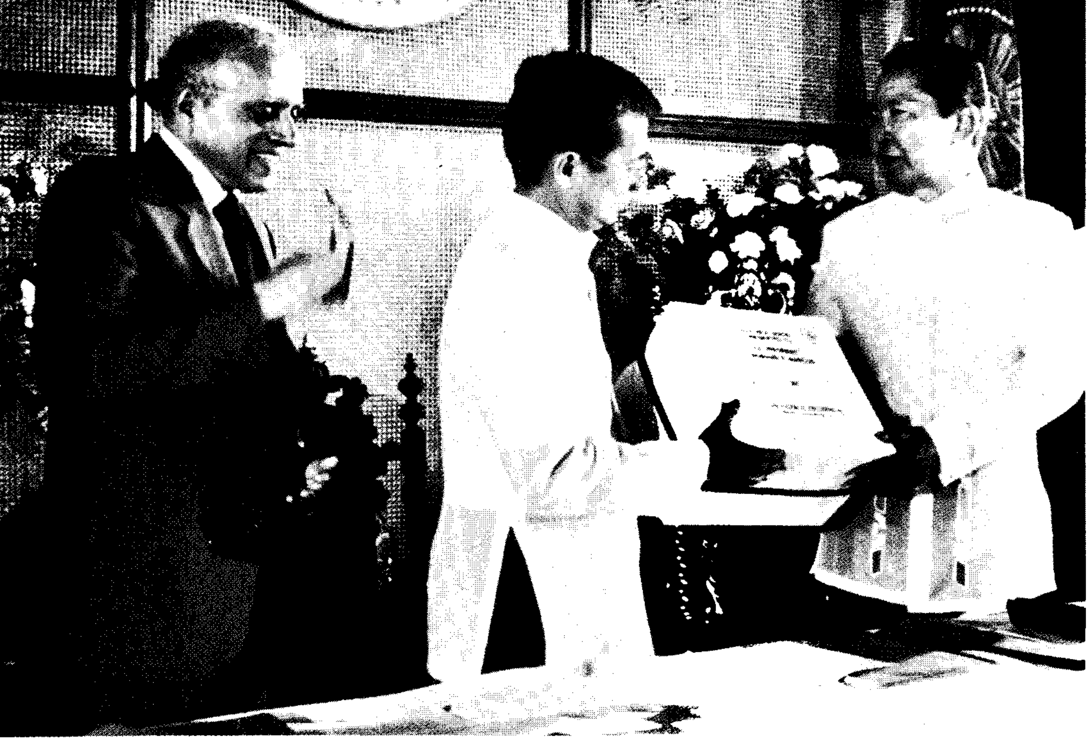
The proceedings of the International Rice Genetics Symposium and the papers presented in a session on grain quality and marketing at the International Rice Research Conference will be individual publications. FAO will publish the proceedings of the International Rice Commission Meeting. This book contains the papers presented at the Multilevel Symposium on Rice Research: Accomplishments and Challenges.

The symposium was attended by ministers of agriculture and policy makers from rice-growing countries and CGIAR member nations, the chairmen and several members of the CGIAR and of its Technical Advisory Committee, eminent agricultural experts, former and present IRRI trustees, past IRRI directors general, and rice scientists from many nations. In addition, 14 outstanding rice farmers from 10 countries participated. The experiences of the outstanding rice farmers are being published as *Insights from outstanding rice farmers.*

A perusal of the papers contained in this book will indicate the complex nature of agricultural transformation. Unless a symphony approach is developed among those responsible for technology development, transfer, and sustenance, it will be difficult to stimulate and sustain the necessary degree of progress in the production of rice as well as other crops. The speakers have discussed, based on their rich personal knowledge and experience, the many concurrent steps necessary to achieve progress. The speakers in the concluding session dealt with future challenges in agricultural research and highlighted methods by which IRRI and national research systems can help ecologically handicapped areas and economically handicapped farmers. A central point in many of the presentations is the pivotal role of science in agricultural progress.

IRRI staff and scholars are grateful to the speakers who so generously gave their time to participate in the symposium and to provide manuscripts of their presentations for this publication. Photographs of two commemorative stamps released by the Government of the Republic of the Philippines are included in this book. Our gratitude goes to the President of the Republic of the Philippines for inaugurating the symposium, to the First Lady for delivering a special lecture, and to the Prime Minister of the Philippines for chairing a special 25th Anniversary lecture on Indonesia's rice revolution which was delivered by the Indonesian Minister of Agriculture. We also wish to thank the session chairpersons and rapporteurs for their tone-setting and organizational contributions.

The book was edited by W.H. Smith and E.P. Cervantes, and was designed and published through the IRRI Communication and Publications Department.



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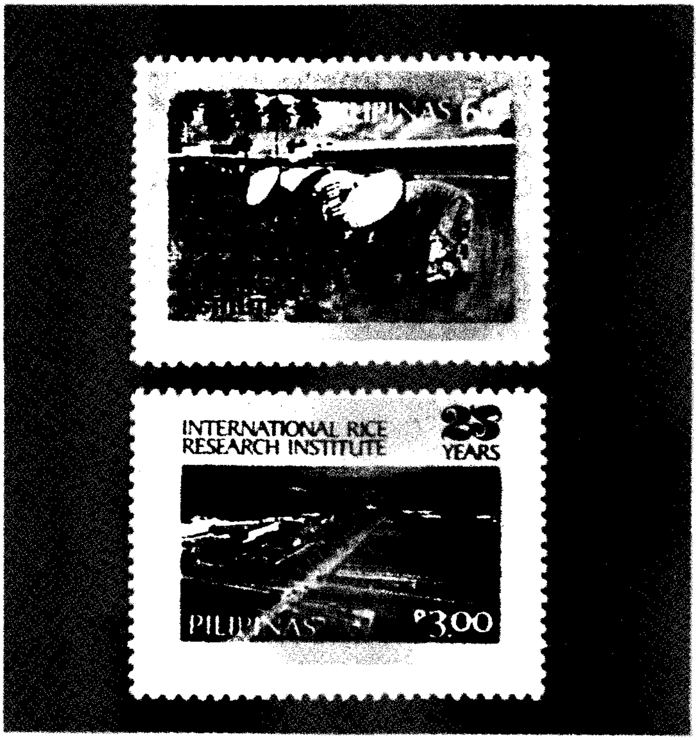


M. S. Swaminathan, IRRI director general, and Philippine Minister of Agriculture S. H. Escudero III presenting Philippine President F. E. Marcos with seeds of newly released IR64.

C. W. Bockhop, IRRI agricultural engineer, with Indian Minister of Agriculture Buta Singh (fourth from left) and party.

Several special events were held during the sessions of the 25th Anniversary Symposium. These included the issuance of commemorative stamps, an international food fair, an exhibit of two Philippine rice farming traditions, a multimedia presentation by IRRI staff and scholars, and a barrio fiesta featuring the Bayanihan Dance Group.

Commemorative stamps

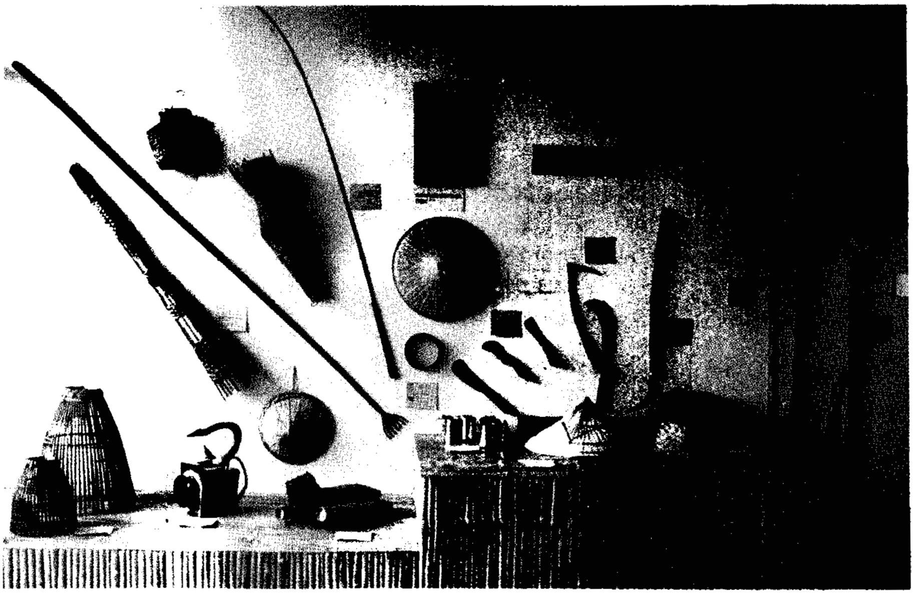
Philippine Assistant Postmaster General Pedro P. Gambalan issued IRRI 25th anniversary commemorative stamps, and presented the new issue to Philippine President Ferdinand E. Marcos and to IRRI. First day covers and sheets of the stamps were issued at IRRI by the Philippine Post Office.

International food festival

Philippine First Lady and Human Settlements Minister Madame Imelda R. Marcos delivered a special lecture in commemoration of IRRI's 25th anniversary. The First Lady also opened an international rice food festival during her IRRI visit. The festival featured foods from many countries. By-products of the rice plant were also displayed.

Rice farming exhibit

An exhibit of two Philippine rice farming traditions was opened. Implements used by Ifugao and Tagalog farmers in traditional rice cultivation and ritual objects related to rice were displayed. The Ifugao people constructed the rice terraces and irrigation systems of Banaue, and many of them still follow age-old cultivation practices. Tagalog farmers live in Central Luzon, the rice bowl of the Philippines; most of them plant modern rices and utilize improved technology.

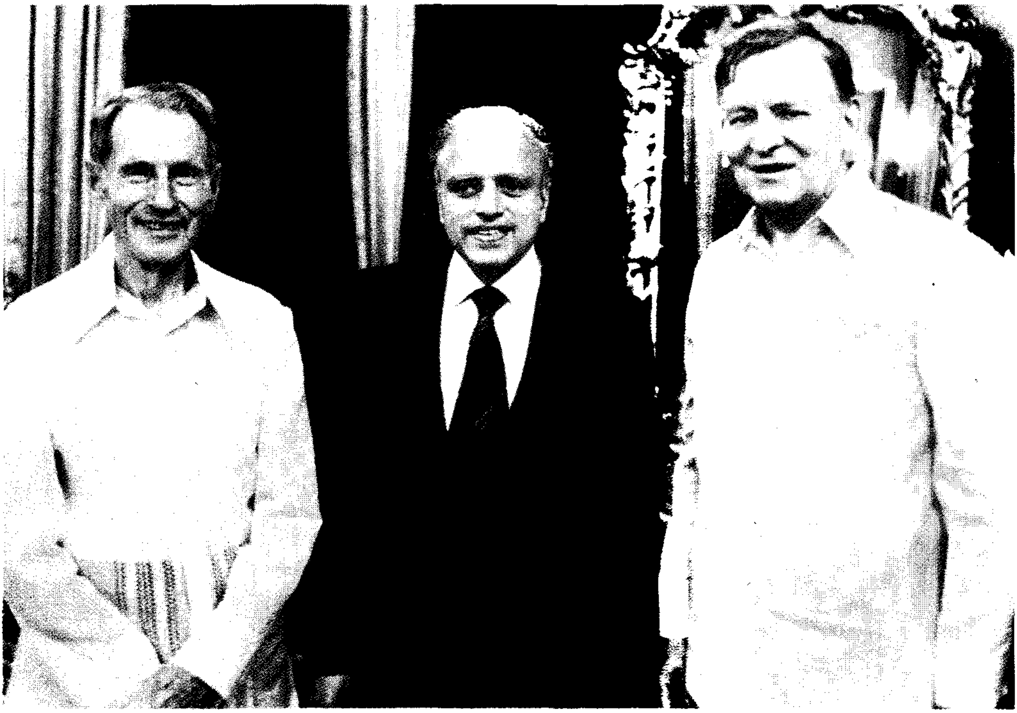


Power of cooperation
A special multimedia presentation of slides, film, and dance and song was presented by IRRI staff and scholars. The presentation, entitled *The power of cooperation: 25 years of the International Rice Research Institute,* traced IRRI's development and growth and highlighted significant events during the Institute's first 25 yr.

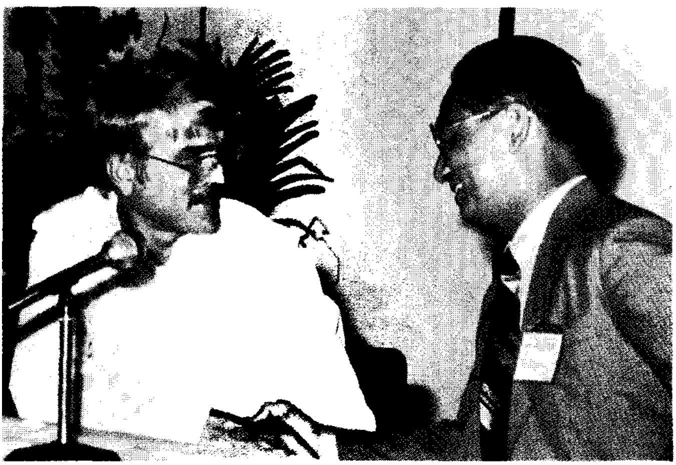
Bayanihan dance group
IRRI honored the 150 symposium participants with a traditional Filipino barrio fiesta (village festival). The barrio fiesta included native foods and a program by the Bayanihan Dance Group, which performs traditional Filipino dances.

Outstanding Farmer Sova Rani Dey receiving her award from IRRI Director General M. S. Swaminathan and President F. E. Marcos of the Philippines.

Deputy Minister of Agriculture Barom Tanthien of Thailand.



R. F. Chandler, Jr., former IRRI director general; M. S. Swaminathan, IRRI director general; and N. C. Brady, former IRRI director general, at the 25th Anniversary inauguration ceremonies at Malacañang Palace.



T. R. Hargrove, IRRI editor, with Chinese Minister of Agriculture He Kang.

INAUGURAL SESSION

K. HEMMI
Chairman, IRRI Board of Trustees

WELCOME

It is with very great pleasure that I extend to all of you a very warm welcome on the occasion of the inauguration of IRRI's 25th Anniversary Symposium by His Excellency, Ferdinand E. Marcos, President of the Republic of the Philippines. We are particularly privileged that Your Excellency has spared the time to encourage us with your presence and advice in this beautiful hall. IRRI has been fortunate in its location in this picturesque country inhabited by a friendly and hospitable people. We are grateful to the Government of the Philippines for the support and help extended to IRRI during the past 25 yr, thereby enabling IRRI to effectively discharge its research and training mandate.

IRRI has become the hub of a global network of rice scientists and scholars, all working toward the common goal of helping farmers to produce more and better rice. The relationship between IRRI and the University of the Philippines at Los Baños (UPLB) and other associated organizations like the Philippine Council for Agriculture and Resources Research and Development (PCARRD) and Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) has been strong and mutually beneficial. More than 620 IRRI scholars have earned their postgraduate degrees at UPLB. The IRRI Board of Trustees is fortunate to have as members the Minister of Agriculture and Food of the Philippines and the President of the University of the Philippines System.

Above all, you, Mr. President and the First Lady, have generously encouraged IRRI scientists. The issuance of two special commemorative stamps by your Government and your visit to IRRI in 1982 to release the book on the history of IRRI written by its first director, Dr. Robert F. Chandler, Jr., are just two examples of your own personal interest in the work of IRRI and the welfare of rice scientists and farmers.

I need not take your time to recall on this occasion the history of IRRI or its scientific impact. This has become part of contemporary agricultural history. IRRI scientists have also written a book summarizing the results of the work done during the past 25 yr through partnership between national research systems and IRRI. I would like to express our gratitude to the Ford and Rockefeller Foundations and the Government of the Philippines for their vision which led to IRRI's establishment in 1960.

Looking back, the establishment of IRRI at Los Baños marked an important turning point in the agricultural destiny of many of the rice growing nations of South and Southeast Asia as well as in parts of Latin America and Africa. From 1971, IRRI's financial support has come from a broad spectrum of donors who, motivated by the common goal of removing hunger and malnutrition, organized the Consultative Group on International Agricultural Research (CGIAR).

On behalf of IRRI, I would like to thank the Chairman of the CGIAR and the representatives of many CGIAR members for joining us today. I thank them for their support to IRRI and their continued commitment to promoting agricultural research relevant to the needs of the Third World.

I would also like to welcome the many farmers, both from the Philippines and from other nations, who are here. Mr. President, you will be honoring them shortly and I would like to say that no amount of honor can do real justice to our sense of gratitude to the farmers of the world.

IRRI's 25th Anniversary Symposium on "Rice Research: Accomplishments and Challenges" which you will be shortly inaugurating has been structured to stimulate and promote multilevel participation and discussion. We have Ministers of Agriculture and other policy makers who decide the key issues of resource allocation for agricultural research and development and also make other decisions which can stimulate both production and consumption. We also have the farmers who have to convert research results into grain and other food products. In between, we have the agricultural experts and scientists who must interact with the policy makers and farmers. Thus, we have a unique combination of participants: a meaningful horizontal interaction among them gives rise to a rice symphony. It is only when all the members of a symphony orchestra play harmoniously that we have melody. In the same way, it is only when the three major groups of participants in the rice production symphony — decision makers, scientists, and farmers — all have the same wave length that we will have the prerequisite for enduring agricultural progress.

I am indeed happy that you have all given your valuable time to come here. I thank you and welcome you. My special words of welcome are to the

Ministers of Agriculture of major rice growing countries, my fellow Trustees, past and present, former Directors General, IRRI scientists and national scientists, farmers, and farm leaders. We thank you, Minister Escudero, for including in this ceremony the program for recognizing the work of Outstanding Rice Farmers and Extension Workers of the Philippines. I would like to congratulate those whose contributions will be recognized shortly. We rejoice at their success.

Eternal vigilance is the price of good and stable agriculture. New pests and pathogens and soil problems arise all the time. Therefore, varietal diversity and a periodic replacement ofvarieties are essential to sustain high and stable yields. It is in this context that we are happy that the Philippine Seedboard has recently decided to release two more IRRI-bred strains for cultivation by farmers under the names IR64 and IR65.

We are confident that the Philippines will not only maintain its remarkable agricultural progress but will also make even greater progress in the coming years. It is a privilege for us in IRRI to participate in the exciting adventure of agricultural transformation in progress in this beautiful country.

S. S. HUSAIN
Chairman, Consultative Group on International Agricultural Research, and
Vice-President, International Bank for Reconstruction and Development, USA

WELCOME

I am honored and pleased to welcome you to the 25th Anniversary Symposium of the International Rice Research Institute (IRRI) on behalf of the Consultative Group on International Agricultural Research (CGIAR), honored because the audience is so illustrious, and pleased because it gives me an opportunity to pay tribute to IRRI, a truly fine research institution that has made remarkable contributions to agricultural development worldwide. It also gives me the opportunity to explain the role of the CGIAR, the organization that finances IRRI and the 12 other research centers in the CGIAR system, and to recognize the sources of support both IRRI and the CGIAR system have received over the years.

The CGIAR, or the Group as we call it, has 49 members, 39 of which are donors and 10 representatives of developing countries. Collectively and entirely voluntarily, they support the research activities of 13 international agricultural research centers, which include IRRI. The CGIAR has no written charter or constitution, no bylaws, and no written rules of procedure or administrative manuals. No votes are taken, no constraints are imposed on members, and no sanctions are imposed if a member does not fulfill a commitment or decides to leave the Group. Its members do, however, share a common set of objectives and a common ideal. Also, most importantly, each donor gives direct to the research center of its choice. There is no pooling of funds or any form of formula funding. It is in effect an association, governed by consensus and self-imposed disciplines rather than by rules and regulations, where each member has complete freedom of action. The centers supported by the Group are also very independent. Each one is an autonomous organization, directed by its own Board of Trustees, with its own legal personality, its own charter and bylaws, and its own ways of doing business. This independence is vital to the CGIAR system and a prime reason for its success.

If independence and freedom of action are a key feature of the system, then another is the ability to accept change with a minimum of fuss. Originally when the first centers were started, the assumption was that the centers should conduct research on their own premises, using their own staff and facilities. Increasingly, however, they are outposting their staff to work more directly with national research institutions. The centers are also increasingly the focus of many interlocking networks of research activities, each incorporating research institutions in both the developed and the developing countries of the world. In this way, a wide range of institutions, apart from and additional to the international centers, are harnessed to work on a broad spectrum of research programs and activities, each contributing their individual resources and skills. The centers are now, therefore, an important instrument to foster cooperation between countries irrespective of political differences, and to mobilize far greater resources for agricultural research than the CGIAR system itself can provide. This is a very exciting concept with wide implications.

IRRI is an institution that needs no formal introduction. I will not try to summarize its scientific achievements, not even the highlights, because they are so numerous and because during the next three days you will be hearing more about such matters. I would, however, like to mention perhaps the most important aspect of both the CGIAR and of IRRI — the men and women who founded the institution, and all those who have contributed so much to the institution over the last 25 yr. And I include here, of course, all those in the national research institutions who, as full partners in a joint endeavor, have been instrumental in developing the new varieties and improved technologies that have been so successful. Let us also not forget the hundreds of thousands, or millions, of farmers who grow rice, without whose entrepreneurial abilities, faith, and prodigious hard work the technology developed by IRRI and its collaborators would not have been so widely used.

I would like to pay tribute and offer my thanks to the Government of the Philippines for the support it has provided to both the CGIAR and IRRI during the last 25 yr. The Philippine Government is a donor member of the CGIAR, one of the 39 I mentioned earlier, and has steadfastly and consistently provided contributions in kind and a great deal of moral support. That support, particularly in the early years, will never be forgotten.

When one pauses to think of what IRRI and its collaborators have achieved in the last 25 yr, one's faith in mankind is greatly reinforced. The achievements of rice researchers and rice farmers, which have been spear-headed by IRRI and its collaborators, symbolize the capacity of human beings to work together for the common good. We are justified, I believe, in being optimistic about the future, a future in which this institution, and all those with whom and for whom it works, will continue to play a significant and rewarding role.

FERDINAND E. MARCOS
President, Republic of the Philippines

INAUGURAL ADDRESS

This is a day of twofold significance for our country and our people, and it adds meaning to this celebration that we are joined here by so many friends from so many countries and international organizations.

On the one hand, today is Farmer's Day in our country, and this is the day when our entire nation pays tribute to those millions of our people who farm and produce the bounty from our land.

Today also marks the completion of a full quarter-century in the life of the world-renowned International Rice Research Institute (IRRI), whose work has meant so much to life and progress in the Philippines and in the rest of the developing world.

To us it is fitting that these landmark occasions be celebrated together, for each, in a sense, embodies the other. That is to say, if we have reason to celebrate Farmer's Day it is partly because of what rice research has done to transform the rice farms of our archipelago. Similarly, the quarter-century of IRRI's existence takes its meaning, if I may venture to say, from the technological revolution it has wrought not in the laboratory, but in the yields of rice farms and the incomes of rice farmers here in the Philippines and in the rest of Asia and Africa.

For the top officials and supporters of IRRI, to meet some of our farmers in the flesh merely epitomizes, in my view, the great bond that has been built during the past 25 yr.

When we think back to 1960 when IRRI was born, we can see only too clearly what kind of spearhead this Institute has been in the modernization of rice agriculture in our century. Everywhere then, there was stagnation in the products of rice and the productivity of rice agriculture. IRRI has truly led the way in doubling and even tripling rice yields all over the world. Its unrivaled achievements in rice research have earned for it the distinction of being the world's premier agricultural research center. Indeed, IRRI has come to represent for us one of the greatest triumphs of science in perhaps the most urgent of human causes: the struggle to relieve world hunger and poverty.

The presence here today of the agriculture ministers of major rice growing countries of Asia and Africa amply demonstrates the far-reaching impact of IRRI's contributions to the world food endeavor. Three ministers here are by themselves responsible for producing food for nearly half of the world's population. I am referring to the Ministers of Agriculture of China, India, and Indonesia. If we count the population of all the other countries whose ministers are here, we have with us men and women who have to provide food for about 60% of mankind.

The crusade against world hunger must continue, and this is an auspicious moment to take stock once again of the pledge made at the world food conference in 1974 that "No child shall go to bed hungry and no man shall fear for his next day's bread" at the end of the decade of the seventies. Eleven years have passed since that pledge was made by the international community, and yet the vision and the hope of the world food conference still elude us. Hunger is still the blight on millions of lives in the developing world. The famine that now stalks Ethiopia and other African countries in the Sahelian Zone is a painful reminder to all of us that the scourge is still unbeaten.

Speaking for the developing nations of the South at the Cancun Summit in 1981, I called attention to the fact that 21 nations throughout the world were hungry, and that 12 other nations were on the verge of hunger. Yet even as we were engaged in trying to unravel the issues between north and south, death from hunger, especially among children in Asia, Africa, and South America, continued unabated.

The formidable challenge that remains, however, should not blind us to the real advances that have been made.

IRRI represents one major advance that surely has made the meeting of the challenge more feasible.

The individual efforts of many countries in Asia and Africa represent yet another encouraging indicator. For truly during the past two decades, the vision of the Green Revolution took root in our lands. If I refer here mainly to what we in the Philippines have done, it is only to illustrate the larger effort that is taking place.

In Cancun the participating nations agreed that as a first priority in solving the world food problem, developing countries should evolve their own food strategies, utilizing their own indigenous resources, supplemented by external assistance where necessary. The point of our call to action was that no amount of outside assistance can or should substitute for in-country efforts to combat hunger.

FOOD SUFFICIENCY AND SELF-RELIANCE

This theme lies at the core of our food production efforts during the past 12 yr. We have increased our food production drive by adopting and implementing a national food strategy built on the systematic linkage between production and consumption.

After years of being a perennial rice importer, we attained self-sufficiency in rice through the Masagana 99 program. Although it has been claimed that we reached a self-sufficient level of production in 1969, it was really in 1976 that we achieved self-sufficiency, 3 yr after we launched Masagana 99. The following year, we began to export. I should express my people’s gratitude to IRRI once more for the high-yielding varieties that made these gains possible.

Two years ago, however, we began to encounter production shortfalls brought about by the combined effects of an 8-mo drought in crop year 1982-83, a succession of devastating typhoons, spiralling costs of production, and a virtual standstill in agricultural credit. But we shall soon regain self-sufficiency.

This year’s crop is expected to be the largest ever, surpassing our 1982 record crop. We expect a palay harvest of 8.2 million metric tonnes or 5% higher than last year’s harvest and 1.2% over our 1982 record crop.

We continue to enjoy self-sufficiency in pork and poultry products as well as vegetables. Aquaculture, which now accounts for 23% of total fish catch, has been proving to be our quickest growth area for domestic food production as well as export.

Our program for self-sufficiency in yellow corn should be getting a big boost with an expected dry season harvest of 18.6 million cavans or 933,000 metric tonnes. This is 15.5% more than what we produced during last year’s dry season and is the largest dry season crop we would be harvesting in the past 5 yr.

To step up our gains and further heighten the tempo of agricultural development, we have adopted certain reforms that substantiate agriculture’s regained primacy in the Philippine development agenda. This is in keeping with agriculture’s primal place in the national economy. The sector employs roughly 50% of the labor force, contributes a little over one-fourth of the gross domestic product (GDP), and accounts for about one-half of annual export receipts.

MARKET DEREGULATION

The second half of 1984 saw the gradual phase-out of market interventions that dampen production and investment incentives. Withdrawal of government mediation in areas where market forces can work best has become a basic thrust of agricultural policy.

In keeping with this thrust, we lifted price ceilings of corn grits, pork, chicken, meat, and eggs. Rice remains on the control list but we are going to delist the commodity at harvest in October this year. The adoption of a multitiered pricing scheme was a step we took toward the eventual lifting of interventions in the rice market.

Even as we give room to the wider play of market forces in input and output pricing, we shall maintain floor prices for essential commodities to reduce seasonal fluctuations in farmgate prices.

To help our rice farmers cope with the rising cost of inputs, particularly fertilizer, I am announcing a higher support price for palay effective immediately. The new palay support price will he ₱3.50/kilo or 15 centavos higher than the present support price of ₱3.35/kilo.

In line with the policy to give room for greater private sector participation in areas where private enterprise can operate effectively, the government has relinquished its exclusive role in the exportation of rice and the imports and export trade of corn and feedgrains subject to guidelines formulated by the National Food Authority (NFA).

Likewise, sugar trading is now entirely in private sector hands with the conversion of the National Sugar Trading Administration (NASUTRA) into the Philippine Sugar Marketing Corporation (PHILSUMA). PHILSUMA is totally owned by sugar planters and millers in proportion to their actual production. We have also liberalized the exportation of coconut products.

In line with our structural adjustment program, the tariff reforms we are implementing include a 5-yr program of phased reduction in poultry tariffs. Tariffs on chicken meat and eggs are now down to 50% ad valorem from 70 and 100% respectively.

INSTITUTIONAL CHANGES

With agriculture as the lead sector in our agenda for national recovery, we have undertaken organizational changes to strengthen coordination among the government agencies responsible for agricultural development. The integration of agencies in agriculture mandated by Executive Order 967 streamlined planning and implementation of programs in agriculture.

At the same time, we are strengthening farmer participation in policy formulation and program implementation through the creation early this year of a National Farmer’s Advisory Committee where 18 farmer groups are represented by their leaders.

We continue to develop farm cooperatives, with special emphasis on strengthening managerial and entreprennial capabilities so that cooperatives can function as viable business enterprises. To generate more funds for cooperatives development, let me enjoin all governors and mayors to undertake joint agribusiness ventures with farm cooperatives in their jurisdiction by drawing on their 20% development fund for seed capital.

FINANCIAL INCENTIVES

Despite the tight credit supply, the government sought the continued flow of funding support to the country's farmers. We have set aside ₱539.69 million for production loans for our programs in rice, corn, soybeans, rootcrops, ipil-ipil, and azolla at a concessional rate of 15%. Of this, ₱290.93 million has served the production and processing credit requirements of some 48,000 farmers.

We expect the present tightness of agricultural credit to ease following the signing of our new money and trade credit agreements with the Philippines' creditor banks. As the credit situation eases, interest rates should stabilize. On top of this, a $100 million agricultural loan fund we are negotiating with the World Bank, supplemented by $20 million in bilateral assistance from the United States, should help restore the supply of agricultural credit from institutional sources to normal levels.

Last week, I directed the Central Bank to adopt a 10-yr restructuring scheme which would allow rural banks with high arrearages to pay their loans. The scheme provides for a 5-yr moratorium on the payment of loan principals. This should come as a welcome relief to rural banks.

CROP ZONIFICATION

In tandem with the reforms we have undertaken in marketing, sector management, and credit, we continue to devise ways to improve farm production and productivity. We have implemented a crop zoning scheme to provide a reliable production base for both domestic and export markets. To date, we have mapped 6.4 million hectares in 26 provinces on the basis of their soil and agroclimatic suitability for certain crops.

INTENSIFIED USE OF INDIGENOUS INPUTS

To help our farmers cut production costs while reducing the country's dependence on costly imported inputs, increased use of indigenous inputs is now a priority concern. In particular, there are 19 types of organic fertilizer in the list of accredited fertilizer products for our priority food and animal feed programs. These are produced by 19 accredited local manufacturers with a combined production capacity of 50,000 metric tonnes/year. With organic fertilizers thus accredited in our food programs, farmers may now use a portion of their production loans secured from participating lending institutions to purchase organic fertilizer.

While encouraging local production of processed organic fertilizer to replace part of our costly chemical fertilizer imports, our medium- and long-term strategy for expanding the use of indigenous inputs gives priority to on-farm production of organic fertilizer by farmers. Thus, a key component of our program to promote indigenous inputs is the promotion of azolla propagation in rice farms. Azolla can replace up to 25% of the nitrogen content of chemical fertilizers used for the main season rice crop. We now have 130 provincial propagation centers and 3,840 community nurseries to serve the azolla inoculum requirements of 167,500 ha of riceland.

LOCATION-SPECIFIC TECHNOLOGIES

With ever-rising production costs, indigenous and low-cost technologies have become a compelling concern. Our farmers and fishermen need advanced technologies suited to their special conditions.

We have made substantial headway in upgrading yields of irrigated lowland rice farms but productivity in upland and saline, drought-, and flood-prone areas remains low. There is a need to develop local capabilities in dealing with problems affecting rice production that are unique to the Philippine situation.

As a first and pivotal step, I am authorizing the creation of a research coordinating center for a national grid of cooperating institutions engaged in rice research. The center shall pursue research thrusts aimed at maximizing rice yields and increasingfarmer income under minimum levels of farm inputs and investments.

We have allotted ₱15 million to support the Center's start-up and operation expenses for 1985. This initial amount shall be drawn from the RP- Japan Fertilizer grant or any other bilateral fund sources in the Ministry of Agriculture and Food.

THE ROLE OF IRRI

Even as we embark on the full-scale implementation of national research programs in rice, we shall continue to look upon IRRI's proven capabilities for assistance. For one, IRRI's gene bank of 77,000 distinct varieties of rice collected from all over the world is a priceless pool that all national research centers can tap in developing better and higher yielding strains.

Just now, we have witnessed the release of the latest rice variety from the Institute, IR64, whose birth was in itself a unique event. I understand that this variety was developed from parents drawn from China, Indonesia, Korea, The Philippines, Thailand, Vietnam, and the United States.

IRRI's International Rice Germplasm Center and its development of IR64 are but two examples of the Institute's many achievements over the past 25 yr that have brought us closer to our vision of a world without hunger.

To the founding fathers of IRRI who have taken time to join us today, to the IRRI Board of Trustees, to the Institute's scientists and administrators, my congratulations and esteem for making the Institute the pillar of excellence in agricultural research that it is today.

Let me also take this occasion to commend the Consultative Group for International Agricultural Research (CGIAR), whose chairman we have with us today, for its work in bringing the fruits of science and technology to the developing world through the 13 International research centers which the CGIAR supports. We in the Philippines take pride in having been the first developing country to become a member of the CGIAR. Despite our limited resources, we sought to contribute a modest amount to the group's funds to substantiate our commitment to strengthening agricultural research in the developing world.

Indeed, I need hardly emphasize that science and its applications in technology are transforming the destinies of nations. In the Philippines, the progress made during the last 20 yr in improving rice production and productivity has been greater than that witnessed during the preceding 2,500 yr. From the time the early Ifugaos started carving rice terraces in the Banaue mountainsides up to 1966 when IRRI released its first high-yielding variety, IR8, our peak rice production level stood at 2.6 million tonnes. This year, we expect to harvest about 5.4 million tonnes of milled rice — the highest production level we shall have attained thus far.

Needless to say, the progress we have achieved in the last two decades would not have been possible without the sweat and toil of the farmer, aided by the extension worker who brings to the farmer the technological innovations that scientists turn out. I, therefore, commend the outstanding farmers and extension workers in the Philippines whom we have honored today. Their distinguished performance serves as an example for all Filipinos to emulate.

To the outstanding rice farmers of the world who have journeyed from their countries to accept their awards, I say congratulations and may your tribe increase. It pleases me to see several women among the awardees, as this is a long overdue recognition of the vital role played by women in agriculture. In developing countries, women comprise more than one-third of the agricultural labor force, and they have become a large and potent force for modernizing the rural sector. We are proud and happy that we have a Filipino farmer among the awardees - Mr. Serapio San Felipe, who was earlier chosen as one of the outstanding farmers of the Philippines in 1981.

However excellent and dedicated the work of scientists and extension workers may be, it is ultimately only the farmer in the field who can transform advances in science and technology into the food that sustains us all. This is why on this occasion we honor the rice farmers of the world as well as our own farmers in the Philippines. The awards symbolize our profound gratitude to farmers around the world, They are the unsung heroes in the crusade against world hunger.

Today farmer, extension worker, and scientist join in this assembly. And it is only fitting that they should join together, for on their cooperative labor lies our hope for banishing hunger from this earth.

OUTSTANDING RICE FARMERS OF THE WORLD

IRRI honored 14 outstanding rice farmers from 10 Asian countries during the inaugural session of its 25th Anniversary Symposium. The farmers — two of them women — received their awards, a carved wooden trophy and a citation, from Philippine President Ferdinand E. Marcos at Malacañang Palace.

The farmers, each of whom farms 5 ha or less, were chosen from among nominees submitted to IRRI by national research and extension agencies, the Food and Agriculture Organization of the United Nations, and other agricultural development groups.

These successful rice producers developed their own packages of technology appropriate to the realities of their ecological environments and institutional setting. They transformed modern technology developed in research laboratories and experimental plots into simple, rapid, and low-cost farm practices suited to local needs.

In addition, these farmers did not hoard their science-based knowledge. Moved by a spirit of service, they unselfishly shared their knowledge and skills with others less gifted or advantageously placed. Thus, they were recognized for their self-reliance and service to others in their communities by the most discriminating of evaluators: their fellow farmers.

These self-effacing men and women remind us that rice is not grown in conference halls or laboratories. It is planted, nurtured, and harvested in thousands of fields in obscure villages by men and women such as these. Beyond IRRI's governing bodies and scientific work, these farmers and their families form the Institute's ultimate constituency.

Our best hope for food self-sufficiency rests on the shoulders of small farmers who constitute the great majority of producers in the developing world.

The 14 outstanding rice farmers honored by IRRI and the citations for which they received their awards were:

ABUL KALAM AZAD, *Dinajpur District, Bangladesh,* for pioneering on his riceland the use of integrated nutrient supply systems involving farmyard compost and chemical fertilizer, which enabled him to triple rice production; and for developing and promoting a pattern of intercropping, relay cropping, and crop rotation that allows farming families to be gainfully employed throughout the year;

QU YONG SHOU, *Hunan Province,* People's Republic of China, for performing practical field experiments that largely reduced rice flower sterility caused by cold weather, thus enabling rice farmers to surmount the cold injury problem and achieve yields of 17 t of rice/ha for 2 crops; and for converting his riceland into a demonstration farm where other farmers could learn better management techniques;

SARDAR JAGJIT SINGH HARA, *Ludhiana, Punjab, India,* for his scientific management of a rice farm; innovativeness in producing high quality seeds; and for his key role in the diffusion of new farming technology and bridging the gap between potential and actual yields;

MRS. SOVA RANI DEY, *West Bengal, India,* for developing a remunerative rice farming system that gave yields of 9 t of summer rice/ha and 5 t of winter rice; for her judicious adoption of modern farm practices and high-yielding varieties; and for unselfishly sharing her knowledge with other farmers;

NEKKANTI SUBBA RAO, *West Godavari District, India,* for harvesting an average yield of more than 8 t of rice/ha by planting high-yielding varieties and practicing good farm management; and for active collaboration with the All India Coordinated Rice Improvement Project in testing new varieties and producing certified seeds, thereby helping to establish mutually beneficial links between scientists and farmers;

SUMBER KARYA TANI FARMERS' GROUP, *East Java, Indonesia,* for developing an economically and socially viable village cooperative that collectively prepared group production plans, carried out essential farm operations, and secured production inputs, credit, and services to increase rice production and promote nonfarm activities, which increased family income and saving; and for encouraging among members self-reliance and the awareness that personal interest is secondary to the interest of the community and that the basic element of leadership is good example;

RAHAYU FARMERS' GROUP, *West Java, Indonesia,* for developing an economically and socially viable village cooperative that collectively prepared group production plans, carried out essential farm operations, and secured production inputs, credit, and services to increase rice production and promote nonfarm activities, which increased family income and savings; and for encouraging among members self-reliance and the awareness that personal interest is secondary to the interest of the community and that the basic element of leadership is good example;

KOICHI KIMURA, *Akita, Japan,* for developing rice cultivation techniques that reduce by 60 to 70% the labor requirements for growing rice while harvesting more than 7 t of rice/ha; for demonstrating a profitable rice farming system; and for being a selfless farm leader and adviser;

MRS. ETSUKO TADA, *Iwate, Japan,* for introducing efficient and economical methods of mechanization of rice cultivation that helped women and the aged to practice high productivity rice farming; for her leadership in promoting cooperative farming; and for being a dependable consultant to farm families seeking information on rice farming and home life;

YEON DO KIM, *Geyongsangbuk-Do, Republic of Korea,* for harvesting more than 13 t of rice/ha, the highest ever in the Republic of Korea, using high-yielding varieties and advanced farming technology; and for unselfishly sharing with others his successful farming experiences;

MOHD. NOR BIN KAHLAN, *Selangor, Malaysia,* for his success in semimechanized rice farming of transplanted, broadcast, and drilled rice; and for being a dynamic model farmer in demonstrating new rice production technology to others and thereby becoming a leader in technology transfer;

SERAPIO SAN FELIPE, *Morong, Rizal, Philippines,* for attaining steady production of more than 10 t of rice/ha by planting high-yielding rice varieties and following good soil fertility management involving compost composed of animal manure and crop residues and application of chemical fertilizers; and for being the earliest effective barefoot technician deputized by the Ministry of Agriculture and Food to help rice farmers in nearby communities;

WIBOON INCLAI, *Phitsanulok, Thailand,* for harvesting more than 8 t of rainfed rice/ha using local tools and new varieties; adopting improved cultivation techniques promoted by the agricultural extension office; and for willingly sharing his knowledge with other farmers; and

VO VAN CHUNG, *Tiengiang Province, Vietnam,* for successfully integrating traditional and new technology into a simple and low-cost cultivation package enabling him to harvest yields of 12-15 t/ha a year from 3 crops of rice; for actively cooperating with agricultural research institutions in testing new varieties and cultivation techniques on his farm; for sharing his farming skills and seeds of high yielding varieties with other farmers through the An Phu Agricultural Cooperative of which he is the chairman; and for proving to others that rice farming is a satisfying means of livelihood.

IMELDA R. MARCOS
First Lady, Republic of the Philippines,
Minister of Human Settlements, and Governor of Metro Manila

ECOLOGY AND EQUITY: FOUNDATIONS OF SUSTAINABLE AGRICULTURAL DEVELOPMENT

I am delighted by this opportunity to join the International Rice Research Institute in marking the completion of its first quarter-century. To the officials and the entire staff of the Institute, I want to express my admiration and my sincere congratulations. And to all the distinguished guests who have come from many parts of the world for this occasion, I wish to extend a warm welcome.

Indeed, as President Marcos said earlier, the Philippines has every reason to join this observance in the spirit of celebration. The Philippines is fortunate to be host to the Institute whose accomplishments have made it the world's premier agricultural research center. The work of IRRI, particularly in the discovery of high-yielding rice varieties, provided the impetus for a revolution in our farms, which not only brought technological change but also proved the vast potentials of the human resources of this country, from its leaders to the common man.

The development of high-yielding rice varieties provided the Philippine Government the opportunity to launch an agricultural development program that integrated the different phases and sectors involved in the production, marketing, and consumption of the country's staple crop — rice. As a result, in 1976 the Philippines not only became self-sufficient but also became an exporter of rice. But the Philippines will be ever grateful to IRRI for it was the high-yielding varieties that opened the way for the unprecedented and spectacular gains realized by the Philippine rice program.

IRRI may be said to be a victim of its own success. For today it is its very success that inspires us in the Philippines, as in other developing countries, to expect more from the institute in coming years. It makes us hope that the IRRI will have an even greater impact on the lot of people in developing countries, particularly the rural poor.

This expectation is largely impelled by the awareness that even as farms realized increased yields through new technologies, conditions arose which complicated the quest of farmers and consumers in developing countries for remunerative yields and stable prices.

The propagation of high-yielding varieties entailed the use of inputs, particularly fertilizers, which developments in the international economy have made prohibitive in cost. As Minister of Human Settlements and Governor of Metro Manila, I have been concerned that agricultural technologies must have more impact on resolving the dichotomy between urban and rural areas and on checking the huge unplanned expansion of urban areas, a phenomenon plaguing not only the Philippines but many other developing countries. Rural men, women, and children continue to abandon their homes in the countrysides to go and live on the pavement of large cities and in urban slums because of inadequate opportunities for gainful livelihood or employment. This suggests that low agricultural yields are a part of the web of deprivations at work in our countrysides. Some migrants may be called *ecological refugees* — fleeing from a deterioration or breakdown in the ecology in rural areas brought by the depletion of soils, spread of deserts, loss of tropical forests, pollution of air and water, extinction of plants and animals, or destruction of productive coastal areas.

To be true to its commitments to excellence and social relevance, IRRI obviously cannot rest on its laurels of the last quarter-century. Developing countries look to IRRI for the introduction of technologies that can bring cheaper agricultural inputs, particularly fertilizers, and ensure these countries' ecological balance. For its next quarter-century, a singular challenge facing IRRI, I submit, is the development of a comprehensive set of technologies that will strengthen self-reliance in any given country or region.

At this point, with your indulgence, I would like to speak of our experience as Governor of Metropolitan Manila. Ten years ago, when I assumed office, I was confronted with a dying metropolis composed of seventeen towns and cities. It became imperative to conceptualize a rational, comprehensive delivery of basic services, namely, water, power, food, shelter, clothing, education, medical services, ecological balance, livelihood mobility, and transportation. The situation was such that the deprivation of one basic service would spell the beginning of the death of the city. We have kept faith with our oriental tradition that problems can be recycled into opportunities.

One of the main problems of the city has been the tremendous amount of garbage produced every day. To cope with the problem, some 15,000 metro aides were organized to clean the city. These aides, who found dignity and self-fulfillment in their work, immediately transformed Metro Manila from a decaying city to a cleaner metropolis for its almost nine million residents. Heretofore, the government spent ₱200 million to maintain the cleanliness of the city. This was reduced to more than one-half — from ₱200 million to ₱70 million which not only provided employment to 15 thousand men and women and made it cheaper to clean the city but, more importantly, developed a sense of awareness on the part of the people, a social conscience to help fellow humans, the metro aides, keep Manila clean.

On another level, we have converted Metro Manila’s garbage problem into an asset by making towns and cities within the metropolitan area into laboratories where the recycling of garbage is an integrated program. Metro Manila produces 3,000 t of garbage a day or more than a million tonnes yearly, 40% of which can be recycled into organic fertilizer. The importance of this program of recycling the wastes of the city assumes great significance when one considers that the Philippines imports about 700,000 t of fertilizer every year, costing us half a billion dollars in foreign exchange. Here is an example where waste (garbage) is recycled to asset (fertilizer) and where urban development is complimentary to rural growth and development.

The prospects for the wider use of the organic fertilizer recycled from Manila’s garbage seem promising. Experiments in Los Baños indicate that rice grown with the use of this organic fertilizer has an increased protein content and nutritive value.

Another program we have emphasized in Metro Manila deals with ensuring an ecological balance in the metropolis. Manila, being 2 ft below sea level, has suffered from perennial floods. To solve this problem of floods after a heavy rainfall, pumping stations have been installed, esteros or streams have been declogged, and the city’s drainage system has been improved.

But for a more permanent solution and to complement these efforts in improving the city’s environment, a green belt of 40 million trees now surrounds Metro Manila. Within the last 10 yr, some seventy million trees have been planted, thirty million in the city proper and forty million in the La Mesa Dam area. Keeping a desired water table we are able to ensure enough water supply for the city. This program also fulfills the basic requirement of seven trees per person to meet his oxygen needs. One important aspect of this tree planting program is that the trees are a renewable source of energy and animal feed through the production of leaf meal.

Borne out of our experience as Governor of Metro Manila, we have also been privileged as Minister of Human Settlements to replicate this integrated program in other towns and human settlements of the country. The Ministry evolved a model community of fifty homes called Bliss, each a self-contained human settlement primed by housing but provided with the other basic services of water, power, food, clothing, education, sports and recreation, medical services, mobility, transportation, and ecological balance. Bliss projects are not only the beginning of satellite cities but are also the radiating points for human settlements.

Thus, Bliss became an acronym for a model human settlement, a microcosm of Manila which not only ensured the delivery of the eleven basic needs but also provided an environment for the fulfillment and happiness of every man, the ultimate goal of every human being.

Hopefully, therefore, with the creation of these self-reliant human settlements throughout the country, rural migrants need not seek their fortunes in Metro Manila and other cities. This development thrust has been part of the comprehensive reforms of the new Republic on all fronts — social, political, and economic — under the peaceful, democratic revolution initiated by President Marcos in the New Republic.

Experience has taught us that it is imperative for leaders to look at problems holistically. The fulfillment of basic services in any given human community calls for a balancing, complementary effort, both rural and urban, national and international. Thus, the challenge today, for mankind to develop and progress, is for peoples of the world to work hand in hand with scientists and experts in a united effort to bring about a balanced environment for humanity to survive and flourish. But as we work for the progress and development of mankind, we must reach out to the inner being of man in the strengthening of his spirit to bring about his self-confidence and ultimately make him a self-reliant human being.

We in the Philippines, after about 500 yr of colonization, are more than ever convinced of the primacy that must be given to the development of the human resource. In the past 3 yr, the Philippines underwent extreme trials of various types, natural, economic, and political. It was beset by earthquakes, tidal waves, volcanic explosions, and two typhoons that were the strongest in the century.

The Aquino assassination brought a climate of suspicion and mistrust and ensuing political and economic disruptions when for 3 yr we suffered an economic drought from 483 banks. But the nation prevailed and survived. And the saving force was the Filipino common man, the two million Filipinos working all over the world bringing foreign exchange that prevented an economic disaster in the Philippines.

Once again this has substantiated the commitment of the New Republic under the leadership of President Marcos that man is our ultimate and most valuable resource. This commitment is borne out by the fact that while the Philippines had a population of 30 million people in 1966 and a literacy rate of 61% then, today, with doubled population — 54 million — we enjoy a literacy rate of 92% — one of the highest in the world.

It also is our belief that to make a man self-reliant is to provide him with the energy within, a spring-source to fire his thoughts for greater creativity and growth that will ultimately redound to the progress of his country. This has been the ultimate goal of the New Republic — a balanced economy, the delivery of basic services, the ethic of self-reliance, and a balance of man's outreach and inreach, firm in the belief that man’s vigorous spirit is the fountainhead of creativity for his progress and development, giving him self-confidence to become a self-reliant, self-sufficient human being.

Let me conclude by once again congratulating IRRI, the CGIAR, and the global network of agricultural scientists on the most valuable work they have done in recent decades. Your work brings hope to millions of lives all over the world.

After 25 yr of success, it is with greater confidence that IRRI can look forward to bringing about not only increased rice production but also the evolution of a balanced ecological environment. It can develop comprehensive technologies for regions of the world to maximize their potential for food production, coupled with the wider application of recyclable wastes to reduce costs of production. These should enable us to contend with the growing population and nutritional needs of mankind especially the rice-consuming peoples of the Third World.

As an international institution, IRRI will now be faced with the global problem not only to increase rice production but also to have a global plan for the next century based on the world's demographic profile to contend with the rice needs not only of a decade or two but until that time men will be able to level off their population growth. This becomes crucial when we consider that two-thirds of mankind are rice consumers. It is now time for IRRI to initiate an integrated, holistic plan of action. I hope you will continue your research with greater vigor and dedication in the years ahead.

The poet Rabindranat Tagore said: "A candle which itself is not lit cannot light others. A teacher who is also not learning cannot teach others." IRRI is a bright candle that has helped remove darkness in countless homes. Let this affirming flame be ever bright through your continuous quest for better technologies at the service of humanity. My good wishes are with you.

A. AFFANDI
Minister of Agriculture, Republic of Indonesia

THE RICE REVOLUTION IN INDONESIA: THE INDONESIAN EXPERIENCE IN INCREASING RICE PRODUCTION

I would like to congratulate the International Rice Research Institute on its 25th anniversary. Twenty-five years is certainly a very short period in the history of mankind. But, during that period IRRI has accomplished many valuable things in helping us in our effort to provide ourselves with enough food.

I feel very much honored to be invited to this important occasion. We will have a chance to meet each other and share experiences for the benefit of all.

I would like to discuss with you the Indonesian experience in increasing rice production in our efforts to fight hunger.

Generally speaking, there has been considerable progress in world food production. Yet there have been serious food shortages in various low-income developing countries. The number of malnourished people in these countries continues to grow. Deaths directly or indirectly related to food and nutrition problems still occur.

It is clear that the material gains from development are not very well distributed among countries and among people within countries. Food in sufficient quantity and sufficient quality is still beyond the purchasing abilities of many people with very low incomes.

The December 1984 Food Outlook of the United Nations Food and Agriculture Organization states that the 1984 forecast of world cereal production was about 8.5% higher than the 1983 estimate. But the striking feature was that production in the high-income developed countries rose by

16.6%, while that of the low-income developing countries rose by only 1.7%. This figure was below the rate of increase of their population. The most distressing figure was that cereal production in the low-income food-deficit countries' rose by only 1.0%, which means that their per capita production decreased by 0.8%. Although these forecasts may not be exact, I think the forecast trend is valid.

Based on figures published by Iowa State University in 1973, a young economist from Indonesia (2) indicated that by 1985 there will be a surplus of 42 million tonnes of cereal in the world. But the distribution among groups of countries is not promising at all. Low-income countries together were predicted to suffer a deficit of 115 million tonnes, while high-income developed countries will achieve big surpluses. By 2000 the deficit suffered by low-income developed countries would worsen, rising to as high as 256 million tonnes.

Again, these predictions may not be entirely accurate, especially because they were based on old data. But with the current situation, I fear that they may not be far from the truth.

This is the irony of world food production. The countries that actually do not need food in abundance can produce as much as they want, whereas those who are in serious need of food for existence cannot produce enough for themselves.

From a purely technical agronomic point of view, increasing food production is not difficult. Results from soil, agronomic, and other experiments will show which paths to follow to achieve significant increases in food production. Hence, for the high-income developed countries, increasing food production will be no problem at all. They have the necessary expertise, the technology, the capital, and the skill.

On the other hand, for developing countries in general, increasing food production is very difficult. Obviously it is not merely a technical problem. Technical, economic, social, and cultural problems must be simultaneously considered.

We all know that in the developing countries the productivity of agriculture in general, and of food in particular, is relatively very low. The small size of farms, the lack of financial resources, the very small amount of inputs supplied, the low educational level of the farmers, the existence of disguised unemployment, and many other factors are intricately interwoven, so that the problem of increasing food production enters the so-called vicious circle of low productivity, low income, and low investment.

Considerable support in various forms has been given to the developing countries by the high-income developed countries. Material support, e.g., loans and grants, expertise, advice, recommendations, and consultation have been extended, yet food production in the developing countries ingeneral could not be increased significantly and in a fairly stable manner. Hence the problem of hunger and malnutrition has not been overcome.

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[1]Includes all food-deficit countries with per capita income below the level used by the World Bank to determine eligibility for IDA assistance (i.e., US$805 in 1982).

In developed countries, the most advanced cultural technologies have been applied to food production and results have been astonishing. By applying these advanced technologies these countries have increased their food production so they not only feed their own people but also export food.

Experts of developed countries recommended that these advanced technologies be applied in the developing countries. The technologies include modern irrigation techniques, efficient water management, high-yielding varieties, and modern plant protection. With the help and support of experts from developed countries, many low-income developing countries applied such advanced cultural technologies.

The achievements, however, have not been very encouraging. Some projects produced very good results. But most of them were, for practical purposes, unsuccessful - results were far below expectations.

This situation appeared very strange and resulted in lengthy and intensive debates. Many people could not understand why the advanced technologies which were so successful in the developed countries failed in the low-income countries.

Such was our experience in Indonesia. Since the 1950s, Indonesia was determined to increase its food production, particularly in rice, to attain self-sufficiency. We implemented a 3-yr intensification program for rice production. We were optimistic that we would achieve self-sufficiency in rice within that 3-yr period.

To ensure rice self-sufficiency in the long run, the intensification program was followed by a program of expansion of agricultural lands to be used for large-scale mechanized upland rice production.

The results of both programs were far from satisfactory. After 3 or 4 yr the programs were stopped and the government institution responsible for their implementation was disbanded.

Criticism was then addressed to our agricultural scientists in the executive offices of the Department of Agriculture, in the research centers, and also in agricultural colleges, concerning our inability to increase food production.

Various analyses were done by experts in the different branches of agricultural science. The soil scientists tended to see factors within the boundary of soil sciences, such as inadequate amounts of applied nutrients, lack of microelements in the soil, and poor soil physical structure, as the main cause of the failure.

The agronomists tended to blame the farmers' inability to use cultural methods such as proper land preparation, use of high-quality seeds, and proper weeding.

The phytopathologists and entomologists tended to point out farmers' inability to use proper protection methods such as varieties tolerant of insects and diseases, sanitary cultural practices, and proper and adequate use of pesticides.

The rural sociologists and agricultural economists tended to feel that the programs failed because farmers were not motivated due to lack of material and nonmaterial incentives.

The analysis of the experts in the various branches of the agricultural sciences could be continued, and in any case we could be certain that their findings would point to factors falling in their own disciplines. Of course, the experts' diagnoses and prescriptions were correct and valid. But their solutions to individual problems were not enough to turn around production.

At that time, I could not understand the situation myself. Then I came across a publication, edited by Millikan and Hapgood (1) titled *No easy harvest.* The publication presented a very good picture of why it is so difficult to increase agricultural production in general, and food production in particular, in developing countries. With the permission of the authors and publisher, we translated the book into Indonesian and it became an important reference for our students and teachers.

Millikan and Hapgood point out that agriculture is a systems problem. Activities in agriculture proceed in a system. If one or more links in the system are missing or go wrong, the whole system is affected, thus jeopardizing the process of agricultural development.

Some experts identified important subsystems:

- upstream industries and/or agribusiness dealing with the supply and distribution of inputs, like high-quality seeds, fertilizers, pesticides, agricultural implements, and so on;
- the subsystem of agricultural production activities;
- the subsystem of postharvest activities, including processing; and
- the subsystem of marketing and consumption.

Within each subsystem, there usually is a long chain of activities.

The food problem will never be solved satisfactorily by considering only one subsystem, or by taking the subsystems separately, ignoring their interrelationships and their interdependencies.

Besides an understanding of agriculture as a system, we must also meet some basic requirements to get agriculture moving.

Again I refer to Millikan and Hapgood. They point out two very basic requirements:

1) That there be a very strong commitment among national and provincial leaders to give very high priority to food production, as reflected in manpower and budget allocation and policy decisions in favor of food production; and
2) That there be at least a certain stage of national political stability.

Looking at the Indonesian intensification and extensification program in the late 1950s and early 1960s, I think that the main reason for the lack of success was that those two basic requirements were not met. Of course, other unfulfilled requirements, such as lack of skilled, trained, and experienced personnel; lack of financial resources; and lack of research findings supporting the implementation of the programs, aggravated the failure.

I believe that the five well-known essentials listed by Mosher to get agricultural moving, i.e., markets for agricultural products, ever-changing technology, the presence of needed inputs, production incentives, and transportation, should come after the two very basic requirements mentioned. Unless there is a very strong commitment among the leaders, Mosher's five essentials could hardly be implemented. To get an ever-changing technology, for instance, strong research centers with sufficient manpower and budget allocation are needed.

Mosher's ideas have been very popular in Indonesia. His books and readings are used by every agricultural faculty in the country. Many agricultural development scientists in Indonesia follow Moshers's way of thinking.

It is not necessary to debate Mosher's five essentials. They are straightforward and simple, but basically true and valid. Detailed formulation of these essentials, however, is no easy task. Confronted by very limited human and nonhuman resources, we had difficulties in assigning priorities to the details of these essentials. Lengthy discussions and heated debate could not be avoided during the formulation of these very details.

With a little more knowledge and experience as we entered the first Five-Year Development Plan of Indonesia in 1969, the intensification program for rice production was formulated. Firm commitments from the national leaders were ascertained[2]:

> "The Government gives a very high priority to the development of the agricultural sector, and increasing food production is one of the most important objective of agricultural development."

As a follow-up to the government's policy, a presidential decree was issued in 1969. Proper budget and facilities to implement the program were allocated and an organizational structure was established. The rice areas under the intensification program were divided into village units, each unit comprising three or more villages. In each village unit four delivery institutions were established: 1) field extension workers to extend assistance to farmers; 2) village unit banks to extend credit to farmers; 3) village unit cooperatives responsible for distributing farm inputs and for postharvest handling, processing, and marketing of agricultural products; and 4) village kiosks for retailing farm inputs directly to the farmers.

The program was administered by guiding institutions, which were interdepartmental bodies covering all levels of government administration. The interdepartmental body at the national level was called the Intensification Program Steering Body; that at the provincial level, the Directing Body; and those at the district, subdistrict, and village level, the Implementing Bodies.

In the production subsystem, the five principles of good cultural methods — use of good seeds, good water management, good plant protection, proper fertilization, and good soil preparation — were implemented as one package.

The four delivery institutions, the guiding institutions, and the implementation of the package of good cultural methods were vital, decisive factors for the success or failure of the program. When those factors perform

[2] Rencana Pembangunan Lima Tahun Ke-1, Republik Indonesia, December 1968.

satisfactorily, the implementation of the intensification program proceeds with satisfactory results.

In addition to the organizational structure, the program was supported by various government policies including input subsidies, credit, pricing, and marketing.

Soon after we began to implement the plan, we learned that it is easier to make plans than to successfully implement them. During the 1970s we had to make a lot of adjustments in the operation. In fact, we ran many aspects of the operation on a trial-and-error basis.

When I evaluate the results of our efforts in the last 15 yr (3 consecutive Five-Year Development Plans), I think that despite many shortcomings, some still existing, our price production has performed satisfactorily. The area in the intensification program has increased from about 1.6 million hectares in 1968 to about 8.6 million hectares in 1984 (Table 1) and rice production increased from about 12 million tonnes in 1968 to about 26 million tonnes in 1984 (Table 2).

The input distribution network from the factories or importers to the villages was already established when the program began. Except in very remote and isolated areas, we had few complaints about the time of delivery, and the amount and kind of inputs made available to rice farmers. At the beginning of the program not more than a quarter of a million tonnes of fertilizer was distributed. Last year, about three million tonnes were supplied and distributed to our farmers, most of whom are rice farmers.

At the beginning of the program the farmers were not organized. After 15 yr we have about 200,000 farmers' groups that form the basis of our extension activities. Hence, although at the beginning of the program we had to face millions of rice farmers with traditional attitudes concerning agricultural development, after 15 yr they understand intensification. They know and are eager to apply the packages of good cultural methods.

I am pleased to say that IRRI contributed significantly to this stage of development of rice production in Indonesia. The injection of new blood that IRRI gave to us to promote our rice production was the provision of the high-yielding varieties IR5 and IR8. At first, the Indonesian people did not appreciate these varieties because of their unfamiliar taste. It is true that IR5

Table 1. Area in the Rice Intensification Program, 1968-84.

Year	Area (ha)	Year	Area (ha)
1968	1,596,343	1977	5,277,771
1969	2,131,252	1978	5,648,482
1970	2,004,511	1979	5,855,332
1971	2,006,063	1980	6,408,336
1972	3,262,905	1981	6,866,821
1973	4,111,640	1982	7,458,427
1974	4,090,403	1983	7,790,588
1975	4,247,397	1984	8,631,843
1976	4,473,749		

Table 2. Rice (milled) production in thousand tonnes, 1968-84.

Year	Production (thousand t)	Year	Production (thousand t)
1968	11,666	1977	15,876
1969	12,249	1978	17,525
1970	13,140	1979	17,872
1971	13,724	1980	20,163
1972	13,182	1981	22,286
1973	14,607	1982	22,836
1974	15,275	1983	24,006
1975	15,185	1984	25,825
1976	15,845		

and IR8 do not meet our consumers' taste preferences. Yet these varieties opened our eyes to the fact that it was really possible to increase our rice production. Through very close cooperation between IRRI and our National Food Crops Research Center, various high-yielding varieties became available, which gradually changed our traditional rice cultivation into a modern one. Various high-yielding varieties were bred, that combined high productivity with popular taste characteristics. Among these high-yielding varieties were Pelita I-1 and Pelita 1-2. In 1984, about 6.6 million hectares were planted to improved rice varieties (Table 3).

In 1974, with a feeling of optimism, we closed the first and entered the second Five-Year Development. During the first period we increased our rice production an average 4.7% a year, despite a setback in production in 1972 due to a long and severe drought. I think that an increase of 4.7% is good enough when compared to the growth rate of our people, which was about 2.3% a year.

At first we thought that by the end of our first Five-Year Development Plan in 1973, we would be self-sufficient in rice. This was not so. Although production increased by 4.7% a year, the demand for rice by the Indonesian people rose by 4-5% a year. Indonesians associate rice with status. They feel that eating rice gives them higher status than if they eat other sources of carbohydrates, except wheat. For all practical purposes we do not produce wheat.

Hence, rice production could not keep up with the rising demand, and rice still had to be imported, in varying quantities.

Table 3. Area planted to improved rice varieties, 1976-84.

Year	Area (ha)	Year	Area (ha)
1976	3,658,841	1981	5,694,265
1977	4,041,828	1982	5,777,104
1978	4.657,964	1983	5,694.36 1
1979	4,999,637	1984	6,626,947
1980	5.369,273		

In 1976, we were shocked by the disaster caused by the brown planthopper. That disaster will be remembered forever by the Indonesians engaged in rice production: government officials, research and extension workers, and farmers. In almost no time, hundreds of thousands of hectares of our rice were wiped out by those small but very dangerous insects. We panicked and did not know how to protect our crop. We sprayed pesticides from the ground and from the air, but they were ineffective. The insects continued destroying our rice crop. Many farmers lost almost everything.

Not knowing what to do, we thought of going back to our old varieties. Our entomologists, however, informed us that this would not help. They said that once the brown planthopper was there, the old varieties would also be destroyed because they also are not tolerant of the pest.

There was no way back. But, during the crisis, IRRI came to our aid by sending IR26, a tolerant variety. That was the starting point of our fight against the brown planthopper. It took us about four rice seasons to overcome the disaster. It was not until mid-1978 that we felt we had won the fight. The disaster caused by the brown planthopper was somewhat aggravated by a rather prolonged dry season in 1976 and 1977. Those were unlucky years for Indonesia. Our rice production almost stagnated, which caused an air of pessimism among many of our scientists. Indeed, the brown planthopper disaster could be overcome, the seasons became normal again. Yet we were still not confident whether the setback in production could be recovered in the coming years. This situation marked the beginning of our second Five-Year Development. The demand for rice still increased by 4-5% a year, but the rate of increase in production was only about 3.8% a year. Again large quantities of rice had to be imported.

Our senior officials and our scientists had a very difficult assignment to come up with something big and significant to compensate the setback in our rice production. A series of meetings were held to discuss the matter. It seemed that new varieties with significantly higher yield potentials than the ones already in circulation could not be expected, not from IRRI nor from our own research center. A better cultural method including improvement in fertilizer application was advisable, but at best, it could only give marginal returns.

In 1979 we decided to begin with a social innovation by encouraging the farmers' groups to embark on group farming. Before, our farmers, although organized in groups, worked individually. Hence the consistency of their activities over an area could not be assured. In case of pests, for instance, some of them felt very much obliged to protect their plants, but others did not. In water management, where group action was really needed, some farmers did well, but others did not. So, a high average yield from an extended area of farms could not be assured.

In group farming, a farmers' group of 50-100 farmers cultivating 25-50 ha was encouraged to operate as one organizational unit. They made the plan themselves, decided what rice variety to plant and when to begin soil cultivation, and so on. The delivery and guiding institutions tried not to intervene in their activities, but were always ready to serve the group.

In Indonesia, we have a name for group farming — *special intensification.* For most of the honorable guests present, this kind of group farming is probably common, and there is nothing really special about it. I am told that this practice is common in countries such as South Korea and Taiwan.

But for Indonesia, it was something new. It was an innovation to turn around our stagnating rice production. Results were astonishing. Productivity per hectare increased 30-50% above the usual levels achieved by individual farmers using improved practices. Now, more than 90% of the rice areas in Indonesia are under the intensification program. Of these, more than half are under special intensification.

Supported by good weather, during the third Five-Year Development, we increased our rice production by an average 6.l%/yr. I know the contribution of special intensification was very significant. The stagnation of rice production was over.

After these ups and downs, I believe our rice production has become self-propelling.

Data on fertilizer use from 1969 to 1983, pesticide use from 1968 to 1982, area of irrigated fields from 1973 to 1984, and rice area harvested from 1968 to 1984 are given in Tables 4-7.

Once, we thought that the self-propelling stage of rice production could be achieved easily. We learned that it was not at all easy. The International Rice Research Institute deserves much credit for helping us achieve this stage of development. I do not have words to express our gratitude to IRRI. But believe

Table 4. Use of NPK fertilizers for food crops, in tonnes, 1969-83.

Year	Amount of fertilizer (t)		
	N	P_2O_5	K_2O
1969	155,185	36,264	1,009
1970	162,077	31,618	3,596
1971	194,583	29,649	2,416
1972	228,013	21,393	1.967
1973	312,038	65,292	1,875
1974	290,830	95,720	6,769
1975	311,329	110,216	1,010
1976	313,304	99,267	3,019
1977	443.442	1 04,727	9,675
1978	478.905	126,905	11,769
1979	550,923	129,956	17,869
1980	797,862	210,222	11,082
1981	946,049	299,159	14,905
1982	1,060,066	354,509	43,349
1983	973,374	317.268	54,354

Table 5. Use of pesticides for food crops, 1968-82.

Year	Insecticides (t)	Rodenticides (t)	Fungicides (Kilolitre)	Others (t)
1968	631	40	–	–
1969	1,209	34	–	–
1970	1,076	52	–	–
1971	1,556	33	–	–
1972	1,362	45	–	–
1973	1,504	116	743	73
1974	1,638	56	744	73
1975	2,464	84	521	21
1976	3,432	158	189	40
1977	4,268	113	100	42
1978	4,165	121	67	151
1979	4,191	79	612	268
1980	6,387	78	464	363
1981	8,943	109	1,273	–
1982	11,080	94	927	–

Table 6. Area of irrigated fields, 1973-84 (ha).

Year	Technical	Semitechnical	Simple	Total
1973	2,069,147	1,134,858	625,626	3,829,631
1974	1,401,838	645.941	403,444	3,646,333
1975	2,252,785	1,005,991	650,020	3,908,796
1976	2,344,503	1,044,261	741,658	4,130,422
1977	2,447,132	1,052,679	837,339	4,337,150
1978	2,468,085	1,113,144	838,421	4,419,650
1979	2,452,311	1,080,244	850,093	4,382.648
1980	2,429,206	1,035,581	811,656	4,276,443
1981	2,491,632	1,054,790	988,338	4,534,760
1982	2,627,366	1,098,349	1,118,420	4,844,132
1983	2,750,488	1,113,785	970.756	4,835,029
1984	2,799,916	1,275,381	844,363	4,947,502

Table 7. Area of rice harvested per year, 1968-84.

Year	Area (thousand ha)	Year	Area (thousand ha)
1968	8,021	1977	8,360
1969	8,014	1978	8,929
1970	8,135	1979	8,804
1971	8,324	1980	9,005
1972	7,898	1981	9,382
1973	8,404	1982	8,988
1974	8,509	1983	9,162
1975	8,495	1984	9,636
1976	8,369		

me, your services to the rice farmers of Indonesia will be remembered by them forever.

Our experiences have taught us some very important lessons. First, we learned that it is difficult to insulate our rice production from the vagaries of nature. I am not talking about catastrophes such as typhoons. I am taking about abnormal rainy seasons, and especially abnormal dry seasons. A long and severe dry season, like that we experienced in 1972, can significantly damage our rice production.

Second, we learned that there is always a possibility that development could create big problems. When we embarked on adopting the high-yielding rice varieties in Indonesia, we did not have the slightest idea that this development would bring the brownhopper disaster. Even our scientists at that time could not warn us about such possibility. In fact, when the disaster came, they were also surprised. Not intending to accuse anyone, I think that this is a shortcoming on the part of the scientists in research centers. Every time scientists in research centers develop something new, they should anticipate problems which may be associated with the innovation. It must not be a surprise at all. Of course, I realize that this kind of work is expensive, but it should be done.

Insofar as the brownhopper is concerned, I am pleased to see that IRRI and our National Research Center have taken such steps. Scientists already anticipate that after three or four planting seasons the biotype 1 brown planthopper would develop into biotype 2. The varieties tolerant of the biotype-1 insects would no longer be tolerant of biotype 2.

So, when in some places in Indonesia biotype 2 brown planthopper pest was detected, the scientists were ready. In fact they had prepared the therapy — IR36 and other varieties.

The third lesson we learned was that it is not ideal for a nation to depend on just one staple food, like rice in Indonesia. In addition to the possibility that it is not healthy for the people to consume just one food, it puts a very heavy burden on production. A very small shortage in production could create unpleasant effects for the people. And if this trend continues, in the long run, production will not be able to cope with the demand, and resources allocation cannot be optimal.

Although rice production in Indonesia today is self-propelling some things still make us uneasy.

First, hundreds of thousands of hectares are planted to the same rice varieties. Scientists consider it very dangerous with respect to the possibilities of attack by insects or diseases. The main reason for this situation is that the people in Indonesia, and maybe in other developing countries, are too sensitive to taste. Although many varieties are recommended by scientists and officials, only a few have the taste suited to the palate of the people. In Indonesia, one of these is Cisadane, a high-yielding variety, tolerant of brown planthopper, with a taste considered suitable by almost all the population. This variety is now planted on more than one million hectares.

We are doing our best to diversify rice varieties suitable for smaller areas with tolerance for different insects and diseases.

Second, in various places the quality of rice produced is considered below the expected standard. In the past we did not have the time to think about quality because all our efforts were geared toward increasing the quantity of rice.

There is even an anecdote among people in Indonesia, that the quality of our rice is so bad that “even the brown planthoppers do not like it, let alone people.”

Now, that enough rice is grown, we have the time to pay more attention to quality improvement. Again, I rely on the IRRI scientists and on our national research centers for help. I hope that the anecdote I have just mentioned will not be heard in the future.

Third, our experience shows that after 4 or 5 yr, rice production tends to level off, possibly because of the effect of the law of diminishing returns. New innovations, either technical or social, are required to push the production up again. This is probably what Mosher meant by “an ever-changing technology” as one of his five essentials to get agriculture moving. The only difference might be that Mosher was referring to technical innovations only, and neglected social innovations.

In the late 1960s and early 1970s, the IR5 and IR8 technology, in conjunction with the social innovation of organizing the intensification program, pushed the then levelled-off rice production strongly upward.

Toward the second half of the 1970s, rice production levelled off because of the brown planthopper disaster and prolonged drought. Again technology, which produced brown planthopper-tolerant IR26, IR36, and other varieties, coupled with the social innovations of the special intensification, pushed production strongly upward.

In a couple of years, I fear that rice production will again level off. Some technical and/or social innovations should be sought now to act as another upward push. What could it be? Technology producing varieties with still higher yield potential? I think that since the 1970s the yield potential of the rice varieties bred in IRRI and that of varieties bred in our national research centers have been about the same.

If this is the case, what can we expect from breeding technology which can act as an upward push on our production? From the point of view of management what kind of social innovation can we expect to do the same thing?

These are the challenges which must be faced by technical and social scientists in the executive offices of the Department of Agriculture of Indonesia, in research centers, and at universities.

We in the developing countries have many similarities in our food production. We encounter many obstacles in our efforts to increase food production. Our farmers are cultivating small plots of land, they are financially very weak, and additionally, skilled and trained personnel are scarce. Our productivity is low because the application of modern technology is hampered by technical, social, cultural, and economic factors. Some of our people are still below the poverty line and hunger and famine always shadow their lives.

While expecting proper help from the developed countries, I believe that we in the developing countries should try to solve our food production problems by ourselves. In this endeavor, we should keep close contact with each other. Let us share experiences, so that we can take the possible positive points in a short cut and avoid making similar mistakes.

Let us also ask IRRI to continue its services for the benefit of our countries. I never doubt that IRRI will continue to be our friend in need.

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IRRI'S RESEARCH AND 'TRAINING AGENDA

IRRI's thrusts in research and training have been recently summarized in a publication entitled *International rice research: 25 years of partnership.* I shall, therefore, refer only to some major concerns being addressed by IRRI scientists in collaboration with national research systems, and I shall briefly refer to the global rice scenario.

World rice production reached a record level of about 468 million tonnes in 1984. The outlook for production during 1985 is good so far. A major problem faced by farmers is the decline in the price of rice. World rice prices in US dollars in 1984 and early 1985 fell to the lowest level since 1977. The fall in real terms was even sharper although it will be premature to forecast what might happen on the price front during the rest of this year and during 1986. The large supply available from the 1984 crop and weak international demand suggest that prices are likely to remain low at least during the rest of 1985. The volume of trade in 1984 was about 12.2 million tonnes, the highest in recent years. Significant gains have been made by Thailand — in 1984 it met nearly 40% of the world market needs. The USA, China, Pakistan, and Burma together provided another 45% of the quantities exported. Despite this increase in quantities exported, the value of exports was only US$3.8 billion in 1984 as compared to the average figure of $4.6 billion during 1979-81. Unfortunately, the cost of inputs like chemical fertilizers tends to go up even as rice prices go down. Although this has affected the producers' income, the lowering of rice price has been of significant nutritional benefit to poor consumers.

IRRI studies have shown that in 8 Asian countries, fertilizer use contributed 24% of the total increase in rice production (2). Obviously, therefore, the relative prices of inputs and outputs will be a major determinant of the future rate of adoption and diffusion of new technologies. A great challenge to policy makers is developing measures that can concurrently promote greater production by small farmers and greater consumption by the urban and rural poor.

FAO's projections on the total quantity and rate of increase in rice production needed during the rest of the century are indicated in Table 1. It should not be difficult to achieve the growth rates indicated in the FAO projections if economically viable and ecologically sound technological packages are spread among small farmers through appropriate services and government policies. There is, however, no room for complacency because rice is produced and consumed largely by small and poor farmers in most parts of Asia where more than 90% of the world rice is grown and good land is increasingly going out of agriculture. In contrast population pressures will increase substantially in coming decades (Table 2).

The experience of the last 20 yr has shown that even a 5% drop in global rice production could lead to more than 200% increase in the world price of rice. Also, because the major rice crop of Asia is grown during the southwest monsoon, monsoon aberrations can have repercussions on production in several countries at once. These and the following reasons make it absolutely essential that we do not relax our efforts in rice research and development.

1. More poor people depend on rice than on other cereals. A small percentage gain in rice production will have a much greater impact on food supplies than, for example, a large gain in cassava.
2. Rice requires greater investment on maintenance research designed to

Table 1. Production of rice (paddy), 1974-76 average, and projections for 1990 and 2000, world and main regions.[a]

Country or region	Production (million t)		Annual increase (% per yr)		
	Actual average 1974-76	Projected Year 2000	Actual 1974-76	Projected 1980s	Projected 1990s
Africa	5.4	18.8	0.5	5.9	6.2
Far East	169.2	330.5	3.4	3.0	2.1
Latin America	13.9	29.4	2.3	3.3	3.1
Near East	4.6	10.2	0.6	3.7	3.9
90 developing countries	193.0	388.9	3.2	3.1	2.4
China	128.4	222.1	3.7	2.9	1.7
Developed countries	25.7	28.3	–0.4	0.2	0.8
World	347.1	639.3	3.2	3.0	2.1

[a]Projections based on revised normative scenario of *FAO's study of agriculture: toward 2000,* as presented to the International Rice Commission in 1982. Data for developing countries refer to 90 countries accounting for 98% of population of developing world outside China; world total excludes remaining developing countries.

Table 2. Population projections: 1980 to 2100 (population in millions).

Selected countries	1950	1980	2000	2025	2050	2100	Total fertility rate-1982	Year in which NRR=1
China	603	980	1,196	1,408	1,450	1,462	2.3	2000
India	362	687	994	1,309	1,513	1,632	4.8	2010
Indonesia	77	146	212	283	330	356	4.3	2010
Brazil	53	121	181	243	279	299	3.9	2010
Bangladesh	44	89	157	266	357	435	6.3	2035
Nigeria	41	85	169	329	471	594	6.9	2035
Pakistan	37	82	140	229	302	361	5.8	2035
Mexico	27	69	109	154	182	196	4.6	2010
Egypt	20	42	63	86	102	111	4.6	2015
Kenya	6	17	40	83	120	149	8.0	2030
Regions								
Developing countries:								
Africa	223	479	903	1,646	2,297	2,802	6.4	2050
East Asia	587	1,061	1,312	1,542	1.573	1,596	2.3	2020
South Asia	695	1,387	2,164	3,125	3,810	4,172	4.9	2045
Latin America	164	356	535	732	856	921	4.1	2035
Subtotal[a]	1,670	3,298	4,884	6.941	8,400	9,463	4.2	2050
Developed countries	834	1,137	1,263	1,357	1,380	1,407	1.9	2005
Total World	2,504	4,435	6,147	8,298	9,780	10,870	3.6	

[a]Regional figures do not add to developing countries subtotal due to rounding. Source: (5).

defend the production gains already made in favorable environments. This is because of the continuous changes in insect and disease pressures and in soil stresses. A crop like wheat, on the other hand, is relatively better off in maintenance research requirements. An effective maintenance research program in rice will need a network of *hot spot* centers where anticipatory breeding and screening work can be done.

3. Rice is grown in a variety of seasons and in a wide range of latitudes, altitudes, and soil conditions. Most other cereals cannot grow under such a wide range of environmental conditions. Consequently, many national research systems give greater importance to rice in their farming systems research.
4. Countries like China, India, Bangladesh, Sri Lanka, and several others in South and Southeast Asia will face a serious *land hunger* problem in the coming years. Therefore, they have to meet the increasing requirements of food only through a vertical growth in productivity and through a greater intensity of cropping. This will need a greater input of strategic research in areas like hybrid rice, early-maturing but high-yielding varieties, etc.
5. World trade in rice is only about 10-12 million tonnes. Also, very little rice is used as animal feed. In these two respects, rice differs prominently from food grains like wheat, barley, maize, and sorghum.

This is because most rice is grown by small farmers and consumed in the areas where it is produced. We must intensify research that can reduce production cost through substituting farm-grown inputs for market-purchased ones. This can be done only by taking full advantage of emerging techniques in biotechnology, genetic engineering, and molecular biology. Such research is expensive and largely conducted by commercial companies in Europe and North America. This is one of the reasons why the Rockefeller Foundation chose rice as the principal crop for attention under their genetic engineering research. We need to improve our capability in genetic engineering research if we are to maintain our relevance to the advanced national research systems.

6. Rice cultivation coupled with the adoption of integrated pest management procedures can help reduce the dangers from vector-borne diseases in the command areas of irrigation projects. This aspect is of particular significance in parts of Africa and in Southeast Asia.
7. In wetland areas, the introduction of pest- resistant rice varieties helps to make rice - fish integrated production systems possible.

Let me now indicate how IRRI and rice scientists in the national research systems, in advanced laboratories, and developed and developing countries face the new challenges. The six major priorities in our research and training agenda are:

1. sustaining and expanding production gains in irrigated areas;
2. extending frontiers of high-yield technology to areas of moisture stress and/or excess (i.e., drought- and flood-prone areas);
3. enhancing productivity in problem-soil areas;
4. improving the income and employment potential of rice farming systems through concurrent attention to on- and off-farm employment;
5. adding a dimension of resource neutrality to scale neutrality in technology development by substituting farm-grown inputs for market-purchased inputs; and
6. improving methods of training, information dissemination, and skill and knowledge transfer.

These programs are designed to enhance the productivity, profitability, stability, and sustainability of major rice farming systems of the world. The research approaches chosen for this purpose can be broadly grouped into three categories:

1. maintenance research intended to defend the gains already made,
2. downstream research designed to solve location-specific problems faced by farmers because of ecological and/or socioeconomic factors, and
3. upstream research that aims to utilize the opportunities provided by recent advances in areas like biotechnology, genetic engineering, microelectronics, satellite imagery, and computer sciences to solve downstream problems.

If we study world rice production by cultural type, we find that irrigated areas contribute 76% of the production; rainfed lowland areas, 16%; rainfed upland areas, 5%; and deep water areas, 3%. Although rainfed areas contribute only 24% of the world's rice, they are exceedingly important from the human angle. Such ecologically handicapped areas also often are inhabited by economically poor peasants. Therefore, the significance of rainfed rice improvement must be measured as much in terms of human welfare as in terms of contributions to total production.

Land is a shrinking resource for agriculture (Table 3). To elevate and stabilize rice production in different environments, we must understand in greater detail the major features of these environments in relation to their production potential. An international group of rice scientists coordinated by IRRI has identified the following major categories of rice growing environments (1, 3).

1. *Upland*
   a. Upland with long growing season and favorable soils (LF)
   b. Upland with long growing season and unfavorable soils (LU)
   c. Upland with short growing season and favorable soils (SF)
   d. Upland with short growing season and unfavorable soils (SU)
2. *Rainfed lowland*
   a. Rainfed shallow favorable soils
   b. Rainfed shallow drought prone
   c. Rainfed shallow drought and submergence prone
   d. Rainfed medium-deep waterlogged
3. *Deep water*
   a. Deep water (50 cm and 100 cm water depth)
   b. Very deep water (more than 100 cm water depth)
4. *Irrigated*
   a. Irrigated with favorable temperature
   b. Irrigated, low temperature, tropical zone
   C. Irrigated, low temperature, temperate zone
5. *Tidal wetlands*
   a. Tidal wetlands with perennially fresh water
   b. Tidal wetlands with seasonally or perennially saline water
   c. Tidal wetlands with acid sulfate soils
   d. Tidal wetlands with peat soils

Table 3. World populationandarea in cereals, 1950 and 1980,with projections to year 2000.

Year	Population (billions)	Area in cereals (million ha)	Area per person (ha)
1950	2.51	601	.24
1980	4.42	758	.17
2000	6.20	828	.13

Source: U. N. and USDA.

The world's wetlands are at last receiving more attention. The scope for bringing additional wetland soil under rice production is immense in Africa and Latin America (Table 4). The relative importance of upland areas in Asia, Latin America, and Africa, together with a classification of uplands based on the duration of rainfall and the fertility of the soil, is indicated in Figure 1.

IRRI's strategy for rainfed rice research begins with the definition and precise characterization of the target ecosystems. Genetic materials are developed for each major environment based on an understanding of the ecosystems. Similarly, the soil, water, and crop management practices are adapted to each ecosystem. Finally, when appropriate material and management techniques are available, a more intensive cropping system is designed for testing in production projects.

The question is often asked whether there is any immediate potential for yield increases in upland rice. Data from international trials suggest that a substantial untapped yield reservoir is waiting to be utilized. Data from the International Upland Rice Yield Nursery for 1975-83 indicate that the top two entries consistently outyielded the best local check (Fig. 2). Multilocation breeding and testing provide opportunities for selecting for stability of performance and wide adaptation. In this way, the complementary strength of different breeding stations and environments can be meaningfully integrated.

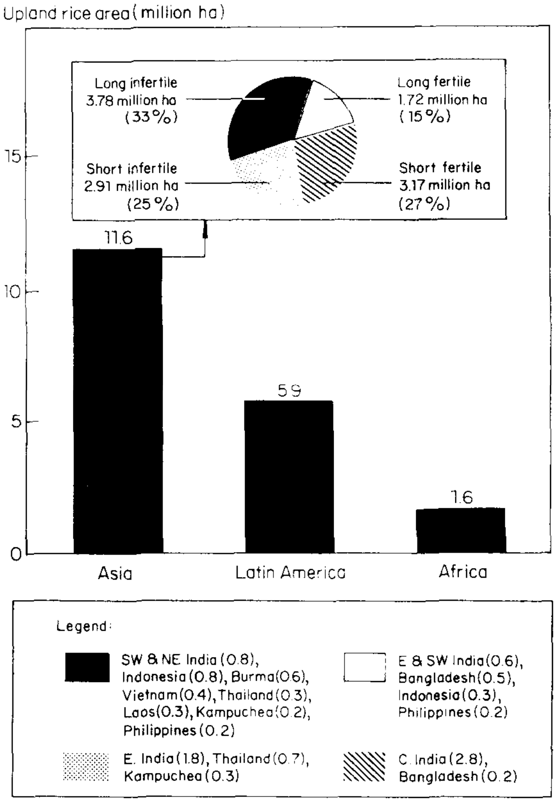
Another great challenge to rice scientists is developing economically viable technologies for improving the yield of rice and other crops in stressed and toxic soils. IRRI calculations show that about 86 million hectares of riceland in South and Southeast Asia are affected by salinity, alkalinity, acid sulfate, and peat soil conditions. The precise approach to improving crop productivity in problem-soil areas should be based on the factors responsible for the problem. Under conditions like coastal salinity, civil engineering work to keep away the salt water should be coupled with the use of chemical amendments and plant breeding techniques.

Because of its philosophy of working for small and resource-poor farmers, IRRI gives priority to the breeding of varieties that combine good yield potential with tolerance for or resistance to a wide range of soil toxicities and deficiencies as shown in Table 5. In addition to the breeding approach, IRRI is developing management packages that will help bring out the full yield potential of new varieties in problem-soil areas.

Table 4. Wetland soils for rice production on three continents.

Region	Area of wetland soils[a] (million ha)	Rice area harvested[b] (million ha)
South and Southeast Asia	121	90.3
Africa	203	4.9
Latin America	231	8.2

[a]Based on analysis of the FAO soil maps of the world by Sanchez and Buol (6). [b]Source: (1).



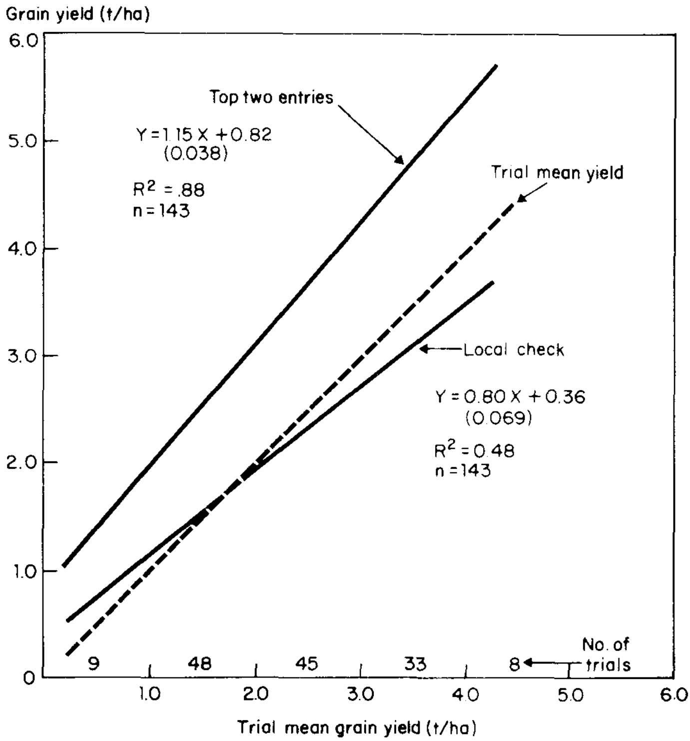
1. Relative geographic distribution of tropical upland rice production.

ECOLOGICAL SUSTAINABILITY

Following the spread of what is popularly referred to as "Green Revolution" techniques, there has beenwidespread concern for the long-term sustainability of crop production using such techniques. The major concerns are:

1. gene erosion caused by substituting large numbers of local strains with a few high yielding ones;
2. the danger of pest epidemics arising from genetic homogeneity in material planted over large areas under intensive monoculture;
3. pesticide residues in plants, animals, and drinking water caused by the indiscriminate use of chemical pesticides, particularly those that have long residual toxicity; and
4. soil degradation and erosion arising from intensive exploitation of the soil and the use of heavy machinery leading to pulverization of the top soil and compaction of the subsoil.

As an international institute which should work for more rice not only for today's population but also for more rice forever, IRRI is deeply concerned



2. Regression of the top two yielding entries and the yield of the local check variety on the mean yields of the International Upland Rice Yield Nursery, 1975-83. Values on parentheses are the standard errors of the slopes.

with these ecological issues. I would like to indicate briefly our approach to these problems.

1. *Gene erosion.* IRRI has pioneered the collection and conservation of rice genetic resources. IRRI's Germplasm Center has currently more than 77,300 strains of rice collected from 101 countries. Wild species and material are represented by about 1,900 accessions. We have about 3,000 strains of *Oryza glaberrima* from West Africa and more than 65,000 accessions of *Oryza sativa.* The IRRI rice collections probably represent the most extensive and scientifically managed and utilized germplasm collection in any crop. A five-year plan was developed in 1983 in consultation with national research systems to complete the collection of rice germplasm material with priority to endangered habitats and fragile ecosystems.

   IRRI also collects and maintains the germplasm of Azolla, an important biological source of nitrogen in rice soils. Data on the present Azolla germplasm collection are given in Table 6.

2. *Genetic homegeneity.* Through a multidisciplinary genetic evaluation and utilization program, IRRI screens the germplasm collection for

Table 5. Reactions[a] of IR varieties to adverse soils.

	Wetland soils							Dryland soils	
	Toxicities					Deficiencies		Iron deficiency	Aluminum and manganese toxicities
	Salt	Alkali	Peat	Iron	Boron	Phosphorus	Zinc		
IR5	4	656			3	5	5	4	5
IR8	4	658			4	4	4	4	4
IR20	5	745			4	3	3	4	5
IR22	5	643			3	3	3	5	5
IR24	3	543			3	3	4	3	4
IR26	5	666			3	2	6	4	3
IR28	7	554			3	3	5	6	5
IR29	6	644			3	5	3	0	0
IR30	5	633			3	3	3	0	0
IR32	5	755			3	3	5	5	5
IR34	5	333			3	3	3	0	0
IR36	3	333			3	6	3	2	2
IR38	5	545			3	3	3	5	4
IR40	5	643			3	3	3	0	0
IR42	3	434			2	2	4	5	5
IR43	4	755			4	3	3	3	3
IR44	3	544			3	3	4	4	4
IR45	4	654			3	3	4	4	4
IR46	3	344			2	5	3	4	3
IR48	4	754			2	3	5	4	3
IR50	4	435			3	3	3	4	4
IR52	3	433			3	3	3	4	5
IR54	4	535			2	2	3	4	4
IR56	3	435			3	3	4	0	0
IR58	3	444			4	4	3	0	0
IR60	3	446			3	5	5	0	0
IR62	4	543			0	4	6	0	0
IR64	3	345			4	4	4	0	0

[a]0 = no information, 1 = almost normal plant, 9 = almost dead or dead plant, Based on greenhouse and field tests by C. Patena, M. T. Cayton, M. Orticio, C. Quijano, V. Quimsing, N. Uy, R. Reyes, and J. Solivas.

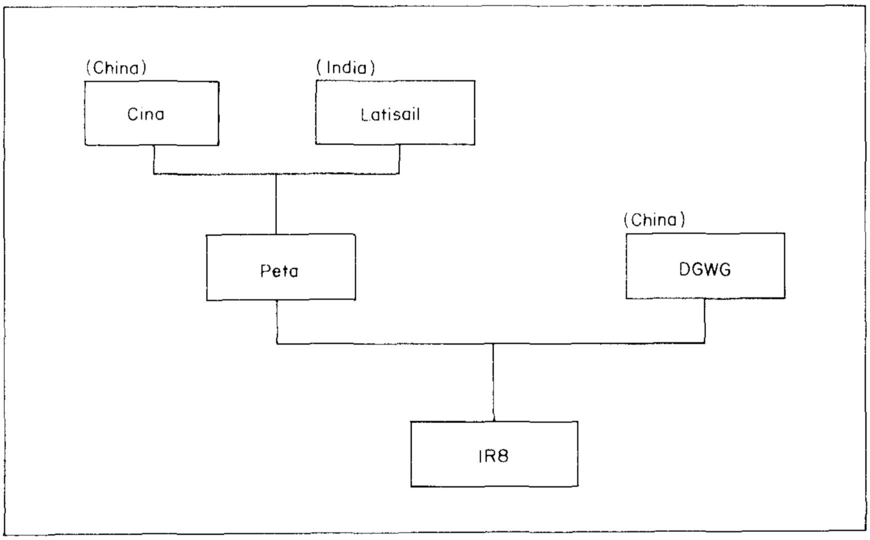
Table 6. Azolla germplasm collection maintained at IRRI (as of 18 Jun 1985).

	Collections (no.)	Countries (no.)	Area
A. pinnata var. *imbricata*	86	18	Asia, Africa
A. pinnata var. *pinnata*	5	1	Australia
A. nilotica	1	1	Sudan
A. filiculoides	24	7	America, Europe, Asia
A. rubra	3	1	Japan
A. caroliniana	15	5	North and South America
A. mexicana	5	2	USA, Guyana
A. microphylla	11	2	Ecuador and Paraguay

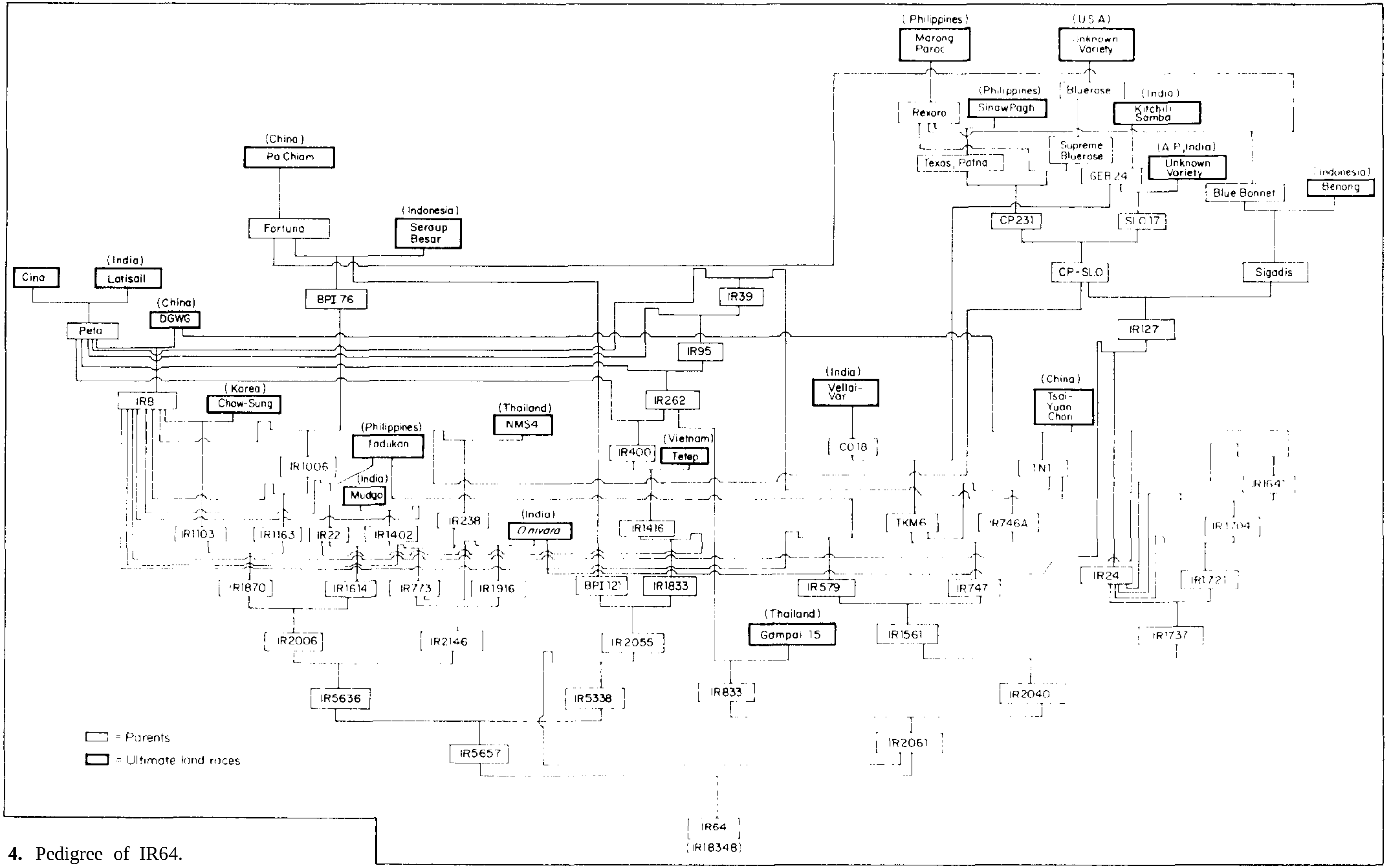
Table 7. Sources of resistance to insect pests: contrast between wild rices and cultivated strains.

Insect pest	Accessions tested (no.)		Resistant accessions (%)	
	Varieties	Wild rices	Varieties	Wild rices
Whitebacked planthopper				
Sogatella furcifera	47,089	449	0.83	46.3
Brown planthopper				
Nilaparvata lugens				
Biotype 1	45,122	446	0.93	45.7
2	15,068	445	1.88	37.8
3	16,402	448	1.76	39.7
Zigzag leafhopper				
Recilia virescens	2,383	422	1.51	51.7
Green leafhopper				
Nephotettix virescens	48,961	447	2.60	53.4
Yellow stem borer				
Scirpophaga incertulas	22,920	322	0.11	21.7

valuable genes and utilizes them in a very extensive hybridization program. Wild rices, in particular, have proved to be excellent sources ofresistance to many insects and diseases (Table 7). To show the extent of breeding work which goes into the making of modern rice varieties in contrast with an early high yielding strain like IR8, I would like to draw attention to the pedigrees of IR8 released in 1966 and IR64 released by the Philippine Seedboard in 1985 (Fig. 3, 4). IRRI does not name or



3. Pedigree of IR8.



4. Pedigree of IR64.

release any variety. Naming or releasing a variety is the responsibility of the national authority. IRRI sends its elite breeding material to rice workers all over the world through the International Rice Testing Program (IRTP). IRTP helps pool the best available breeding material and genetic stocks in national research systems and in IRRI. Details of the IRTP nurseries distributed in 1984-85 are given in Table 8.

3. *Pesticide residues.* IRRI develops and introduces integrated pest management procedures involving varietal resistance, biological control, cultural practices, and the use of minimum essential chemical pesticides based on careful monitoring of pest incidence in the fields. Pesticides are recommended only when the pest population exceeds the economic threshold from the point of view of potential damage to crops. I would like to illustrate the Integrated Pest Management (IPM) approach with a recent example relating to the control of black bug in Palawan Island, Philippines.

   Since it was first reported in the Philippines in 1979 on the southern tip of Palawan, the black bug *Scotinophora coarctata* has

Table 8. IRTP nurseries distributed in 1984.

Region	Nursery sets (no.)		Total
	Cultural types[a]	Specific stresses[b]	
East Asia (4 countries)	30	59	89
Southeast Asia (6 countries)	253	165	418
South Asia (6 countries)	219	140	359
West Asia and North Africa (4 countries)	22	18	40
Sub-Sahara Africa (16 countries)	203	101	304
Latin America (10 countries)	52	23	75
Europe (4 countries)	1	5	6
Oceania (3 countries)	8	2	10
Total	788	513	1,301

[a]Irrigated Yield-Very Early (IRYN-VE), Irrigated Yield-Early (IRYN-E), Irrigated Yield-Medium (IRYN-M), Rainfed Upland Yield-Early (IURYN-E), Rainfed Upland Yield-Medium (IURYN-M), Rainfed Shallow Water Yield (IRRSWYN), Irrigated Observational (IRON), Rainfed Upland Observational (IURON), Rainfed Shallow Water Observational (IRRSWON), Deep Water Observational (IRDWON), Floating Rice Observational (IFRON), Tide-Prone Observational (ITPRON). [b]Cold tolerance (IRCTN). salinity and alkalinity tolerance (IRSATON), acid lowland, acid upland, blast (IRBN), bacterial blight (IRBBN), tungro virus (IRTN), brown planthopper (IRBPHN), whitebacked planthopper (IRWBPHN), stem borer (IRSBN), rice thrips.

spread northward and is now distributed throughout the rice-growing areas of Palawan. Control recommendations have largely been confined to the use of chemicals.

IRRI recently initiated a multifaceted effort to control the black bug. This involves 1) the development of sampling techniques, 2) determining of economic thresholds, 3) releasing of egg parasites and entomogenous fungi, 4) testing of resistant rices, and 5) use of chemicals.

We have developed a sequential sampling model that should save time in sampling yet provides accurate information on treatment decisions. We also are analyzing threshold data which include time of infestation.

We have found that plant damage ratings and grain yield losses from feeding by the black bug were lowest on rice cultivars IR10781 - 75-3-2-2 and IR13149-3-2. These cultivars are being tested further.

Our biological control activities include the use of fungal pathogens against the adult bugs and imported parasites against the eggs. We have isolated three species of fungi, and mass produced and used them in field-cage tests. The fungi (especially *Metarhizium anisoplae* and *Beauveria bassiana*) successfully suppressed populations of the black bug to uneconomic levels.

Four species of egg parasites, *Psix lacunatas* and *Telenomus cyrus* from Luzon, *Telenomus chloropus* and *Tissolcus basalis* from the USA, are being reared for release in Palawan. Earlier surveys showed that only one indigenous parasite, *Telenomus triptus,* was recovered from black bug eggs in Palawan. Extensive surveys are being conducted along with releases of the introduced species to determine if the parasites establish themselves in the field and reduce bug populations.

We have tested several chemical insecticides against the black bugs but their costs may prevent their extensive use in Palawan.

Experiments are under way to determine if plowing the fields soon after harvest can reduce bug populations. We have observed that populations can develop in rice stubbles left in the field, especially when ratooning occurs.

Thus, through a combination of genetic, biological, cultural, and chemical approaches, it is hoped that the black bug epidemic can be controlled at low cost and on ecologically sound lines.

4. *Soil degradation.* Through the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER), IRRI promotes greater attention to the care and maintenance of soil health. IRRI's approach to soil health care involves concurrent attention to the chemical, physical, microbiological, and erodability characteristics of the soil. Soil physicists, chemists, microbiologists, agronomists, and water technologists work together. To make the heavy application of mineral fertilizers unnecessary, IRRI promotes an Integrated Nutrient

Supply System under INSFFER. The major components of the Integrated Nutrient Supply system are

a. *Green manuring.* IRRI studies have shown that *Sesbania aculeata* accumulated more than 200 kg N/ha in 60 d. A green manure crop accumulates in 60 d more nitrogen than a rice crop can efficiently use. Results of a 1984 study on nitrogen management in rice preceded by maize fodder, mungbean, unweeded fallow, unweeded fallow + farmyard manure (FYM) and Sesbania green manure showed that green manuring with no nitrogen application produced yields comparable to those obtained with application of 100 kg N/ha after maize fodder and 50 kg N/ha after the other three treatments. Thus, suitable crop rotations can enrich the soil and thereby reduce dependence on inorganic fertilizers. The precise choice of the green manure crop and management system will have to be developed in consultation with farmers on local preferences and possibilities.

b. *Biofertilizers.* The rice field provides excellent conditions for biological nitrogen fixation. The important nitrogen-fixing agents are the free-living blue-green algae, Azolla in symbiosis with blue-green algae, and bacteria associated with rice and legume-rhizobium symbiosis. In 1980, IRRI scientists brought Azolla to South Cotabato in Mindanao and observed that Azolla grows well in the area. In fact, farmers were using Azolla as green manure for rice. IRRI developed, in cooperation with the Philippine Ministry of Agriculture and Food (MAF), a simple method to test the suitability of soil to support Azolla growth and found that soil phosphorus supply is the most critical soil factor for Azolla growth. The MAF identified about 30% of irrigated rice soils in the Philippines suitable for Azolla growth by adopting this simple technique. Azolla has been used for centuries to enrich the soil in rice fields in China and Vietnam. Although the technology of Azolla use is now well developed, many technical constraints remain. Experiments are in progress to solve problems such as tolerance for high temperature, insect and disease damage, need for phosphorus application, and year-round maintenance of Azolla. However, it should be stressed that the maximum amount of nitrogen fixation, except those by green manure legume, is about 40 kg N/ha in tropical conditions. The current status of the use of different nitrogen-fixing agents in rice soils is indicated in Table 9.

c. *Mineral fertilizers.* Chemical fertilizers are very effective but are an expensive agricultural input. As much as 50% of the nitrogen applied to the crop as urea may be lost, particularly with poor water management. Some of the reasons for the low efficiency of fertilizer nitrogen are

- loss by ammonia volatilization;
- nitrification followed by denitrification;

Table 9. Present state of use of nitrogen-fixing agents in paddy soils.

Nitrogen-fixing organisms in rice field	Possible use proven	Technologies available	Current use by farmers
Legumes	+	+	+
Azolla	+	+	+
Blue-green algae	+	±	-
Bacteria in soil			
with straw	+	±	±
with rice root	+	-	-

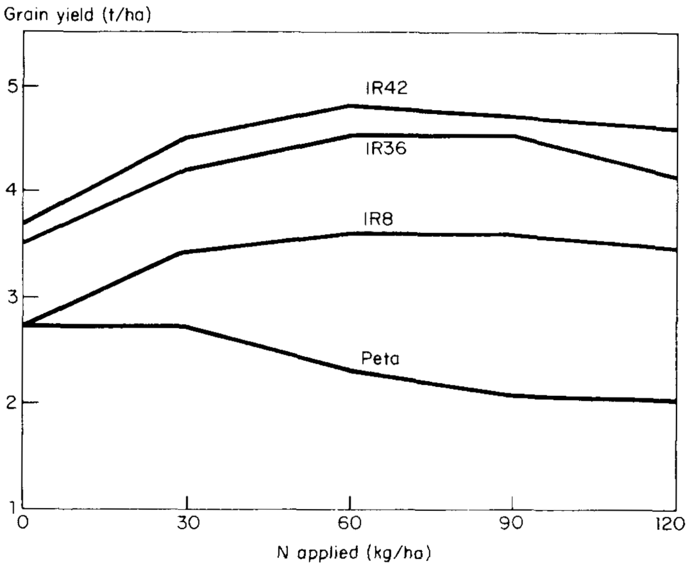
±Only in llimited extent or unconsciously used.

- biological immobilization, especially by algae;
- fixation by ammonium nitrogen by clays;
- leaching;
- runoff; and
- seepage.

Scientists of IRRI, the International Fertilizer Development Center (IFDC), and national research systems have developed methods for reducing or eliminating losses caused by these factors. Simple fertilizer placement machines have been developed for urea supergranules and prilled urea. Thus, fertilizer use efficiency can be greatly enhanced.

5. *Cultivation of efficient genetic strains.* Contrary to some views that high-yielding varieties require high fertilizer input, modern semidwarf and nonlodging rice and wheat varieties yield more than traditional tall varieties at all levels of nitrogen application. This is true not only in IRRI experiments in the Philippines but also in many other rice growing countries. The superior performance of the semidwarf varieties can be attributed to their ability to transfer a large proportion of total dry matter (photosynthates) to grains. The tall varieties, in contrast, allocate a large proportion of total dry matter to stems, leaves, and plant parts other than grain. *Therefore, the relevance of locally adapted modern varieties to small farmers increase when the cost of fertilizer is high and its availability low.*

Another significant aspect of IRRI's work relates to the selection of varieties which have higher ability to utilize the available soil nitrogen. For example, under the same conditions of soil fertility, IR42 yields more than IR36 and IR8 (Fig. 5). Thus, through a combination ofvarietal choice, organic recycling, cultivation of green manure crops, application of biofertilizers, and use of essential quantities of inorganic fertilizers, we can develop a method of meeting the nutrient needs for achieving high yields on a sustainable basis. Balanced nutrition holds the key to both good yield and maintenance of soil health at a high level of productivity. The methods of providing balanced



5. Grain yield response of 4 rices to different levels of nitrogen. Data are average for IRRI and 3 experiment stationsofthe Bureau of Plant Industry(Ma1igaya, Bicol, and Visayas), 1976-1984 wet seasons. (Data source: IRRI, Agronomy Department.)

nutrition to the crop will have to be standardized for each area. In some areas, rice straw is burned. IRRI scientists have shown that incorporating the rice straw in the soil can improve soil fertility.

ECONOMIC SUSTAINABILITY

Farmers tend to receive in real terms lower prices for rice now than during the 1970s. On the other hand, input costs are going up. The decision of farm families with reference to input purchases will depend on consideration of cost, risk, and return. Obviously to farmers, net and stable income per hectare is what is important and not gross yield per hectare. IRRI's approach to economic sustainability is as follows.

1. *High cost of inputs.* By adopting integrated pest management, integrated nutrient supply, and scientific water management procedures, production cost can be reduced considerably. By cultivating locally adapted modern varieties with a broad spectrum of resistance to insects and diseases and a broad spectrum of tolerance to soil toxicities and deficiencies, dependence on chemical pesticides and expensive soil amendments can be diminished. Together with good land and water management and improved postharvest technology, it should be possible to achieve high yields without much increase in production cost. Postharvest operations like threshing, milling, and storage are

exceedingly important. For example, in a country like Burma, rice yield expressed in terms of rough rice (paddy) or unmilled rice is high but it goes down steeply when expressed in terms of milled rice, thereby indicating that the milling recovery is low.

2. *High risk.* Risks arise from weather aberrations, pest epidemics, and market behavior. IRRI has promoted detailed studies on the relationship between climate and rice production. The rice weather interaction is being studied very carefully at 31 locations under the International Rice Testing Program. We need to intensify our research in agrometeorology and use more extensively remote sensing techniques to monitor crop growth and yield. It is now possible to adjust the maturity of the crop to suit seasonal conditions. Pest problems can also be managed through integrated pest management. Market forces leading to large undulations in price will have to be watched and whenever necessary, governments will have to assure farmers of a fair price.
3. *Low return.* Productivity per hectare, farm management efficiency, relative cost of inputs and output, and the weather pattern all determine the net return per hectare. IRRI has standardized a methodology for analyzing the constraints responsible for low and uncertain returns.

Another aspect of economic sustainability is the provision of adequate opportunities for both on-farm and off-farm employment in rice farming areas. This will help enhance total family income. IRRI and the national research systems conduct such studies under the Asian Rice Farming Systems Network. This network now includes livestock as an integral component.

In addition, a project was initiated in 1983 jointly by the University of the Philippines at Los Baños and IRRI with financial support from the Asian Development Bank to demonstrate how the prosperity of rice farming families can be improved. This project has the following three components:

1. *Rice production technology.* Techniques for producing more rice per hectare at as low a cost as possible are demonstrated. The techniques include cultivating high-yielding and pest-resistant varieties, substituting farm-grown inputs for market-purchased ones, and enhancing input-output ratio through the scientific management of purchased inputs.
2. *Rice farming systems.* Methods of increasing income and employment through the optimum use of the land, water, and labor resources available to a small farmer are demonstrated. Multiple cropping, intercropping, and mixed farming involving rice and livestock or rice and fish constitute the major components of the demonstration.
3. *Biomass utilization.* Methods of using the whole rice plant efficiently through the preparation of value-added products from the straw, bran, and hull or husk are demonstrated.

In 1984 rice production in terms of grains was about 468 million tonnes, but the rice crop also produced more than one billion tonnes of other plant parts like roots, straw, leaves, bran, and hull. Therefore, we should look at the effective utilization of the entire plant and not of the grain alone.

FORWARD EDGE

Although our overriding priority is the development of techniques for ecologically handicapped areas and economically handicapped farmers, we have to work concurrently on raising the ceiling to yield in irrigated areas. In China, more than 8 million ha were under hybrid rice in 1984. We are now actively working with Chinese scientists as well as with scientists of several other national research systems in improving the productivity of rice further through the exploitation of hybrid vigor. We are trying to diversify the sources of cytoplasmic male sterility so that we can avoid the dangers arising from genetic homogeneity.

Modern biotechnology and genetic engineering provide added dimensions to our research on the transfer of genes from wild species into cultivated varieties. IRRI has, therefore, intensified its research on different aspects of tissue culture applications and on the development of more effective and reliable diagnostic methods for virus diseases. In the future, we will have to produce more and more rice from less and less land. Higher productivity and greater cropping intensity are the only two major pathways open to countries already faced with a high population pressure on land. IRRI is trying to harness all the tools that science can provide for improving rice production.

IRRI works with the national research systems of almost all rice growing countries through annual work plan meetings and periodic international rice research conferences. IRRI tries to respond to the specific needs of each national research system. If we assume that with the currently available technology, an average rice yield of 6 t/ha can be obtained wherever there is adequate water, we can classify rice growing countries according to the size of the yield gap, the difference between potential and actual national average yields. Rice-growing countries fall into four major groups according to size of yield gap: those with practically no gap, those with less than 25% gap, those with more than 50% gap, and those with more than 75% gap. The major factors responsible for the size of the yield gap may be ecological, technological, political, socioeconomic, and institutional. Through a constraints analysis methodology, IRRI has shown how to identify and quantify the precise factors responsible for the yield gap.

A growing problem encountered in the effective transfer of technology is the absence of a social infrastructure at the village level which can facilitate and stimulate group action on the part of small farmers living in a village or in a watershed. Technologies can be grouped into the following three categories based on their adoption needs:

1. Group I: Individual farmer action (e.g., seed, nonmonetary inputs)

2. Group II: Government action (e.g., research, extension, input supply, input-output pricing, insurance)
3. Group III: Group action (e.g., scientific land and water management, integrated pest management, integrated nutrient supply, producer-oriented postharvest technology)

Only when individual initiative, government support, and community action become blended in a mutually reinforcing manner do we achieve speedy and sustained progress both in agricultural production and agrarian prosperity. Therefore, the social engineering aspects of technology adoption require as much attention as the technological aspect of technology transfer.

TRAINING PROGRAM

Since the founding of IRRI, the development of technical personnel for rice-growing countries has been an important objective of the Institute. From 1963 to May 1985, more than 4,000 scientists and scholars from 71 countries have been trained at IRRI. The type and content of the courses offered are developed in consultation with national research systems. One problem encountered in our training programs is the unevenness of the participants in terms of academic training, professional experience, and English proficiency. IRRI tries to overcome these problems through emphasis on learning by doing. Attempts are being made to impart a degree of language neutrality in knowledge and skill transfer through multilanguage copublication, autoturorial modules, and computer-aided instruction.

In the ultimate analysis, the goal of scientific research is to enhance human happiness. This is why IRRI accords importance to equity issues in technology generation and transfer. An important recent initiative in this field is greater attention to the problems of women farmers as well as women labor in rice farming areas.

IRRI's main goal in this area of research is the standardization of technologies that will help remove drudgery and improve the income of farm women and women agricultural laborers so that the total income of poorer households is enhanced. Evidence suggests that when women have independent access to income, child nutrition is improved. The poorer the household, the greater the need to increase total family income by enhancing the earning capacity of women. Many of the jobs rural women do in rice farming areas are highly mechanical and require practically no skill. Such jobs deserve to be eliminated. However, before technological innovations designed to reduce drudgery and improve productivity are introduced, it is essential to ensure alternative avenues of employment in which those displaced from their traditional occupations by the new innovations can be gainfully employed. In other words, the challenge lies in converting unskilled jobs into skilled ones. Surveys and studies should be designed to this end, rather than merely to obtain more information for publications on the role of women in rice farming systems.

A coordinated program is being introduced in the Asian Rice Farming Systems Network to:

1. examine the impact of technological change in rice-based farming systems on women, with special emphasis on women belonging to small farm families and on women wage laborers;
2. design, test, and adapt technologies to reduce drudgery and increase women's productivity and income by diversifying opportunities for gainful employment in both the on-farm and off-farm sectors; and
3. identify gaps in skill and input delivery systems and in government policies which hamper the full participation of women in technology development and adoption.

Although action on the above lines is feasible and should be taken, *it is important to recognize that science is not a magic wand with which sex inequalities in workload and income can be made to vanish.* This should be emphasized clearly, otherwise false hopes about the capacity of science and technology to remove deep-seated social maladies arise.

In the ultimate analysis, it is only the concern, commitment, and concerted action of agricultural research systems and policy makers that can lead to meaningful results in imparting a women user's perspective in research priorities and strategies. To obtain a correct perception of priorities, there is need for direct interaction between scientists and women farmers and laborers. Scientists will have to listen and learn from resource-poor rural women. The greatest challenge before research and development institutions lies in motivating scientists and technologists to undertake a process of "listening and learning" through collaboration with poor women while developing their research priorities and strategies.

This is why on the occasion of its 25th anniversary, IRRI has invited 14 outstanding rice farmers from 10 countries, including two women farmers, to join us at this 25th symposium and share with us their experiences and insights on how rice production can be continuously increased without detriment to the long-term productivity of the terrestrial and aquatic farming systems.

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ROLE OF SCIENCE AND TECHNOLOGY IN RICE PRODUCTION AND PROGRESS

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FACTORS IN MANAGING AGRICULTURAL RESEARCH IN THE NETHERLANDS

I feel honored to speak to you and your staff on behalf of the Government and the agricultural community of The Netherlands.

In 25 yr, IRRI has become an example to many agricultural research organizations and has helped build the Consultative Group on International Agricultural Research and its network of 13 institutes. It is fair to say that no other research organization has ever had such a profound impact on so many people. As agriculturists we can take pride in this.

Many international organizations have come under severe criticism, and allegations are made that objectives are lost in expanding bureaucracies, but the Consultative Group and its institutes have remained sober, informal, and efficient — an organization farmers can associate with. Let us keep it that way.

As the representative of a country that does not produce rice I will confine myself in my presentation to the role science and technology play in agricultural progress.

Nowhere in the world does that progress happen of its own accord. Many people must make strenuous and continuous efforts for it to happen. And frequently nature sets us back a long way. Natural elements are at the same time allies and enemies of agriculture and, therefore, of humanity. Catastrophes such as the one that occurred recently in Bangladesh give us a sense of powerlessness. Even so we are succeeding more and more to reduce that powerlessness, often through strenuous effort.

Science and technology are two important instruments in our endeavors. I would like to mention the example of our own country.

Without proper water control two-thirds of the Dutch would be submerged by North Sea water. It took us centuries to conquer the sea. We built dikes, we reclaimed land by making polders. Even so, some 100 yr ago our agricultural industry was on the brink of ruin.

However, the global agricultural crisis of that period became the start of the exceptional development of Dutch agriculture.

Our government and producers joined forces and laid the foundations for a coherent system of education, research, and extension. We invested in science, technology, and last, but not least, in our farmers and their families. And in this way, in no more than a hundred years, through close cooperation between farmers, farmers' organizations and the government, we created an outstandingly efficient and successful agricultural industry in a small, highly industrialized, and very densely populated country.

Today, The Netherlands is a major producer of agricultural product, and the second largest exporter of agricultural products in terms of value after the United States. Of course, we are lucky to have a stable climate and a favorable geographic location at the crossroads of the trade routes of Western Europe.

The key to the economic success of our agricultural sector lies in the competence of the farm population. Our farmers are entrepreneurs who want to stay in business. They try their utmost to produce more, reduce production costs, and improve the quality of their products.

With a keen sense of market developments, farmers tend to snatch preliminary results out of the hands of our scientists, and what is more, they start experimenting on their own.

Three factors explain our current skill in farm management and the use of modern technology. First, the educational system. After primary school, most of our farmers attend one of the various agricultural colleges. Furthermore, vocational training enables them to keep abreast of developments.

Second, farmers are offered a vast amount of specialized information, both through the extension services and through professional farmers' organizations.

Third, we have invested in agricultural research, consisting of several types of research establishments dealing with fundamental, strategic, and applied research.

Close interrelationship between these factors was possible because the Minister of Agriculture and Fisheries is responsible for all three factors.

As a result, agricultural science is well and truly incorporated in the agricultural infrastructure of The Netherlands.

I think this is why the distance between science and society is less than in most other economic sectors. Here, farmers' organizations play their own role. They not only exert powerful pressure upon the government, but they are also a partner in our discussions on agricultural policies. Some of these discussions occur within a formal framework, many are of an informal nature.

I now turn to agricultural research and the policy decisions we have taken to keep the system responsive to questions arising in the field.

The Netherlands may be a rich country by international standards, but we are also a small country with only 14.6 million inhabitants. So we must be selective in choosing subjects for research.

The first implicit decision we made — years ago — was not to duplicate research and development already being carried out by private enterprise.

In retrospect, most innovations that are generally considered to have substantially contributed to the shaping of modern agriculture originated with industry and other private enterprise.

Farm machinery, the internal combustion engine, electricity, agricultural chemicals, and microprocessors and computers have all originated with Industry.

Farm cooperatives, public sale of farm products, joint marketing organizations, agricultural banking, farmers' organizations, which are all of great social and economic importance, are the result of private enterprise, and products of the farming world.

So, there are vast areas of research and development where the government never enters.

My Ministry does, however — and this is the second implicit decision — occupy itself with the implementation of farm-level innovations that have originated elsewhere. Results of applied research are quickly available at farm level.

The key word here is *quickly.* This speed is possible partly because The Setherlands is a small country, and partly because of a dense network of' applied research stations and of extension services. In larger countries, this is more difficult to achieve and calls for research to be organized closer to the farms.

The third decision, implicit also, and made long ago, was not to channel large amounts of our restricted budget into research that cannot be expected to provide results applicable at farm level within 10-1-5 yr.

When such subjects are studied elsewhere in the scientific world, we content ourselves with limited participation to stay abreast. In fact, we have adopted a general philosophy similar to that of the Consultative Group.

To sum up, our agricultural research policy has been in line with our insistence on quality. We want to make sure that our existing knowledge is maintained in a coherent manner, that our know-how is kept alive and passed on, and that new knowledge is acquired.

We must continue to find a pragmatic mix of research and development activities. In this manner, science and its great contribution to society as a whole will become better understood.

Scientists and farmers will be increasingly able to associate with each other, as this complementary approach addresses practical problems directly.

This, I am sure, is thegreatest incentive for all concerned, and holds much promise.

Well, fair enough, you may say at this point.

However, most of you know that European agriculture is facing problems and these problems are even more serious in The Netherlands.

More important, we all know that one-third of the world's population still goes hungry.

What policy decisions do we have to make to achieve world food security? You will understand that this question is beyond the scope of this paper. Undoubtedly some of these decisions must be taken in agricultural research.

Since World War II, our agriculture has developed primarily on a high technology production model. Its characteristics are product differentiation, product specialization, high input, orientation to foreign markets, heavy dependence on imported raw materials such as feedstuffs and fertilizers, and high capital investment. Farm size has been increased but the family farm remains the foundation of Dutch agriculture. The opportunities offered by the European Common Market have greatly stimulated these developments.

In terms of production, our agricultural sector has done very well. However, there is another side to the coin, or rather, success has a price.

As you know, Europe produces too much wheat and sugar and too much milk and butter at prices that are not competitive on the world market. Furthermore, high input agriculture is starting to have serious effects on the environment. This is a very complex problem. Let me give you some examples.

Intensive animal husbandry and dairy production in The Netherlands depend on imported raw materials for more than 50% of their feedstuffs. The amount of manure produced in some regions is beginning to exceed the absorptive capacity of the soil. Nitrate is accumulated in surface water and groundwater. Copper, mixed into pig feed, finds its way into the soil and copper toxicity starts to become a problem.

Overemphasis on yield per hectare has increased the genetic uniformity of our crops and reduced the diversity of our cropping systems. A side effect is often increased vulnerability to insects and diseases and the need for more chemical spraying. Economy of scale has seriously reduced labor requirements. All in all there is serious concern about the sustainability of this type of agriculture.

I realize that to many representatives of developing countries I will sound like a rich man complaining about the problems of excess wealth. That is not my point, however. *It is meant to illustrate how, by applying (over)-simplified agricultural production models and preoccupation with technological solutions, we lost sight of a number of additional, often complex, factors with consequences for the environment and society.*

This poses new challenges to research and more specifically to research management.

Today there is much discussion on biotechnology. Will it bring revolutionary changes to agriculture? I am sure it will in some way! I do believe, however, that farmers will still be growing wheat, rice, potatoes, and vegetables after we have incorporated such developments. They will still keep cattle and poultry.

Creating innovations is one side of the problem. Maintaining control over such new developments is another.

There is a growing dilemma between what is technically feasible, economically profitable, and sociologically and ecologically desirable. Science and scientific developments should not dictate the lives of people. Science should seek answers to questions formulated or influenced by those who are concerned with their application. Hence, the key to appropriate agricultural research is the ability to identify the right questions in given situations, be it in Asia, Africa, or Europe.

In many regions, the overriding concern is still how to increase agricultural production. It is equally obvious that in regions that are experiencing serious food shortages, it is not just a lack of technology. Agricultural research, in formulating its objectives, should take a holistic view and from the outset consider the likelihood of adoption of new technology plus its consequences.

To achieve a balance between technological objectives on the one hand and sociological and ecological objectives on the other hand, is in my view the major challenge to agricultural research in the rest of this century.

It is fair to say that the first successes of IRRI were based on straightforward technological production research. However, we also see a growing appreciation of the complexities of agriculture and how these should affect research programs.

IRRI’s research on farming systems should be commended.

The workshops on the role of women in rice farming systems underline the pioneering spirit of IRRI.

Furthermore, a growing orientation to rainfed rice will bring IRRI researchers into contact with a multitude of ecological and social environments.

For some time, IRRI has shown appreciation of the value of genetic diversity and has shown the world how genetic resources should and can be conserved.

The task ahead is how to recreate genetic diversity in farmers’ fields.

Let me conclude by saying that my government considers the support it gives the Consultative Group an effective form of development cooperation. We will continue to support the system as long as is necessary and the organization remains effective. The latter will depend on the dynamism of the individual centers of excellence.

I trust IRRI will continue to set the pace and to ask the right questions, which are the basis for setting the appropriate research objectives.

I wish you another successful 25 yr!

HE KANG
Minister of Agriculture, Animal Husbandry and Fishery, People's Republic of China

RICE PRODUCTION IN CHINA

I was honored, 5 yr ago, to attend the 20th anniversary celebration of the International Rice Research Institute. It makes me doubly happy to be back today for IRRI's 25th anniversary. Please allow me, on behalf of the Ministry of Agriculture, Animal Husbandry and Fishery of the People's Republic of China, and Chinese agroscientists, to extend our cordial congratulations to IRRI and its multinational staff.

Since its establishment in 1960, IRRI has successfully bred a series of fine strains of rice beginning with IR8, popularized numerous technical measures for better yields, and trained many scientists and technicians in rice research for various nations, thus contributing significantly to the development of rice production in many countries. Such outstanding achievements over the past 25 yr have won for IRRI high praise and awards from all sides.

IRRI has carried on fruitful cooperation and established close ties with China. Chairman of the People's Republic of China Li Xiannian and Premier of the State Council Zhao Ziyang, and Chinese Ministers and Vice-Ministers of Agriculture have been to IRRI on their visits to the Philippines, and left with deep impressions. The autumn 1979 meeting of the IRRI Board of Trustees was convened in China and all IRRI Director Generals have visited China. The cooperation and exchange of visits between the scientists of the two sides have been close and frequent. The Chinese Academy of Agricultural Sciences and IRRI have jointly sponsored several symposiums and workshops while Chinese scientists and trainees come to IRRI for cooperative research or further studies.

It is particularly important to note that IRRI actively supported and assisted in establishing the China National Rice Research Institute, for which I wish to express my deep appreciation.

As YOU all know, China is one of the countries where rice originated. Excavations of ancient sites reveal that rice has been cultivated in China for almost 7,000 yr. Moreover, rice always has been the most important food crop in China. Since the founding of the People's Republic in 1949, the Chinese Government has attached great importance to rice production and adopted a series of policies and measures to promote it. Rice accounts for about 30% of the area sown to all food crops, but about 45% of food production. By 1979 statistics, the total area sown to rice was 33.2 million hectares, or 29% more than in 1949. Total output of rice topped 178 million tonnes or 3.7 times that of 1949, and average per hectare yield reached 5.3 t or 2.8 times that of 1949.

The increase of food production from 1979 to 1984 was particularly striking. Although the sown area decreased by 8 million hectares to give more land to diversified farming, total grain production increased from about 300 million tonnes to more than 400 million tonnes and yield rose by 180 kg/ha for grain in general and by 225 kg/ha per year for rice in particular. As a result, China has become self-sufficient in food, with a little surplus, thus creating favorable conditions for the development of forestry, animal husbandry, fishery, and sideline occupations in the country and contributing to greater food security in the world.

China's experience in attaining fairly rapid development of rice production can be summed up, in a nutshell, as relying on policy and science. Specifically, we can single out the following major factors:

1. Relations of production have been reformed and adjusted. After the People's Republic was founded, land reform was carried out throughout China, putting an end to the system of feudal exploitation and boosting agrarian mutual aid and cooperation. By 1956, agricultural cooperatives were set up all over the country, spurring the all-around development of agriculture, including rice production. For a fairly long time afterward, however, the excessively large scale of the agricultural production units and unenlightened management affected the development of agricultural production adversely. Lessons learned from both positive and negative experience gained in running the rural cooperative economy over the previous 20 yr helped us begin to implement in 1979 a series of reforms centered on a system of contracted household responsibility that links remuneration to output based on the collective economy, thus greatly arousing the enthusiasm of the vast rural population by effectively overcoming such shortcomings as equalitarianism in the distribution of revenues. This has contributed greatly to sustained sharp increases in rice production over the last few years.
2. Economic policies have been implemented that are conducive to developing food production. To guarantee food supplies for the people

and to speed the economic reconstruction of the country, a policy of overall planned purchase and sale of grain was introduced throughout China in 1953. The government set uniform prices for grain purchased under the state plan, and has since raised them five times to ensure greater income for rice farmers. In 1965, the government laid down the floor quotas for the planned purchase of grain in each area, beyond which farmers could sell their surplus to the state at a higher price. Beginning in 1965, the overall planned purchase of grain was replaced by contract purchase? with farmers, who are free to sell their surplus grain in the market. When market prices for grain become lower than the state prices for planned purchase, however, the government intervenes to purchase all the grain in the market at state prices, which guarantees the normal income of the farmers and protects food production from being adversely affected by excessively low prices.

To give the farmers an incentive for rice production, the government has a low taxation policy that usually takes up only about 5% of the farmers' revenues from rice production. Within a stipulated period, taxation remains unchanged despite increases in output; furthermore, it is reduced or remitted in areas inhabited by minority nationalities and areas hit by natural calamities, as well as impoverished areas, which still make up about 10% of China's countryside.

The state also runs a national agricultural bank to serve the needs of agriculture by providing loans to farmers. The total of all rural credit in 1984 was R.M.B. 30 billion, almost three times that of 1978.

3. The state has helped farmers improve conditions for production by investing in capital construction of farmland and developing agro-industries. With annual state investments in water conservancy amounting to some 60% of total agricultural investments, large numbers of farmers are organized in the slack winter-to-spring season every year to do water conservation work. As a result of decades' work, national area under effective irrigation has been enlarged from 18.5% of the total cultivated area in 1952 to 45.5%, with practically all rice fields having irrigation facilities. The level of farm mechanization rose sharply during the same period, with total horsepower increasing from a mere 250,000 in 1952 to 265 million at present, of which almost 80 million horsepower is used in irrigation and drainage. All these play an important role in guaranteeing a steadily increasing yield for rice production.

The development of chemical industry has increased application of chemical fertilizer in rice production. The average per hectare application of chemical fertilizer for 1983 was 65.5 kg in terms of pure nutrients; the comparable figure for rice production is usually higher. Production of farm chemicals in 1980 was about 480,000 t; more than half of this was used in rice production. Moreover, agricultural capital goods and inputs are sold by the state at preferential prices, with all losses covered by the national budget. All these have led to a steadily rising labor productivity.

4. We have made vigorous efforts to reform cropping systems and raise the multiple cropping index. Because we have a low 1and:people ratio, advantages in natural resources have been fully tapped to accelerate the development of rice production by expanding the multiple cropping system. Beginning in the 1950s, the emphasis in the reform of the cropping system was on changing a single annual crop of rice to two crops. In consequence, the area under two crops of rice was expanded from the previous northernmost limit of the 28th parallel to the 32nd parallel, and the cultivation of one rice crop followed by one wheat crop in a year extended from the Yangtze Valley to the North China Plain. Whereas China's area under 2 crops a year was only 3.6 million hectares in 1949 or 14% of the total area sown to rice, it covered 12.8 million hectares in 1976 or 38.6% of the total rice area, that is 3.5 times that of 1949. In the last few years, necessary adjustments have been made in cropping patterns with a suitable increase in the area under cash crops. Though somewhat reduced, the area under 2 rice crops a year remains at 10 million hectares.

   In expanding the multiple-cropping area, much effort was made to research and popularize rice varieties that ripen at different times, and to introduce a series of technical measures for improved intensive cultivation, such as rational close planting and scientific application of fertilizer, so that rice production has a combination of "good fields, good cropping systems, good varieties, and good measures for cultivation," while receiving area-specific guidance in agricultural techniques. Thus, the steady increase of rice yields is assured.

5. Great importance has been attached to selection and popularization of fine strains. In the early 1950s, mass movements were conducted among the Chinese farmers to screen and select fine varieties of rice that can replace traditional low-yielding strains. By the end of the 1950s, the first group of short-statured, high-yielding strains such as Dwarf Nante and Guangchang Dwarf had been evolved; by the mid- and late-l960s, dwarf varieties were used throughout China's major rice-growing regions, and the average rice yield had reached 3 t/ha by 1966.

   The successful development and popularization of hybrid rice in the mid-1970s marked another important breakthrough in China's rice production. By 1973, China had achieved the combination of the "W.A." sterile indica rice line with its maintenance line and restorer line for which fine IRRI varieties were used, and popularized them over large areas by 1976. Such hybrid rice normally yields 15% more than regular rice varieties. Consequently. the area sown to hybrid rice expanded rapidly until it reached 8.1 million hectares in 1984 or more than 1/4 of the total area sown to rice. With a cumulative area of 42.6

million hectares sown to hybrid rice from 1976 to 1984, a total of 32 million tonnes more of rice is estimated to have been produced, thus contributing significantly to the sustained increase of rice production in China.

The adoption, in the last few years, of such biological techniques as tissue culture in rice breeding has greatly raised the efficiency of breeding and led to the development of high-yielding strains like Zegeng 66 and Zhonghua 8, which have been introduced in rice production on a large scale.

6. Integrated utilization of paddy fields and greater ecological efficacy is encouraged. Vigorous efforts have been made in China over the last few years to make comprehensive use of rice fields with emphasis on the integration of farming with livestock breeding or fishery. Raising fish in rice fields is a case in point. The area of rice fields where fish was raised was 566,000 ha in 1983, about 70% over 1982. Under such comprehensive use, a hectare usually produces 225-375 kg of fish and a 10% higher rice yield. Meanwhile, much headway has been made in raising ducks in rice fields, growing winter rape seeds or green manure between rice crops, or growing azolla in rice fields. Such integrated use of rice fields, plus a scientific cropping system and use of organic fertilizer, especially fermented rice stalks and green manure, has notably improved the ecological environment for the sustained increase of rice production.

Although we have reaped good harvests for several years and achieved basic self-sufficiency in grain, with a little surplus, we must increase food production steadily to raise our people’s living standards further and improve their dietary patterns. Hence the need to ensure that “full attention continues to be paid to food production while vigorous efforts are made to develop diversified operations.” In rice production, it is necessary both to increase the total output of rice and to improve its quality to meet the growing needs of our people.

To attain these objectives, it is essential to further expand agricultural education, research, and extension. Today, China has 70 agricultural universities and colleges, about 200 institutes of scientific research above the provincial level, and one extension center for practically each of her 2000 odd countries, yet we have to do more to give adequate guidance and training to our farmers so that they can steadily raise and earnestly apply their knowledge of science in farming.

As a developing country and a major rice-producer, China shares with the Asian-Pacific countries the same task of accelerating the development of rice production. The policy of opening to the outside world pursued by the Chinese Government presents broad vistas for expanded cooperative research, academic exchanges, and personnel training in exchanging genetic resources, breeding good varieties, improving cultivation techniques, and so on, between China and other rice-producing countries as well as IRRI. May the friendship grow with each passing day between the agroscientists of China and other rice-growing countries as well as those at IRRI! May IRRI and all rice-growing countries achieve still greater successes in their scientific research and in improving world food supplies!

B. SINGH
Minister of Agriculture and Rural Development
Republic of India

RICE PRODUCTION IN INDIA

I consider it a privilege to be here on this happy occasion of the 25th Anniversary celebration of the founding of the International Rice Research Institute which has done yeoman service for raising rice production in several countries around the world. When we look back to the origin of this great institution we admire the foresight and the wisdom ofthe Ford and Rockefeller Foundations who were responsible for laying the foundation of this institution in 1960 at the present site adjacent to the College of Agriculture of the University ofthe Philippines at Los Baños. The then Director of IRRI made a prophetic statement. "It is entirely possible that within the next 5 yr, a variety of rice will be available that will yield well almost any time and anywhere in the torrid zone. Such a variety would, of course, be insensitive to variations in the length of day, would have lodging resistance and a dormancy period of a few weeks, and would respond to increased soil fertility levels." These prophetic words came true earlier than expected.

In a short time after its establishment IRRI fulfilled one of its most important mandates of distributing improved plant materials to national, regional, and international research centers in the form of semidwarf, short-duration, high-yielding, fertilizer-responsive, and disease- and insect-resistant rice varieties. IR8, a variety released by IRRI in 1966, has become a household word in several rice-growing countries. This variety, because of its wide adaptability and high yield characteristics, gave the necessary momentum to increased productivity. A series of IRRI varieties were subsequently released which were cultivated not only in the country where the IRRI is located but also in several other rice-growing countries. It could be legitimately said that IRRI sparked off "rice revolutions" in several countries.

IRRI supplies not only advanced lines and varieties to different cooperating countries but also segregating material so that rice scientists in different countries can select materials most suitable for their agroclimatic conditions. The close cooperation that exists between IRRI and national programs in the world is an example that could be emulated by several other programs. Even the varieties being developed at IRRI have an international character. For example, IR36 embodies in its parentage 13 varieties from 6 countries. A number of such examples could be quoted to show the collaboration and cooperation that exists in the development of varieties and technologies of IRRI.

Our ancient holy books teach us to show reverence not only for the Almighty God, the parents, the teacher, and the warrior who never shows his back in the battlefield, but also for the person who feeds you when you are hungry. In this context agricultural scientists, whether at IRRI or elsewhere, deserve all approbation from all of us for their significant contributions to produce more rice, wheat, and other essential food commodities, thus reducing hunger in the world.

The significant contributions of IRRI for increasing food production in the world have received recognition in several countries. The first King Baudouin International Agricultural Research Award was presented to IRRI in November 1982. The citation reads,

> Over the last two decades when so much else faltered in the struggle against hunger and poverty, IRRI's quiet, persistent, highly professional and wholly dedicated work touched the lives of millions in the Third World, improving the human condition in truly practical and fasting ways. That such a contribution should have been the result of fruitful cooperation between scientists and food technology experts from developed and developing countries alike is in itself a cause of satisfaction and encouragement.

The 1982 Third World Prize awarded to IRRI in 1983 is ample testimony to the contributions of this institution. That a small research institute born at Los Baños in 1960 through the vision and financial support of the Rockefeller and Ford Foundations and the Philippine Government could be transformed into a global movement for more and better rice for the consumer and greater income and employment for the rice farmer in a span of 25 yr is an eloquent testimony to the institute's contributions.

IRRI, in addition to its work at Los Baños, has, as stated earlier, supplied valuable materials and technologies to different rice-growing countries of the world. The prestigious Genetic Evaluation and Utilization Program (GEU) is now in its 14th year. It has produced rice varieties tolerant of adverse soils, salinity, drought, cold, and submergence. It continues to be a major program involving scientists from all over the rice-growing world.

The coordinated International Rice Testing Program (IRTP) is in its 1lth year. The network strength comes from the national rice scientists who collaborate in evaluating elite germplasm varieties and advanced breeding lines. This mechanism has enabled effective exchange of material and the release of varieties developed in one country, in other countries. Other programs like the International Agro-Economic Network (IAEN), the International Cropping Systems Network (ICSN), the Agricultural Machinery Development Network (ADMN), and the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER), have in many ways contributed greatly to our knowledge in rice research and development. Encouraged with the success achieved, IRRI subsequently shifted to other types of mechanisms for long-term collaboration with national and regional programs. These collaborative arrangements of IRRI with other national institutions/organizations for training and outreach programs lent valuable support to the national programs.

One of the most significant achievements and contributions of IRRI is in germplasm collection, evaluation, cataloguing, and storage. I am told that IRRI now has a germplasm collection of 72,000 genetic stocks. The extensive cultivation of high-yielding varieties, whether of rice, wheat, or any other crop, however beneficial, has led to the gradual elimination of conventional varieties. If urgent steps are not taken, this valuable germplasm with so many desirable characters and which is the common heritage of mankind, will be lost forever. I am very happy that IRRI is making every effort to collect and preserve this germplasm from around the world. I am glad that some of the local collections of India are being extensively used in IRRI and other national programs for various desirable characters like insect resistance, drought resistance, and grain quality.

The Communication and Publications Department of IRRI has published a number of books, bulletins, and newsletters that are a valuable source of information to rice workers around the world.

Another noteworthy feature of the Institute’s varied achievements is the development of scientific manpower. I have been informed that many young scientists from different countries have been trained by this institute. The): come here as postdoctoral fellows for their training or for degree programs. Administrators, policy makers, and farmers visit this institution for information and inspiration.

It is often said that paddy and poverty go together. The work of IRRI has shown that this is not true. The scientists have shown that every part of the rice plant can be exploited beneficially. I am glad to visit a museum at this institution where information on the several uses of different parts of the rice plant, besides the grains, is presented.

The management of rice fields, insects, and diseases is very critical for raising good crops. There is considerable drudgery in rice cultivation. Scientific soil and water management and fertilizer-use efficiency hold the key for a good rice crop. It is very gratifying that IRRI has developed technologies and machinery to improve the efficiency of rice cultivation. These require wide publicity in different countries. A number of varieties resistant to or tolerant of major insects and diseases have been developed and some of these are planted on large hectarages in different countries. Measures for chemical control of pests and weeds have been formulated by IRRI which are of great help to the rice farming community. The transfer of technology is being given high priority in IRRI's production strategies. Similarly. the role of women in agriculture, an area that has been neglected or sidetracked for a long time, is being given due consideration in IRRI's program. There are several other contributions which IRRI has made and which, I am sure, other speakers are going to elucidate. I would in the next few minutes discuss some of the problems of the future to which thought may be given by those scientists assembled here.

It is estimated that the population of the world will be 8 billion by 2015 A.D. Because land is limited, the increase in food production to meet the requirements of the growing population has to come by increasing the productivity of our crops per unit time and area. The world rice production which was 234.72 million tonnes in 1960 and rose to 449.81 million tonnes in 1983, will have to be doubled to meet the food requirements of the projected population.

While good technology and high-yielding varieties are available for irrigated, well-fertilized lands, upland and lowland rainfed areas in the past have not received the required emphasis. Large areas in several countries sustain rice crops under these conditions. In my country, only 35% of the rice area is irrigated and the rest of the area is upland or lowland rainfed, with considerable scope for yield improvement. Farmers in these areas have derived only marginal benefits through the technology so far developed. Similarly, large areas are saline or alkaline. Varieties that can tolerate these conditions have to be developed on a priority basis. Deep water rice also requires special consideration since large areas face this type of situation. The deficiency of minor elements is increasingly reported in recent years. Time will come when scientists should anticipate the problems likely to emerge in the wake of modernization and intensification of agriculture. Only then will it be possible to maintain high levels of production.

Whatever we may say, a large number of rice farmers are poor. They have no capacity to apply high levels of expensive inputs. We must develop intermediate levels of technology to suit farmers. Biofertilizers like blue-green algae and azolla which gave us hope for economizing on nitrogen application have not spread in several countries as they should. Even In India where work on blue-green algae has been in progress for some decades, the technology has not spread except in some parts of Tamil Nadu. Chemical fertilizer is getting more costly, and we have to find alternate sources of nonchemical fertilizers for our crops.

Looking at the limited land and resources at the disposal of the average rice farmer, we have to give him added income through appropriate inter-cropping, multiple cropping, and integrated crop-livestock, poultry, and fish culture. We have to identify appropriate intercropping and multiple cropping systems on urgent basis. In this area I urge greater international cooperation to share ideas, expertise, and materials.

The constant emergence of new races of insect pests and pathogens that attack the rice crop is a continuing phenomenon making our high-yielding varieties susceptible. Although our scientists are developing resistant and tolerant varieties, much more is to be done to bring in stable and durable resistance.

In terms of quality, rice means different things to different people. In several countries, high-quality rice varieties suitable for different tastes are available but these qualities are not incorporated to the desirable extent in the high-yielding varieties which are widely grown. Although our scientists have increased the production capacity of our new rice varieties, the time has come when they have to consider quality as well. Other areas, such as improving the oil content and its recovery from rice bran, and breeding varieties tolerant of cold and drought, should also receive special attention.

The emerging fields like genetic engineering, cell culture, protoplast fusion, tissue culture, anther culture, biological nitrogen fixation, use of wide crosses, embryo rescue technique, etc., are becoming powerful tools in the hands of the plant scientists. While we are reaching a plateau for further increases in yields of modern rice varieties, I am sure the new tools of‘ biotechnology will help us overcome some of the present limitations in breaking the yield barriers.

I am very happy that IRRI has taken initiative to develop different cropping systems to increase the farmer’s profit. Considerable work on this aspect has been done in India. For example, in several parts of India where good irrigation is available, farmers raise 2 or 3 crops which collectively give more than 10 t of food grain/ha per year. Scientists have to devote their attention to developing suitable early-maturing varieties to fit into this type of multiple cropping system.

Looking at the achievements of my country, which is first in the world in hectarage and second in rice production, the technology and the administrative measures and farmers’ enthusiasm have greatly helped increase total production and productivity per unit area in the last three decades. We harvested 20.6 million tonnes in 1950 and about 60 million tonnes of rice last year. As is natural for a large country like India with its diverse agroclimatic regions, disparities in productivity between different areas still persist. Although average rough rice yield is as high as 4.6 t/ha in a progressive state, like Punjab in northwestern India, productivity is between 1.5 and 1.8 t in the eastern region. These regional disparities in rice cultivation point to the vast untapped production potential that can be exploited with the available technology. A massive program to tackle constraints to better productivity has been launched recently on an area approach basis. Based on area-wise constraints analysis, strategies for removing the bottlenecks have been tailored into a program for increasing production and productivity of rice in six eastern states of India. This program puts special emphasis on the removal of socioeconomic and infrastructural constraints by development programs, such as exploitation of groundwater, irrigation, water use efficiency, drainage, land development, land reclamation, tackling of land tenurial problems, consolidation of holdings, storage, postharvest handling, marketing, and easily approachable input outlets, etc., to make a tangible, permanent impact on rice production and productivity in the low-productivity eastern region of the country.

It has been the consistent policy of our government to provide incentives to farmers for adopting improved technology and thereby increasing production and crop productivity. While fixing support/procurement price, it is ensured that it covers production cost and that it provides a reasonable margin of profit. The procurement/support prices have been raised substantially in the recent period to make them more remunerative to the farmers. Since 1979-80 the procurement/support price of paddy has been increased 44%.

It is estimated by our National Commission on Agriculture that we will require about 80 million tonnes of rice by the turn of the century. I am confident that with the available resources of the country and technical manpower, it should not be difficult to achieve this target. I am sure IRRI will continue to give full support to strengthen the rice economy of India through their materials, technologies, and cooperation with Indian scientists. I am extremely pleased to note that IRRI organized, in collaboration with the Indian Council of Agricultural Research, an international conference on lowland and upland rice at Bhubaneswar in 1984. This type of sharing of knowledge and experience between IRRI and other countries is a source of great strength and satisfaction to all of us.

IRRI is young and dynamic and during the short span of its existence of 25 yr, it made significant contributions in alleviating poverty in several countries. Its influence is widely felt directly and indirectly. I have every confidence that with all the expertise and facilities IRRI has, not only will it play a significant role in helping the rice-growing countries of the world, it also will play a catalytic role in influencing the production of other crops which are needed by man and his domesticated animals. It also has an additional responsibility of developing, through close interaction, the national programs of the different countries. In a number of countries, national institutes and programs with a national mandate have been organized. Institutions like IRRI have a global mandate. Toward the realization of national mandate by the national programs and the international mandate by IRRI, there should be greater and more effective collaboration between the two sets of organizations. I am sure the present cordial and collaborative relationship that exists between IRRI and national programs will be further strengthened in the years to come. I congratulate the IRRI scientists for their glorious contributions, I thank the director general of IRRI, and the Government of the Philippines for the privilege of attending the silver jubilee celebration of this famous institute. I wish the institute and its scientists success in the years to come.

G. JAYASURIYA
Minister of Agricultural Development and Research
and Minister of food and Cooperatives,
Democratic Socialist Republic of Sri Lanka

RICE PRODUCTION IN SRI LANKA

On this happy occasion of its 25th anniversary, I congratulate the International Rice Research Institute and offer the warmest greetings of the Government and the rice farmers of Sri Lanka.

Your endeavors, spanning a quarter century of continued research, geared to the development of methodologies for increasing rice production and leading to the improvement of the quality of life of rice farmers throughout the world, have enriched the economies of Third World nations, particularly those of the less affluent of our region. You have thus brought about a revolution in rice production, which is an important milestone in human progress in our time, just as the Industrial Revolution was more than a century ago, and the Electronic Revolution in more recent times.

We have benefited from your success. We can also take pride in the contribution made by our own researchers toward that accomplishment. Many other countries of the region share that feeling, for they, too, have contributed and benefited through that fruitful partnership for the co-prosperity of the region.

It made me very happy to receive a cordial invitation to attend this symposium from IRRI Director General, Dr. Swaminathan, and I thank him for the opportunity to deliver this lecture. I feel it is also a tribute to my country's success in rice research and production. For another reason, a purely personal one, your 25th anniversary inspires very intimate reflections, replete with pleasant memories for me, because it coincides with my 25th anniversary as a parliamentarian — a turn in my career from commerce to public affairs, which resulted in my involvement in rice research and production.

I recall how, in 1960, I was literally thrown among rice farmers as a young newly elected member of Parliament, representing an agricultural district. I must confess that I knew very little about agriculture at the time. However, I became fully involved in it and, later, as Minister of Health, concerned with nutrition problems, rice figured prominently in my work. Now, as Minister of Agricultural Development and Research and Minister of Food and Coopera-tives, rice is a major part of my responsibilities, encompassing research and production as well as distribution and marketing to satisfy consumer pre-ferences at affordable prices.

I am, therefore, inclined to look at rice farming not merely as a livelihood of the people. To us, in Sri Lanka, it is much more: it is a way of life. We treasure its human dimension. It is a mirror of people's endeavor and achievement, and reflects aesthetic beauty and environmental harmony that is not matched by any other major food crop. Much of our population comprises small farmers and their contribution is the base of our ancient civilization and the spring from which has flowed many traditions and practices, folk theatre, and songs. Some of these songs, sung by the farmer while keeping vigil in his watch-hut, help to keep him awake at night and drive away destructive wild animals from his field. His stentorian night song resounding through the fields and valleys also brings enchantment to the countryside where such simple joys give contentment and tranquility to our rural farming community.

Because rice is grown mostly in the developing countries as a staple food, providing a significant source of calories and proteins to the majority, investment in basic rice-related research is ofparamount importance to those of us living in these countries. However, due to limitations ofresources and other preoccupations of national research systems, and the limited investment in this area of research within developed countries, it has become the responsibility of IRRI to perform this pivotal role. We note with satisfaction that it has done creditably in the past and we are confident that it will meet the increasing demands that will be made on it in the future.

Sri Lanka was self-sufficient in her food requirements during its historic past. With the advent ofcolonial rule, however, the island had to import most of her food requirements, including rice. The increasing commitment of the government, since independence, to stepping-up food production through a comprehensive package of policies and incentives, has brought us to the threshold of self-sufficiency in rice. A major thrust of this effort has been the renovation of ancient irrigation schemes and the construction of new water systems for irrigation, and research emphasis directed toward increasing rice production.

Today, of 0.7 million hectares of rice fields, about two-thirds are irrigable, and 0.14 million hectares will be irrigated under the Mahaweli River Diversion Scheme over the next 5 yr. Rice production has increased steadily from 0.91 million tonnes in 1960 to 1.7 million tonnes in 1977. to 2.5 million tonnes in

1983. Significantly, recent increases in production have been due in greater measure to an increase in yields per unit of land rather than the extent cultivated.

This increase in yield per hectare was triggered primarily by new high-yielding varieties developed by Sri Lanka scientists. We recognize that IRRI has played a significant role in our breeding programs, both in identifying the plant habit associated with high productivity as well as in providing genetic material for transferring this plant type to local strains. I must also make reference to the very fruitful exchange of ideas and experience that has been made possible by the numerous training programs, seminars, and workshops organized by IRRI.

We consider it essential that our research workers receive postgraduate research training and that extension workers be knowledgeable in both extension education and technical subject matter. The recently established Sri Lanka Post-Graduate Training Institute has its limitations, and more than a third of our research workers are yet to be trained. I hope that IRRI which, I understand, has a very large training program, will take note of this deficiency.

Manipulation of genetic resources has resulted in the evolution of varieties with a yield potential, averaging 10 t/ha. These new varieties have been further strengthened by the incorporation of resistance to some of the common insects and diseases. Farmers have greatly benefited from these new strains by adopting suitable cultural practices, such as the judicious use of inorganic fertilizer, the application of chemicals for eliminating weed competition, and the effective use of agrochemicals for insect and disease control.

These new varieties and the technology for exploiting their yield potential under field conditions have been available for some time. It is only in the last 6 or 7 yr, however, that their capabilities have had a significant effect on rice production at the national level. This could be attributed to steps taken in the recent past to manage other factors of production, such as inputs, incentives, floor prices, and so on, so as to provide a climate conducive to increasing production.

In introducing these measures, we have tried to look at the whole production process, and to set in place a package of practices that ensures the farmer easy access to the requisites for production, as well as a reasonable return on his investment. The extension service has been reorganized, and quality seed of the new varieties is made available to the farmer in time at a reasonable price. Inputs, such as farm machinery, fertilizer, and agrochemicals, have been made readily available. The government offers a guaranteed price for rice, and effective machinery has been set up for purchasing rice in farming areas. The guaranteed price itself operates as a floor price, and is reviewed and revised regularly.

There is, of course, another side to the picture. Rice production in Sri Lanka, as in the rest of this region, is and will, in the foreseeable future, remain in the hands of thousands of small farmers. The small farmer is understandably sensitive to costs and risk. Our experience has been that production gains from new varieties were being reaped mainly in areas with a stable environment, where the element of risk is low, whereas production increases in areas with less favorable conditions and high risks have been modest.

Sri Lanka has a vast network of ancient, large, irrigation reservoirs. In addition, there are thousands of small village tanks, where rainwater is stored for rice cultivation during the dry season. Most of these small village tanks were inoperative due to breaches in bunds and silting of the tank-beds. The government's vigorous program to desilt and restore these small tanks, and the appointment of committees of local farmers who will be responsible for their maintenance and water management, have been a success, and contributed much to increased production in recent years.

By appreciating that research needs to be more in harmony with the small farmer and his situation, steps have been taken to restructure the research organization and the extension service.

At the same time, an adaptive research program, designed to help research to better understand farmer problems and to develop closer links with the extension service, has been established. Preseasonal meetings and regular meetings during the season have also been organized to strengthen close and continuing links between research and extension. Also the extension service has been restructured on the lines of the well-known and widely accepted training and visit system.

These structural and operational changes have been instituted in the light of past experience and after considerable study. They are, we feel, a positive step toward promoting better understanding between the farmer and the research worker and extension agent.

We have also been conscious of the need for scaling down costs of production and reducing risk. To this end, our plant breeders have succeeded in combining short-duration and high-yield potential in the same variety; progress is being made in incorporating resistance to common insects and diseases into the existing strains of rice. It has also been found that using straw as organic manure reduces the need for applying potash and nitrogen fertilizer.

I would also like to refer to two other related matters. One is the increasing demand for better quality rice as personal income rises. Our rice breeders are attempting to incorporate quality attributes into high-yielding varieties to meet such demands. The other matter is the utilization of rice by-products in agroindustries to improve farmer income.

And what of the future? With the approach of self-sufficiency in rice, we are now paying increased attention to other food commodities, such as high-protein vegetables, pulses, and milk, to ensure better nutritional standards.

Yet another serious issue we must consider in Sri Lanka is the critical land:man ratio. This highlights the need for optimizing use of available arable land.

We also have to take cognizance of the changing attitudes and aspirations of the new generations of farmers who are better educated and are inclined to seek less arduous ways of farming. I am glad that IRRI is actively concerned about this aspect of production, and we, in Sri Lanka, are presently testing a hand-operated transplanter, mobile thresher, and reaper designed by IRRI. At the same time, we must continue to examine ways and means of introducing further simple types of mechanization that will increase labor productivity and reduce production costs.

To make farming attractive, it is also essential to cover risks to crops, and we are operating an Agricultural Insurance Scheme for this purpose. A Pension Scheme for farmers, which I recently proposed, to provide social security to the farmers in illness and old age is now under active consideration.

The future objectives of the research effort must be directed toward increasing and stabilizing the productivity of arable land. The new high-yielding rice varieties, which contributed to increased production, have their limitations. It is possible to exploit their high-yield potential on about 70% of our ricelands that have assured water supplies and environments that favor plant growth. Unfavorable conditions preclude their successful cultivation on the remaining 30% of the rice fields.

Further gains in production on 70% of the land, where conditions for crop growth are favorable, depend first, on stepping up crop yields, and second, on increasing cropping intensity. There seem to be two methods of increasing yields. I understand that the gap between farmers' yields and those reaped in experimental plots with the new varieties, is wider than it should be. The difference is attributed to physical, biological, and socioeconomic constraints. Technologists that will help bridge this gap will provide a ready means of increasing production rapidly and possibly at little extra cost. The other approach to increasing yields is that of developing varieties capable of yielding more than the present strains. I am told that some basic research is necessary before we can achieve this objective. In that event, it is perhaps not too early to begin, and perhaps, we must look to IRRI to provide the leadership in this endeavor.

The other prospect of stepping up production on these lands is that of increasing cropping intensity. Agricultural production is, in effect, a harnessing of solar energy. Since we get abundant sunshine throughout the year, it is logical that we work to exploit it better. This can be done by developing technology for cultivating as many crops as possible during the year. Some measures that come to mind are the introduction of better water management practices and manipulation of planting time, crop duration, and so on. I would also like to mention that our scientists are perturbed by indications of a possible decline in yield, due to continuous cultivation of new varieties on the same land. There seems to be a need to emphasize soil and plant health in the future.

Yields have remained modest on the remaining 30% of the lands I referred to earlier. Occasional flash floods and short spells of dry weather that affect the crop adversely, ill-drained conditions, iron toxicity, salinity, and alkalinity are some impediments to higher yields on these lands. In the long term, it appears desirable to examine the feasibility and cost of adopting physical measures to ameliorate these conditions, wherever possible. Improving productivity in these areas, in the shorter term, involves the development of suitable varieties and cultural practices that are adapted to each specific problem area.

It is then clear that there is a potential for stepping-up rice production. A potential that must be tapped, bearing in mind that gains in production must be accompanied by increasing farm, income, if the new technology is to be acceptable to the farmer. It is perhaps a challenge to our research workers, in this age of the satellite, biotechnology, and other advances. It is a challenge to IRRI and the national research systems in the region, individually and collectively. I am sure that, given the necessary support, research will measure up to the task. IRRI has played a leading role, and made an invaluable contribution to increasing rice production in the past, thanks to the generous support it has received from donor agencies and the Government of the Republic of the Philippines. We are most grateful to them for their support. I have no doubt that IRRI will continue to get all the support it needs for fulfilling the more complex demands in the future.

I hope this session will give serious consideration to these vital problems, and contribute to further the success accomplished by IRRI. I am confident that in the coming years, your efforts will also strengthen the organizational efforts leading to further major breakthroughs to eradicate hunger and banish the specter of famine and food insecurity from the earth.

A. A. ZALI
Minister of Agriculture, Islamic Republic of Iran

RICE PRODUCTION IN IRAN

It is a great pleasure for me to participate as the representative of the Islamic Republic of Iran in the 25th anniversary of the establishment of IRRI and I avail myself of this opportunity to cordially congratulate Dr. Swaminathan and all scientists, researchers, and employees of IRRI for their 25 yr of successful efforts.

Despite all the successful efforts of IRRI, I should mention that we are celebrating this anniversary at a time when food shortages still prevail in many parts of the world and millions of people suffer from chronic malnutrition and famine.

There was much hope that with advances made in science and research, the problem of providing food would be resolved before the end of this century and humanity would rid itself of the anxiety of food shortage forever. Unfortunately, in some countries of the world, these hopes have been frustrated and the problem of food shortage has grown to look more threatening than before.

Why didn’t our expectations come true? The basic prerequisite, that is, scientific and technological progress, has been made. The yield per hectare and yield per hectare per year by multiple cropping have been increased, and new marginal lands have been brought under cultivation. Man’s crop production potential has been increased to an unprecedented scale, so much so that some countries have taken measures to curtail production. We are all aware of the crisis of overproduction in some countries where huge subsidies are being made to encourage farmers to curtail food production. In some other countries ofthe world, however, increases in food production are not keeping pace with food demand and population growth. In some of them, per capita crop production declines each year. Food shortages in these countries is becoming more acute and the specter of malnutrition looms over the heads of their people.

As can be seen, scientific and technological progress in food production did not resolve the problem of food shortage in some Third World countries. In fact, their low level of food production is related to their low level of development. This underdevelopment is basically the aftermath of many years of exploitation and plunder of their resources.

In our opinion, unjust domination and exploitation, which are today continuing under new guises, are the main impediments to development in some parts of the world. As long as this situation is not altered, these countries will be unable to use all their potential and resources to rid themselves of the abyss of poverty and malnutrition. This belief is the result of our bitter experience during the long period of foreign domination over Iran. During this cruel domination, our country was deprived of its natural resources. Huge resources were plundered and our economy was turned into a dependent, petroleum-exporting economy. Our agriculture, which once met our demands, was ruined. Special policies and lack of infrastructural investments hindered the development of our agriculture.

As a result, our country became a major importer of agricultural products during the last years of Shah’s rule and our food dependency on foreign suppliers increased, when, given our vast resources and potential, our country was capable of not only meeting our demands but also of exporting some agricultural products.

After the Islamic Revolution and achievement of our independence, rapid reconstruction of the agricultural sector was recognized as one of the main objectives of the economic development of the country. Reaching self-sufficiency in agriculture became a high-priority task.

Attaining self-sufficiency in our agriculture relies on various concrete facts. Iran has an area of 1,648,000 m^2. Of this, 51 million hectares are arable, with only one-third currently exploited. Of more than 100 billion m^3 water usable in agriculture, only about one-half is being utilized, and that with very low efficiency. As an example, in the southwestern province of Khoozistan, we have about more than 1 million hectares of arable land, of which only 10% is being cultivated. Khoozistan has one-third ofthe surface water resources of the country but only a low percentage is being utilized. In southern Iran, there are vast virgin lands and adequate water which, thanks to favorable climatic conditions, may be brought under cultivation. In northern Iran, in the Caspian Sea areas, where climatic conditions are favorable and where there is ample precipitation, there is a great potential for agricultural development.

Our country has about 12 million hectares of forests, of which 1.4 million are commercial. Pastures and rangelands total about 90 million hectares.

We have the vast fishery resources of the Caspian Sea, Persian Gulf, and Sea of Oman. The fishery resources of the southern waters are estimated at 4 million tonnes/yr.

At the same time, the diversity of climatic conditions in our country is such that the difference between the maximum and minimum temperatures sometimes reaches 40 degrees. In some parts of the country, temperature is 15-20 degrees below zero while in southern areas, the temperature is 20 degrees above zero. This diversity of climatic conditions allows the cultivation of various crops.

Although many high-yielding varieties have been released, the yield per hectare of many of our agricultural crops is still low, which indicates our agriculture's high potential for growth. We also have huge petroleum and mineral resources which can be good incentives for our economic plans and on which our agriculture and industry can rely.

Thus, by exploiting these resources and with plans prepared since the Islamic Revolution, we hope to soon attain one of the main objectives of the Revolution — self-sufficiency in agricultural products.

Because research is the backbone of development, special attention has been paid to agricultural research. Our research institutes have played an effective role in advancing our agriculture by releasing new varieties of wheat, rice, cotton, and other major crops. I would like to elaborate on rice production.

The area under rice cultivation is about 460,000 ha with an average yield of 2.26 t/ha, annually producing more than one million tonnes of rice. Per capita consumption of rice was about 30 kg in addition to 150 kg of wheat. Considering the population of about 40 million after the revolution, it seemed possible to reach self-sufficiency in rice. Therefore, programs were planned to make use of new high-yielding varieties such as Amol2 and Amol3 which were selections of IR28 and Sona. The areas under cultivation of these varieties have increased rapidly and in 3 yr, they covered about one-third of the rice fields, producing an average yield of 4.03 and 4.4 t/ha. The increment was so rapid that we had to consider the problem of genetic vulnerability especially to diseases such as sheath blight which was new to the region, and we had to take steps to slow the growth rate. However, some factors hindered our goal of self-sufficiency:

- Increase in per capita consumption from 30 kg before the revolution to about 40 kg in recent years. This was due to government policies to feed the nation equally. Therefore, rice was provided to many villages which had little chance of consuming rice previously;
- Poor eating quality of new varieties produced some resistance in market. Although we guaranteed a reasonable price and purchased the total production of new varieties, we worked toward better quality and these efforts resulted in development of still newer varieties which are being multiplied and will replace Amol 2 and Amol 3 in coming years; and
- The per capita income of the nation was raised after the revolution

mainly due to increase of income in rural areas. This caused more labor costs and therefore, the cost price of locally produced crops went up. To overcome this hindrance, we have plans to expand the size of the fields to make them suitable for mechanization.

In addition to our national development measures, we took advantage of the advances in agricultural research in recent years and expanded our cooperation with different international research centers. I should acknowledge that this cooperation has been very useful for us and a special place should be given to IRRI here.

Although our cooperation with IRRI began in 1976 we have had indirect cooperation by exchange of genetic materials earlier. I am pleased to state that this exchange of materials has been effective in our breeding projects. Some of the materials obtained were used in selection experiments and other materials were used in hybridization programs to transfer desirable genetic traits such as disease and insect resistance and desirable plant type. In addition, several Iranian experts have participated in training courses at IRRI and after their return have continued rice research programs. Many other Iranian experts are at present in this center taking different training courses.

Because of our great interest in promoting cooperation with IRRI, last year a Memorandum of Agreement was signed for mutual collaboration between the Agricultural Research Institute of Iran and IRRI. I am glad to state that the Government of the Islamic Republic of Iran is willing to expand its scientific relations with IRRI and we are ready to support IRRI in expanding its research and training programs.

Once more, I would like to congratulate IRRI on its 25th anniversary, its distinguished founders, Dr. Swaminathan, and all his colleagues for their continuing efforts and success, which are of great importance to rice producers all over the world. I wish IRRI the best of success in all its future efforts.

S. KAWAHARA
Parliamentary Vice-Minister for Agriculture, Forestry, and Fisheries, Japan

RICE PRODUCTION IN JAPAN

On behalf of the Government of Japan, I would like to emphasize how much I appreciate having been given the honor to participate in the ceremony marking the 25th anniversary of the foundation of the International Rice Research Institute (IRRI).

I would like first of all to pay my deep respect to President Marcos, to the Government and people of the Republic of the Philippines, and to those connected with IRRI, who are presently hosting the 25th Anniversary Symposium.

I wish also to pay my respect to the Honorable G.M. Braks, Minister of Agriculture of the Netherlands, who is chairing this session of the symposium.

Each country of the world must make special efforts if the worldwide problems of food and agriculture are to be solved. In this regard, IRRI's contribution has been outstanding. Indeed, remarkable achievements have been realized with the development of high-yielding rice varieties such as IR36. These undertakings have been made possible through the persistent efforts of all the members of IRRI under the enlightened leadership of the directors of the institute, including Dr. M.S. Swaminathan. I would like to express my deep admiration for the great contribution that IRRI and the Asian region have made in solving some of the problems of food and agriculture throughout the world.

I would like to take this opportunity as the representative of Japan to express my deep feeling of loss over the death of the former Minister of

Agriculture and Food, the Honorable Arturo R. Tanco, last April. Minister Tanco unsparingly promoted the development of agriculture not only in the Republic of the Philippines, but also in the rest of Asia and the world, and the contribution he made to the establishment and expansion of the activities of IRRI was indeed invaluable.

Japan has a small surface area for a comparatively large population and farming, as in many other regions of Asia, is on a small scale. However, through concerted efforts the development of agricultural production has been successful in fields such as animal husbandry, fruit growing, vegetable cultivation, and rice farming.

The development of agriculture in Japan has undoubtedly been made possible by the efforts of the Japanese farmers. However, much of it has stemmed from the government policy including the establishment of land ownership through land reform, a stable price system, and the improvement and dissemination of technology. Furthermore, the activities of agricultural cooperatives have played a major role in the modernization of agriculture.

I believe that the experience of Japan in the development of agriculture can be useful to the countries of Asia that have similar agricultural environments, and will help them in solving problems of food and agriculture in future.

Japan's agriculture can be aptly referred to as a history of rice production. And it can be said that the improvement and dissemination of the techniques of rice production have been reflected throughout time in the development of agriculture in Japan and in the development of the Japanese economy.

As a result, for the past years, rice production in Japan has been extremely stable and the present yield of about 5.8 t/ha (rough rice) is 3 times that of a century ago.

The main factors that have contributed to the development of rice production in Japan are

1. the establishment of field infrastructure, including irrigation, drainage, and land improvement;
2. the development of short-, early-maturing, and high-yielding varieties through the improvement of plant types;
3. the establishment of sound methods of fertilization and intermittent pest control; and
4. increase in labor productivity through mechanization.

Agricultural technology, like any field of natural science, stems from the integration of research results obtained in a wide range of disciplines including social science. Research advances in a particular field resulting from the development of new methods and products have always generated new techniques which have been applied to other fields, hence the continuous increase in new research requirements.

Therefore, to foster the development of agricultural technology, it will be necessary in the future to further promote research in agricultural fields, to develop a deeper and broader understanding of research development in other branches of science and technology, and to make the best use of the results obtained in these areas of research.

For 40 yr, the development and improvement of various materials, machines, and items of equipment associated with technical advances in chemicals, mechanical engineering, etc., have contributed to the expansion of agricultural technology. As a result, agricultural production has been enhanced and distribution of the products has been streamlined.

In addition, recent progress in basic and advanced research involving life sciences, electronics, new materials, energy-related technology, and ocean and space development has indeed been remarkable. It is anticipated that in the course of the technological revolution geared toward the 21st century, the development of research in the life sciences, including the improvement of functions of living organisms, the development and exploitation of biological resources, and the analysis of ecosystems, will play a significant role in future.

In agriculture, it is essential that all relevant areas of research, including advanced and basic research, be integrated and systematized. Therefore, in Japan, for the effective application of advances in science and technology to agriculture, the program and orientation of research are carefully designed. In rice production, emphasis is placed on the following aspects:

1. development of technology to achieve a consistently high level of production;
2. development of technology to control the production environment;
3. development of farming technology to achieve high productivity; and
4. establishment of methods for profitable land use.

Japan is fully aware of the leading role played by agriculture and rural communities in stabilizing economic and social development in developing countries. Therefore, the funds allocated to the programs relating to the promotion of agriculture, forestry, and fisheries account for one-third of the total budget for technological cooperation to effectively promote the development of agriculture and rural communities.

Japan has continuously supported IRRI's activities since the institute was established by granting funds and sending researchers engaged in collaborative projects with their IRRI counterparts. Moreover, since 1984, the Government of Japan represented by the Ministry of Agriculture, Forestry, and Fisheries has set up a special project in *Development of low-input rice cultivation technology under irrigated conditions* to be carried out jointly with IRRI researchers.

The basic concept of Japan's economic and technological cooperation is to promote experimental research so as to design a technology aimed at the integrated development of the rural communities and agriculture, the enhancement of productivity at the small farm holding, and the increase of food output, along the lines of the development plans of the respective countries and the research programs implemented by the international agricultural research organizations.

I would like to conclude my presentation by voicing my deep concern about the serious food shortage afflicting the populations of Africa. I am fully convinced that world food problems should be approached at the international level. In this regard, I would like to emphasize the importance of the research activities carried out at IRRI.

I do hope that the symposium will be successful.

B. TANTHIEN
Deputy Minister of Agriculture and Cooperatives, Thailand

RICE PRODUCTION IN THAILAND

On behalf of the Ministry of Agriculture and Cooperatives and the Royal Thai Government, I would like to express my sincere congratulations to IRRI on its 25th anniversary. I also wish to extend our thanks to the Institute for the warm welcome we have received and for the opportunity to join the other delegates and participants in the exchange of ideas and experiences during the celebration.

IRRI is one of the family of international research institutes that have cooperated with our national research organizations to improve the productivity of major tropical food crops. IRRI, in particular, has been very important to us, especially in its association with the Thai Rice Research Institute, because it deals with the scientific advancement of rice culture and the training of a human resource base for adaptive research and technology transfer.

We realize that the availability of well-trained and highly motivated research and extension personnel is crucial to obtaining a sustained increase in rice production in our countries. Rice is life itself to almost one-third of the world’s 4.5 billion people, and is a secondary staple for another 450 million people. Increasing population and consumer demand places more and more burden upon the world’s small-scale rice farmers. Rice production will increase only through the availability of research results that can be used to increase land productivity and production efficiency. IRRI’s role in this and related tasks will be even more important in the future than it was in the past.

We are fortunate in having sufficient arable land to allow us to produce a surplus of rice. In 1984 we exported a record 4.6 million tonnes — enough to feed 30 million people. However, this figure of 30 million people is less than the population increase of Southeast Asia from 1980 to 1985.

Southeast Asia currently produces about 20% of the world's rice. In 1960-80 both area and yield per hectare increased, and total rice production doubled. However, per capita production remained unchanged. This presents many challenges.

Thailand has nearly 7% of the world's rice area, but its average yield of about 1.9 t/ha is comparatively low and has remained static for many years. Only about one quarter of the rice area is irrigated, and consequently adoption of modern varieties has been very slow. This is partly due to our requirement for specific grain quality, but it also reflects the harsh environment of many of our rainfed rice areas. For example, in 1982-83, our northeastern region, which is 95% rainfed and represents 47% of the country's rice area, had average yields of only 1.2 t/ha.

Total grain yield production of Thailand, however, increased from 14,899 t (8363 ha planted area) in 1974 to 17,774 t (9595 ha planted area) in 1982 due not only to increased planted area but also to improved technologies.

Improved varieties

Varietal improvement is a major field of rice research in Thailand. Previously, cultivars were developed through pure line selection from native varieties and tall traditional types were recommended according to their grain qualities and adaptability to rainfed conditions. In 1969, semidwarf types derived by hybridization were first released as RD1, RD2, and RD3. They are short, photoperiod insensitive, and specially adapted for dry season growth in irrigated areas. Some later varieties designed for rainfed and deep water areas were tall and photoperiod sensitive. These included RD6, RD8, RD15, RD17, RD19, and RD27, RD6 and RD 15 are tall rice derived by induced mutation of Khao Dawk Mali 105. The potential yield of semidwarf types under NPK fertilization is about 3.2-4.4 t/ha at 74-37-37 kg/ha in dry season. For the tall traditional types, potential yield is 2.5-3.4 t/ha at 38-37-37 kg/ha in wet season. In dry season, farmers usually grow near 100% of recommended semidwarf varieties but only about 60% of recommended varieties (semidwarf and tall varieties) in wet season. The future breeding program will emphasize grain quality, low-input varieties, disease and insect resistance, and tolerance to environmental stresses.

Irrigation

Irrigation is one of the most important factors in Thailand because 90% of the paddy area still is rainfed. As a result drought and floods are a problem in northeast Thailand. The Thai Government, therefore, must develop a good irrigation system for rice farmers. Statistics show that in dry season only 330,880 ha of paddy area were supported by irrigation in 1974 whereas

716,960 ha were supported with irrigation water. Irrigation can minimize the risk of plantation investment and increase production to an expected level provided that all other requirements are met. So far, Thailand is able to produce 3.4 t grain/ha in dry season.

Pest management

Damage from diseases and insects widely occurs in rice areas of Thailand. The level of severity, however, depends on both area conditions and planted varieties. Major diseases and insects are blast, sheath rot, sheath blight, ragged stunt virus, brown planthopper, gall midge, and stem borer. Chemical control of diseases and insects is essential for farmers but it causes pollution. The best way to control diseases and insects at present is integrated control such as use of minimal chemicals and resistant varieties.

Integrated Rice Pest Control (IRPC), using resistant varieties, biological, mechanical, and chemical controls, is one of the pilot projects in Thailand. The objectives of the project are to reduce pesticide cost; preserve the natural enemies of rice pests; cooperate and exchange technology and expertise of IRPC concept among the extension officers and researchers; and transfer the IRPC technology to farmers. During 1982-85, the IRPC project was operated at Amphoe Lum Lookka, Pathumthani Province, where the rice plants were heavily damaged in 1981 by brown planthopper, leaffolder, stem borer, armyworm, ragged stunt virus, blast, sheath blight, and rodents. The project covered 80 ha owned by 24 farmer households. With IRPC, grain yield profitably increased in the project area. Consequently, the IRPC project will be operated during 1985-87 at Amphoe Lad Lum Kaew, Pathumthani Province, on 76 ha of 17 farmer householders. The expansion of the project to other regions of Thailand is expected.

Soil and fertilizer

Chemical fertilizer and manure application is another essential factor for increasing grain yield per unit area. It is evident that there has been an increase in fertilizer use. However, there are risks of fertilizer application, especially in rainfed areas. Therefore, the technology of fertilizer application must be considered along with area conditions and socioeconomic situations. The future program of fertilizer application technology is as follows:

1. Crop production improvement by application of-chemical fertilizer and manures, and soil and water management based on the analyses of soil and water in the areas;
2. Soil improvement by reclamation of paddy land with problem soils and utilization of appropriate technology based on specific economic conditions;
3. Technology development by the Soil Science Information Center for development and technology transfer, research and development of technology for production and utilization of chemical fertilizer and organic matter, research and synthesis of natural products to be used

for soil improvement, and research and development of technology for production of soil microorganisms and azolla. The present recommendation for NPK application is 34.4-21.9-15.6 kg/ha in rainfed areas and 68.8-43.8-15.6 kg/ha in irrigated areas. In the future, this recommendation may be slightly increased in rainfed areas.

Rice-based cropping systems

Although several recommended varieties have been released to farmers, and fertilizers and chemicals have been applied, grain yield per unit area remains low. Planting method is another important factor for increasing yield. Also, because Thailand has large areas of riceland where other crops may be grown, multiple cropping systems may increase efficient use of riceland.

Rice-based cropping systems research and development has been successfully implemented in Thailand for 5 yr, particularly in the rainfed areas. In the Department of Agriculture, the Farming Systems Research Institute (FSRI) has responsibility in this field. FSRI is now undertaking wide-scale development activities with the cooperation of the Agricultural Extension Department, the Bank for Agriculture and Agricultural Cooperatives, private companies, and the farmers in Phayao and Lampang Provinces. The cropping pattern is mungbean - rice under rainfed monsoon rains. Another pattern, groundnut - rice, at Bua Yai district of Nokhonratchasima Province also has been successful. This can be adopted by the farmers in the area after having been tested for 4 yr. The policy of the Department is to provide the rural poor, who usually earn their living only from subsistent rice, extra income. Multiple cropping will bring farmers more flexibility and provide them more sources of income.

Mechanization and postharvest technology

The use of agricultural machinery inThailand has progressed rapidly in the last decade. Previously, the farm power sources were human and animal and were utilized in every step of crop production — land preparation, planting, crop maintenance, and harvesting. The Ministry of Agriculture and Cooperatives has seen the importance of mechanization and, therefore, has developed a mechanization policy to introduce appropriate machines to reduce production costs. Another objective is to accelerate the local manufacture of farm machines. From the continuous operation, many types of agricultural machines have been extensively used, for example, two-wheel tractor and small four-wheel tractors, and axial-flow water pumps. These machines are being produced by local manufacturers in all parts of Thailand.

The Ministry of Agriculture and Cooperatives also cooperated with IRRI in the mechanization program for developing farm machines and introducing mechanization. The IRRI-designed rice thresher has been brought to Thailand for testing, developing, and introducing to farmers. The rice thresher reduces cost, drudgery, and threshing time. Twenty-seven manufacturers now produce the thresher. About 3,500 units are produced per year, valued at approximately 175 million baht.

In the last 2-3 yr, a planter, called an inclined plate planter, also designed by IRRI, has been tested and adapted in Thailand. It is attached to a two-wheel tractor for planting rice, soybean, mungbean, maize, sorghum, and wheat. Three manufacturers produce the inclined plate planter and distribute it to farmers directly and through the Bank of Agriculture and Agricultural Cooperatives where farmers acquire loans. The extension program for the inclined plate planter has progressed quickly. The machine is widely accepted by farmers because it reduces labor cost and drudgery, and saves time.

A rice dryer has been designed and introduced to farmers. The Department of Agriculture has also designed and developed a small rice milling machine which has high efficiency, low milling loss, and low cost. This machine is being introduced to local manufacturers and is being recommended by the extension program in all rice producing areas. The prototype is also being introduced in ASEAN member countries.

The Ministry of Agriculture and Cooperatives of Thailand and IRRI have cooperated in rice research and training activities since 1961. These activities include exchange of information on rice varieties, deep water rice culture, rainfed lowland rice breeding, breeding for drought resistance, cooperation in germplasm collection, climatic studies, advice on cropping practices and systems, and specialist training. This collaborative work ha5 resulted in the development of improved varieties and cropping systems which have been of immense benefit to Thailand. Thai scientists and technicians have received valuable training at IRRI, and have transferred their knowledge to improve the research and extension base in our country.

The Royal Thai Government is pleased to participate with IRRI in the International Rice Testing Program, the International Network for Soil Fertility and Fertilizer Evaluation, and the Asian Farming Systems Network.

Continued collaboration is needed for further development of small farm machines, particularly seeding equipment for rainfed areas. In these areas of erratic rainfall, timing of operations is critical, and appropriate machines will help develop more efficient cultural methods. More intensive collaborative efforts between IRRI and Thailand are also sought in the development of upland rice in our north and northeastern regions, and in varietal screening for acid sulfate, peat, and saline soils.

The Royal Thai Government wishes to express its confidence in the benefits which such research will bring to the people of other countries in the region, as well as to the Thai people.

Thailand has, therefore, a critical interest in maintaining and increasing the activities of IRRI in rice research and training, and particularly in the direction of research to more difficult environments. Rice is our highest valued agricultural commodity for both domestic and export markets, and is also our major foreign exchange earner. More than 65% of the rural population are engaged in rice production. Our future cooperative efforts with this institute will help us not only to maintain our present status, but also to enhance our capacity to produce more food in the future.

I feel confident that the deliberations and discussions in this symposium will result in concrete programs of action which will, in turn, help improve the social and economic situation of rural communities in Asia, Africa, Latin America, and the Pacific.

S. H. ESCUDERO III
Minister of Agriculture and Food
Republic of the Philippines

RICE PRODUCTION IN THE PHILIPPINES

It is not often that agriculture ministers and food experts from around the world can come together and share their experiences, and I would like to thank IRRI for making this exchange possible. As agriculture minister of my country, let me say that we are proud and honored to welcome such a distinguished group of the world's leaders in the global food production effort.

Although the problems and constraints of agricultural development differ from country to country, the exchange of experiences we have had since yesterday certainly point to the fact that there are many more similarities in our situations than there are differences. And as we listen to our colleagues from Malaysia and Burma this morning, I am certain that what they have to share with us will add to the wealth of lessons that can be applied to the management of agriculture in our own countries. Although most of our ministers here are from the developing world, the presence of the Minister of Agriculture of The Netherlands gives us an opportunity to draw insights from the advances gained by the industrialized nations.

Even as the gulf in science and technology between North and South underscores the disparity in the quality of life between our two hemispheres, it is clear that the work of international agricultural research centers over the past two decades has done much to bridge the gap. Two decades ago, there were virtually no technologies available to us in the developing world which were suited to the needs of farming in a tropical setting. This was ironic, for the world food problem was — and continues to be — a problem of increasing food production in developing countries. It was only with the founding of IRRI 25 yr ago, followed by the creation of the 12 other international centers supported by the CGIAR in other parts of the developing world, that the world community turned its attention and resources to the development of technologies tailored to the needs of tropical agriculture. The ensuing green revolution speaks eloquently of the fundamental and far-reaching impact of the fruits of science and technology on yields and incomes throughout the developing world.

In the Philippines, as in other developing countries, agriculture is a primary concern as the sector employs roughly 50% of the labor force, contributes a little over one-fourth of gross domestic product (GDP), and accounts for about one-half of annual export receipts. Moreover, 70% of our population live in the countryside and depend mostly on farming and farm-related enterprises for their living.

As we strive to improve the quality of life in our countryside, we have increasingly turned to agricultural research to improve yields in the face of mounting population pressure on dwindling landholdings. Even with the usual financial constraints, our research institutes picked up the challenge and came out with unprecedented feats.

At the time we launched our Masagana 99 rice program in 1973, technology was no longer a constraint. We had available high-yielding rice varieties developed by the International Rice Research Institute, our own University of the Philippines here in Los Baños, and our Bureau of Plant Industry. By the latter half of the 1960s, these high-yielding varieties (HYVs) had been adopted on more than half of our ricelands. Our experience with previous rice programs, however, taught us that technology alone was not enough. Equally important was the need to provide farmers with cheap credit to buy the inputs needed to make the new technology produce to its maximum potential. Although many of our farmers were already using the new HYVs, average rough rice yields in 1970 were only 2.2 t/ha, against a proven potential of 5.5 t/ha.

With Masagana 99, we took a historic move to extend noncollateral credit at concessional rates to farmers. We persuaded rural banks to shed their traditional collateral-oriented mentality and mobilized them to extend non-collateralized, low-interest, short-term credit to farmers under a supervised lending scheme. We overhauled the antiquated rediscounting system of our Central Bank and allowed rural banks to rediscount at 1%, thereby enabling them to lend to farmers at the cheapest rates possible. We guaranteed up to 85% of losses on Masagana 99 loans through an Agricultural Guaranty Loan Fund, and eventually through our crop insurance scheme.

Combining credit with extension, input supply, price support, and political will, we achieved self-sufficiency in rice in 1976 and made our first export shipment in 1977.

Admittedly, after successive years of surplus production, we began to encounter production shortfalls 2 yr ago, due to the combined effects of a drought in 1982-83, a succession of devastating typhoons, a virtual standstill in agricultural credit, and a consumer-biased pricing policy which served to erode real farm incomes.

But with the policy adjustments we have undertaken recently in credit and pricing and marketing, we should regain self-sufficiency soon. This year, we expect to harvest our largest rice crop ever — 5.3 million tonnes of milled rice, representing an increase of 5% over last year's harvest and 1.2% over our record crop in 1982.

After we launched Masagana 99 in 1973, the momentum of agricultural research spurred by the emergence and widespread adoption of high-yielding rice varieties led to the creation of new research institutes and the strengthening of existing ones.

The University of the Philippines' College of Agriculture here in Los Baños was elevated to an autonomous unit with its own Chancellor. The new vibrance and vigor which ensued on campus as a result of this move has earned for U.P. Los Baños the distinction of being the premier agricultural research and education institute in Southeast Asia.

Our next step was to create the Philippine Council for Agriculture and Resources Research and Development (PCARRD) which has the responsibility of coordinating all agricultural research activities, identifying research priorities, and eliminating duplications in research efforts.

Next, we established an Institute of Plant Breeding which has been doing work since 1975 on developing suitable varieties of corn, sorghum, wheat, root crops, forage crops, vegetables, legumes, abaca, cotton, and fruits.

With assistance from the Federal Republic of Germany, we set up a National Crop Protection Center which coordinates the work of a network of regional stations.

Recently, we established an Institute of Biotechnology and Microbiology to harness the exciting possibilities of genetic engineering in breeding new strains that can thrive and flourish in our tropical setting.

As announced by President Marcos two days ago, the latest addition to our network of research centers is a national rice research institute, which shall look into location-specific technologies for rice farming in the Philippines, even as we continue our fruitful collaboration with IRRI.

Research in aquaculture, which is proving to be our quickest growth area for food production and export, got a tremendous boost with the establishment of the Aquaculture Department of Southeast Asian Fisheries Development Center (SEAFDEC) which we developed with help from the Japanese Government. The successful development of prawn technology has enabled us to increase prawn production for domestic needs as well as for export. Our breakthrough in spawning milkfish in captivity constitutes a big stride forward in our bid to grow this fish in abundance and at less cost.

Supplementing and supporting the work of the national centers created in the last decade is a network ofregional research centers which are mostly based in state-run agricultural universities and colleges throughout the Philippines.

In the Ilocos Region, for example, there is the Cotton Research Institute of the Don Mariano Marcos University. In the Visayas, the Visayas College of Agriculture specializes in root crop research. In Central Luzon, the Freshwater Aquaculture Center of Central Luzon State University in Nueva Ecija developed a rice-fish culture technology that has provided the basis for growing rice and fish simultaneously in rice fields. We have also begun to tap the University of the Philippines in Iloilo as a regional center for research on fisheries.

Agricultural research, though, has not been a monopoly of the government. Private agribusiness firms have contributed their own share in the agricultural research effort, and it is in corn research that their contributions have had the largest impact.

The development of downy mildew-resistant corn varieties by the Institute of Plant Breeding and the increasing adoption of new hybrids developed by several private corporations have accounted largely for the phenomenal growth of our production of yellow corn in the past 5 yr. With hectarage expanding at an annual rate of 16.7% and yields increasing at 14.1% yearly, yellow corn production grew at an annual average of 33.2%) from 400,000 metric tonnes in 1981 to 1.2 million tonnes in 1985.

These trends reaffirm the promise of eliminating our large imports of yellow corn for animal feed in the near future and of generating surpluses for export thereafter.

At present, we have as an urgent concern the search for location-specific technologies attuned to the needs of our small farmers. We are concerned with the development of varieties less reliant on fertilizers and chemical pesticides, especially in rice, corn, and other feedgrains. This is also true in the livestock subsector where we need to develop animal breeds more suitable to local conditions, particularly in the case of cattle and dairy animals.

With mounting input costs, we are intensifying research on rice-based farming systems aimed at maximizing rice yields and increasing farmer income with minimum levels of farm inputs and investments.

We have also been moving on a shift of policy thrust from irrigated to rainfed rice farming partly to redress the imbalances in yields and incomes between rainfed irrigated farms. Our rainfed agriculture project in Iloilo Province has succeeded to a large degree in spreading rice-based multiple cropping technology.

In the Iloilo project, first-crop harvests for rice average 4 t rough rice/ha and second-crop harvests average 3.5 t/ha. Third crops are mungbeans, peanut, cowpea, corn, sorghum, and watermelon.

The use of new early-maturing varieties suitable for multiple cropping and the modification of rice culture for more efficient water usage increased farm productivity by as much as 100%. With the planting of two major crops, an additional third crop, and complementary livestock and poultry projects, farm income has likewise increased.

As we look to the future, the new frontiers for science and technology in Philippine agriculture are vegetable and fruit processing and by-product utilization. We incur much waste in the vegetable and fruit industries because of inadequate storage facilities and poor handling practices which could be drastically curtailed by processing. At the same time, our ailing sugar industry could take some relief from processing of its various by-products such as molasses and bagasse into manufactured products.

In these and other pursuits, the counsel of your experience would be a big help for us.

GOH CHENG TEIK
Deputy Minister of Agriculture, Malaysia

RICE PRODUCTION IN MALAYSIA

According to some experts, agroclimatic conditions do not make Malaysia an ideal place for rice planting. Malaysia is a rain forest country. When the natural rain forests are cleared, it is better to replace them with tree-crops, like rubber, oil palm, and cocoa, than to introduce short-term crops like rice. In this way, the disruption to the ecological balance is minimized. Moreover, Malaysia's soils are not as fertile as the alluvial soils of Burma and Thailand or the volcanic soils of Philippines and Indonesia. As such, heavy inputs of fertilizers are required to keep the topsoil fertile.

These agroclimatic factors do not negate the importance of rice planting in our country. They merely make Malaysia a high-cost producer by comparison with major rice-producing countries like Burma, Thailand, the Philippines, and Indonesia.

Since independence was achieved in 1957, the Malaysian Government has vigorously increased the acreage of tree-crops, especially rubber, oil palm, and cocoa, but it has not neglected rice. On the contrary, rice is accorded the highest priority. And it claims the personal attention of state and federal ministers, right up to the Prime Minister.

Why? There are two main reasons. First, rice is regarded as a security crop by the government. As the staple food of the Malaysian people, it is eaten two or three times daily. Malaysians find it difficult to live through a single day without rice! The older generation remember the dreadful Japanese occupation of 1941-45 during which many inhabitants were forced to subsist on tapioca when rice imports were cut off. Rice is 39% of the caloric intake of the Malaysian people. It is, therefore, important, for security reasons, to maintain an appropriate level of self-sufficiency in rice production.

Second, rice provides employment to much of the farming population. In 1983, rice accounted for 473,340 ha under cultivation and provided an income to 138,900 households or about 80% of all who are employed in agriculture. Because the returns from rice are low, rice farmers are among the poorest of the agricultural producers in the country. In 1983, it was recorded that 54% of the total rice-farming households were below the national poverty line.

What measures is the Malaysian Government taking to assist rice farming and rice farmers? The Malaysian Government supports rice farming in the following areas:

1. *Irrigation.* Although there was some development of irrigation before independence, since independence it has proceeded at an accelerated rate. In 1956-75, M$754 million was spent on irrigation development, or about 30% of the total public expenditure for the agricultural sector. As of 1983, 334,700 ha had been provided with irrigation compared with 279,250 ha in 1971. As a result of these developments, 67% of the rice area can be double-cropped.
2. *Planting materials.* Investment in irrigation must be complemented by research and extension since the development and adoption of short-term rice varieties is a prerequisite for successful double-cropping. Research institutions within the Ministry of Agriculture, Malaysia, have been on a relentless search for the highest-yielding rice varieties. The research results of foreign research centers like IRRI have been fully tapped. Over the last two decades, 15 rice varieties have been developed and released to farmers.
3. *Fertilizers and pesticides.* Fertilizers and other chemical inputs are heavily subsidized to encourage their use. Currently, each rice farmer receives free fertilizer for use in up to a maximum of 2.43 ha. Through the use of an integrated extension system, the farmers have access to technical advice on the application of inputs, like fertilizer, water, and pest control.
4. *Mechanization.* Because of labor shortages, and its resultant high cost, the government encourages mechanization. The use of machines for plowing, planting, and harvesting has become common in the larger irrigation schemes. The purchase and ownership of machines are encouraged by subsidized loans.
5. *Marketing.* To facilitate the marketing of produce, and ensure a stable producer price of rice, the Government, through the National Padi and Rice Marketing Board, maintains guaranteed minimum price of paddy. In practice, the domestic price is maintained at a level much higher than imported price, reflecting the country's position as a relatively high-cost producer of rice.

6. *Credit.* To ensure that farmers do not face cash-flow problems during planting, the government, through the Agricultural Bank, maintains a short-term credit program. Rice credit is provided at very low, if not zero, interest. In 1982, 42, 681 borrowers availed themselves of this loan facility. Besides the Agricultural Bank, the Farmers' Organisation Authority also grants loans to farmers' cooperatives.
7. *Institutional support.* The government provides institutional support to rice farmers by helping to organize them into district-level cooperatives and farmers' organizations. In 1982, there were 1,184 cooperatives and farmers' organizations, most of which were rice-based. The combined membership of these institutions was 389,251 persons.

There is no doubt that these measures increase productivity and improve rice farmers' income. The average yield per hectare has risen from 2.5 t/ha in 1963 to 3.2 t/ha in 1983. At the same time, the percentage of rice producers living in poverty has decreased from 88% in 1970 to 54% in 1983 for Peninsular Malaysia.

The Malaysian rice sector is well advanced in terms of infrastructural development. However, the rice industry still has problems. A few major problems restrain expansion of the sector.

First, uneconomic farm sizes continue to pose a problem. Very few farmers operate plots exceeding 4 ha. The average plot per farmer is about 1.26 ha for Peninsular Malaysia and 1.42 ha for Sabah and Sarawak. Small farm sizes make it impossible to introduce mechanization and reap the economies of scale.

Second, farmers in minor rice-growing areas and rainfed areas abandon their rice fields. By 1985, abandoned rice fields have exceeded 160,000 ha (compared with 400,000 ha still under cultivation). Although temporary abandonment of riceland is not peculiar to the rice sector, prolonged abandonment over four planting seasons can become a serious problem.

Third, the rice sector is faced with an aging population of rice farmers. The average age of rice farmers is estimated to be 45 yr. Children of rice farmers are not interested in their parents' occupation. Most prefer to enter into other trades in the rural areas or they migrate to the towns in search of better employment opportunities. As a result, old farmers now predominate in rice farming and the paddy sector is facing an acute labor shortage.

To overcome these problems, the Malaysian Government is embarking on the following programs:

- Intensifying production in the *ricebowl* areas. Nine large-scale rice-growing areas totalling 221,000 ha have been or will be provided with adequate irrigation facilities to enable double-cropping. These are MADA, KADA, Krian/Sg. Alanik, Barat Laut Selangor, Seberang Perai, Endau-Rompin, Seberang Perak, Kemasin-Semarak, and Besut. By striving for higher output through 1) the use of highest yielding varieties, 2) efficient utilization of the irrigation system, and 3) adoption of modern farming practices, the farmers in these areas can earn higher income and ensure themselves a reasonable standard of living. At the same time, hopefully, they can attract more youths to enter rice farming.

- The only way to overcome the problem of uneconomic-sized holdings is to consolidate them into plots that are large enough for modern farming practices to be introduced and for the economies of scale to be reaped in full.
- Where riceland has been abandoned due to lack of irrigation water, farmers will be encouraged to diversify into other economically viable crops like oil palm, cocoa, fruits, and vegetables which guarantee high returns. The rice producers' welfare is of paramount importance. If they cannot obtain an adequate income from rice, they should switch to crops like oil palm, cocoa, fruits, and vegetables that yield higher returns, or raise poultry, livestock, fish, etc.

In conclusion, let me state that Malaysia is a high-cost rice producer. To produce 1 t of rice, the public sector subsidy is about 54% of the cost. We have no ambition to achieve 100% self-sufficiency, let alone to become a rice-exporting country. We want to produce only enough to meet our security requirements. And we want to do so where we can do so *productively!* As a matter of fact, the government is examining ways and means to reduce the cost of producing rice. Now that the world economy is facing a period of slower growth, it is necessary for Malaysia and other developing countries to be extremely cost-conscious and productivity-minded.

R. RANDJIETSINGH
Minister of Agriculture, Animal Husbandry, and Fishery
Republic of Surinam

RICE PRODUCTION IN SURINAM

On behalf of the people and the Revolutionary Government of the Republic of Surinam, I express my deep respect to the President and the Government of the Republic of the Philippines, Director General Dr. Swaminathan and the staff of the IRRI, and to all involved in the activities of IRRI, for your willingness to participate in these activities, and for the achievements in the fight against hunger and poverty for the benefit of the common man. There is no doubt that without IRRI's efforts the world food situation today would have another face.

When IRRI started in 1960, Surinam already had 11 yr of experience in rice breeding. Immediately after that all useful genetic and other materials we had were made available to IRRI for a broader use.

The exchange of information and research materials between Surinam and IRRI was and still is an important stimulus and a great help to our research workers.

Modernization of rice cultivation in Surinam started around 1930. The government supported the operation. For this purpose some years later a Foundation for the Development of Mechanized Agriculture in Surinam was established. The objectives were:

1. to develop rice varieties suitable for mechanization and adaptable to our own local environmental conditions;
2. to develop adjusted land preparation, direct sowing, and harvesting techniques;
3. to develop postharvest techniques suitable for mechanization;
4. to encourage proper use of pesticides and fertilizers; and

5. to develop multiple cropping systems.

At the start it was a challenge to our researchers and many problems had to be overcome. Gradually, however, the research resulted in some fundamental solutions. Although the newly developed techniques were meant for use on large farms, its influence was not confined to large farms. The small farmers also adopted the techniques with close supervision of the agricultural extension services.

By 1972, the mechanization process was a success. A very labor-intensive rice cultivation system was replaced by a labor-extensive system. The results of the research brought along with it a new farming system in which new locally developed rice varieties were fully adapted to our environmental conditions and had very high yield potential. Full mechanization in all phases of rice production, adjusted to our own climatological and soil conditions, was introduced. A set of good cultivation practices for direct sowing with pregerminated seed and adequate water management was also accepted by our farmers.

Although ongoing research programs had to be slowed after 1970 because of financial constraints, some work continued. In the near future, however, research will be reactivated. Within this framework, it is natural that the ties with IRRI will be made closer.

As of 1984, the area planted to rice in Surinam was about 44,000 ha. Each year 2 crops of rice were produced in the major part of the planted area. Average yield per crop in 1984 was 4.0 t/ha. Rice production increased 70% from 1975 to 1984 to a quantity of about 300,000 t yearly. We are geared to reach a production volume of about a half million tonnes per year by 1990. For this purpose, several projects consisting of systems of canals for irrigation are under construction. Also, a set of measures is being taken by the government to educate the new farmers, disseminate information to existing farmers, develop appropriate technology particularly for the rice sector, conserve and manage other natural resources, and safeguard financial means and guaranteed income for the farmers. Since 1919 Surinam has been self-sufficient in rice and the surplus has been exported.

Although we are a very tiny spot on the globe, with relatively small population (350,000 people) and surface area(about 160,000 m^2), we would like to continue to contribute, in our own way, to the fight against hunger. Because we understand that we all are children of the world, we consider it an exclusive obligation on all men to do something to bring some light in our fellowmen's lives. We would like to fulfill this obligation as much and as soon as possible. In doing so, we can say that we need each other, and I think that IRRI offers us a great means for this purpose.

May your work continue to contribute to the efficient operation of the total food production machine, so that we can offer our fellowmen food at fair prices.

Again, I would like to express our gratitude for the wonderful work that you have done and intend to do in the future.

J. T. HOPA
Minister of Agriculture, Forestry, and Fisheries
Vanuatu

RICE PRODUCTION IN VANUATU

The Republic of Vanuatu is a Y-shaped archipelago made up of 80 islands, stretching some 850 km from north to south, located in the southwest Pacific. Total land area is 12,000 m^2 of which 45% is potentially arable land. However, only 17% is currently exploited for agricultural purposes, despite the fact that both the soils (mainly volcanic and fertile) and the climate (tropical to equatorial with well-distributed rainfall) are conducive to the development of arable and livestock farming. (Average annual rainfall varies from 3,000 mm in the north to 1,600 mm in the south, while average maximum temperatures vary from 30 °C in the north to 29 °C in the south. Average minimum temperatures vary from 21°C in the north to 18 °C in the south. Average relative humidity varies from 87.6% in the north to 75.0% in the south.)

The population is estimated to be 130,000 with an annual rate of growth of about 3%. Ni-Vanuatu society is overwhelmingly agricultural, with an estimated 87% of the labor force engaged in pure subsistence or mixed subsistence and related agricultural activities. The subsistence cultivation of root crops such as yams, kumala, taro, and cassava, and the raising of pigs are still the basic agricultural activities for most of the rural population. However, these activities are supplemented by cash cropping which provides 80% of the country's total exports — the major export being copra, although there are important exports of beef, cocoa, and coffee.

The value of these exports is exceeded every year by the value of imports, giving the country a chronic balance of trade deficit, which is financed by tourism earnings and aid flows.

Table 1. Imports for domestic consumption.

Item	Import (million VT)[a]					
	1979	1980	1981	1982	1983[b]	1984[b]
a) Food, soft drinks	938	818	915	97 1	1023	1170
% of b)	23.6	22.9	23.4	21.0	19.7	20.2
b) Total import	3978	3567	3905	463 1	5187	5801

[a]VT106 = US$1.00. [b]Classification was changed from CCCN to SITC, therefore, it is not strictly comparable with previous years.

A large proportion of imports are food items (Table l), although the country has relatively large areas of highly productive land and a low population density. One of the goals of the first National Development Plan, 1982-86, was to increase economic self-reliance; one area singled out for attention was the reduction in the reliance on food imports. The objectives of the agricultural sector contained in the plan emphasized this point ". . . promote self-sufficiency where economic, in food . . . ." One of the projects proposed to achieve self-reliance was the development of rice production. Rice is no longer grown in Vanuatu except in one island at the southern part of the country (Tanna) where upland rice has been cultivated by one farmer on a hobby basis. Upland rice was grown in Espiritu Santo in the 1970s on a commercial basis but suffered from severe insect and disease attacks. Production ceased in the mid-1970s.

Rice imports into Vanuatu are considerable and represent a large expenditure of foreign exchange. Table 2 shows that rice imports represent a major component of total food imports, and have averaged one-fifth of the value of total food imports since 1979.

However, unlike in other countries in the South Pacific, per capita dependence on rice is not increasing. Since records were first kept in 1959, there has been no evidence of an increase in the annual per capita consumption of rice (Table 3). Consumption has averaged 37 kg/person per year.

The main starch in the diet is provided by locally grown root crops and plantains and there is no evidence that they are being abandoned in favor of rice. Rice is a convenience food — it requires no preparation, and cooking time

Table 2. Rice imports.

Item	Import (million VT)[a]					
	1979	1980	1981	1982	1983	1984
a) Rice	198	170	198	201	220	279
% of b)	21.1	20.8	21.6	20.7	21.5	23.8
b) Total for food and soft drinks	938	818	91 5	971	1023	1170

[a]VT106 = US$1.00.

Table 3. Estimated annual per capita consumption of rice (kg).[a]

Year	Annual per capita consumption of rice (kg)	Year	Annual per capita consumption of rice (kg)
1959	48.2	1971	44.8
1960	35.9	1972	38.2
1961	32.9	1973	40.5
1962	31.6	1974	38.3
1965	38.4	1975	32.3
1966	36.6	1980	35.3
1967	49.2	1981	24.8
1968	44.4	1982	28.7
1969	42.4	1983	33.5
1970	35.7		

[a] Population data: 1967 = 77,988, 1979= 111,251. Growth rate = 3.00453%/yr.

is less than for root vegetables. Because of this it is mainly consumed in the urban areas and in institutions (hospitals, schools, and prisons).

Practically all of the rice is imported, mostly from Australia. Of this, more than 95% consists of medium-grained Calrose rice. The soft cooking quality of this variety is highly desired. The consistency of the cooked product approaches that of the traditional root crops.

In 1982, the government requested consultants to assess the feasibility of establishing a large-scale (1,300 ha) irrigated rice project in the largest island, called Espiritu Santo, which would provide rice for the local market. Unfortunately, the project was not implemented for a variety of reasons including

- poor financial and economic returns from the project;
- the high additional cost of associated infrastructural developments, e.g., roads/bridges, which would have been required;
- the risk of introducing both a new crop and a new technology into the country;
- the absence of any previous research activities to test rice varieties in the country; and
- the high level of cloud cover throughout the year which would reduce yields. (Average daily sunshine hours fluctuate between 6.1 in November and 3.9 in July, with an annual average of 5.1 h.)

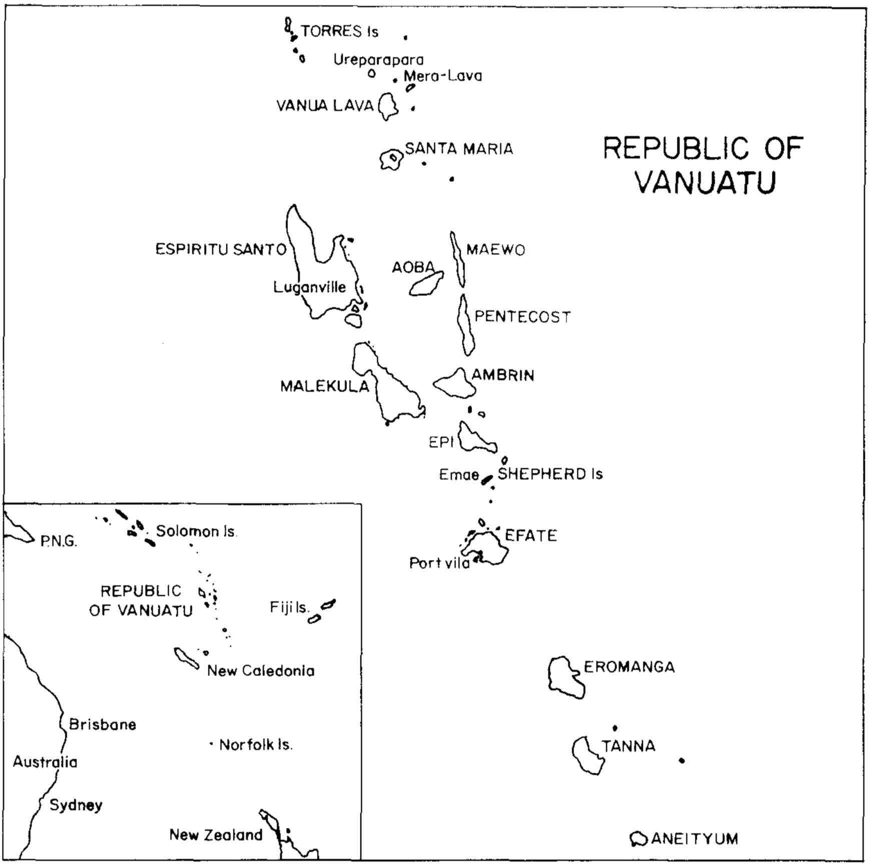
For this reason, the Department of Agriculture has undertaken a program of research on the development of small-scale upland rice production. A varietal test in Efate evaluates the performance of 20 introduced varieties of rice and a control trial using the variety that has been grown in Tanna.

The varietal test in Efate uses varieties of different origins including IRRI, Fiji, and Institut de Recherches Agronomiques Tropicales (IRAT) (Table 4). They have been laid out according to IRRI recommendations in IURYN (International Upland Rice Yield Nursery) trial plots, comprising 10 rows (5 m long) 0.3 m apart. At harvest, random metres of plants are pulled and analyzed.

Table 4. Rice varieties tested in Efate in 1983.

Variety	Source	Variety	Source
IR43	IRRI	IRAT 112[a]	IRAT
IR9669 Selection	IRRI	IRAT 133[a]	IRAT
UPLRI-5[a]	IRRI	IRAT 13[a]	IRAT
UPLRI-7[a]	IRRI	IRAT 78[a]	IRAT
IR3839-1	IRRI	IRAT 106[a]	IRAT
IR6023-10-1-1	IRRI	IRAT 170[a]	IRAT
IR6115-1-1-1	IRRI	IRAT 114[a]	IRAT
IR5931-110-1-1	IRRI	IRAT 136[a]	IRAT
IR10068-11-1	IRRI	SAUTU	Fiji
IRAT 10[a]	IRAT	IAC 25[a]	Tanna
IRAT 110[a]	IRAT		

[a]Varieties that have been selected for continued use in the trials. The rest of the varieties were abandoned because they had either too short a stem (<50 cm) or too long a growing cycle (>170 d).



1. Map of Vanuatu. Performance of different rice varieties will he evaluated in Tanna, Espiritu Santo, and Efate.

Support and advice from the tests have been received from both IRRI and IRAT which have recommended varieties and lines considered suitable for the trials, given the climatic characteristics peculiar to the test site.

Low minimum temperatures (20°C) during June-August and low sunshine hours throughout the year are limiting factors. These low temperatures were shown to have an unfavorable impact during ear emergence and pollination — they delay the development of the inflorescences and cause grain sterility.

The next step which we are now taking is to compare the performances of different varieties in other climatic zones throughout the country (Tanna and Espiritu Santo, as well as Efate; [Fig. 1]) and to carry out trials on other overseas varieties.

Last year we obtained technical assistance from the Government of the People's Republic of China to carry out upland rice trials and demonstrations in Tanna and to assist farmers interested in rice growing for local consumption. The assistance is scheduled to last 2 yr. Some rice varieties have been brought in from China; their suitability to environmental conditions in Tanna is being tested.

In 1984 the existing collection was supplemented with new varieties obtained from IRAT (Table 5) and mechanized trials of the three most promising varieties from the 1983 trials (IRAT 110, IRAT 112, and IRAT 13) were planted on large trial plots in Efate. Unfortunately yields were again low (average of 1.5 t of rough rice/ha), as a result of late planting, vigorous competition from weeds, and, as with the initial trials, low number of sunshine hours during panicle maturity.

Given the lack of success with strains obtained from IRRI in 1983, we have been fortunate in getting IRRI to provide other very early-maturing breeding lines for our rainfed trials. We received 21 more lines early this year (Table 6).

We, therefore, now have a collection consisting of 42 upland rice varieties which will be used in further trials throughout the country in the next few years to identify those most suited to our ecological conditions. The assistance extended by IRRI in our research work has been extremely useful and we are very grateful for such rapid and comprehensive responses to our requests for assistance. As our work expands I am sure that contacts between this institution

Table 5. Introductions of (IRAT) rice varieties, 1984.

Variety/line	Source/origin	Variety/line	Source/origin
IRAT 144	Upper Volta	IRAT 219	Brazil
IRAT 177	French Guiana	IRAT 221	Brazil
IRAT 208	Cameroons	IRAT 233	Brazil
IRAT 209	Cameroons	IRAT 237	Brazil
IRAT 212	Ivory Coast		

Table 6. Introductions of (IRRI) rice varieties, 1985.

Variety/line	Seed source	Variety/line	Seed source
IR74702-6-3	1001	IR25621-135-1-1	1016
IR13427-45-1-2-2-2	1005	IR2584083-3-2	1017
IR13540-56-3-2-1	1006	IR28128-45-3-3-2	1018
IR18348-36-3-3	1007	IR28187-70-3-1-3-1	1019
IR18350-229-3	1008	IR28211-43-1-1-1-2	1020
IR19058-107-1	1009	IR28239-94-2-3-6-2	1022
IR19735-5-2-3-2-1	1011	IR29658-43-3-2-1	1024
IR19743-46-2-3-3-2	1012	IR29658-69-2-1	1025
IR21015-196-3-1-3	1013	IR29658-69-2-1-2	1026
IR24632-34-2	1014	IR29670-15-2-3	1027
IR25588-7-3-1	1015		

and Vanuatu will intensify — I believe there is a lot which we can learn from one another.

Finally, and not wishing to denigrate the work already done on rice production development in Vanuatu, I am doubtful that the time is yet right for introducing rice production into the farming systems of the smallholder in Vanuatu, for the following reasons:

1. it requires large inputs of labor during the hottest time of the year;
2. these labor inputs are required at the same time labor inputs peak in the existing farming system;
3. the crop requires more sophisticated care and equipment (both for cultivation and processing) than do the traditional root crop staples;
4. the crop must be harvested when ready and investment in storage is required, whereas root crops are harvested when needed for consumption/sale — a form of in-ground storage;
5. the crop must be planted and harvested at specific times in the year, whereas root crop husbandry allows greater flexibility;
6. the crop appears to be more susceptible to damage from both pests (rats and birds) and bad weather during growth than are root crops, and
7. smallholders virtually have no experience in rice cultivation whereas they are proven experts at root crop husbandry.

My ministry is still keen in undertaking rice research so that we have varieties suired to local conditions and available for distribution to farmers interested in trying the crop. We also have high-yielding varieties available should we decide to go ahead with the large-scale, mechanized cultivation of the crop to conserve our foreign exchange earnings. I look forward to continuing support from IRRI for our research activities.

M. A. GRANGER
Director, National Agricultural Research Institute
Guyana

RICE PRODUCTION IN GUYANA

It is my great pleasure to be able to address such a distinguished forum today on this, the 25th anniversary of the world-renowned International Rice Research Institute. It is with humility that I stand here to represent my Prime Minister, His Excellency Hugh Desmond Hoyte, who, for reasons of state, could not be here. He has, however, directed me to convey to you his personal regrets and to extend on behalf of the people and Government of Guyana and on his own behalf, warmest congratulations and the very best wishes for the success of your 25th anniversary celebration.

He says that you of IRRI, and your sponsors and supporters have every reason today to be proud of your achievements and contributions to the elimination of the problems of world hunger, and of your vanguard role in developing appropriate technologies and in catalyzing the application of science to the relevant and sustainable development of so many developing countries. He wishes you to know that Guyana fully appreciates and supports the role IRRI is playing in filling the void of basic research on problems relevant to Guyana and many developing countries of the tropics — a void that we ourselves with the best will cannot now fill.

The appropriate harnessing of science is a prerequisite for development. Science is one of the foundations upon which contemporary culture and civilization has been built and will continue to be developed. The present disparity between nations reflects among other things basic differences in scientific and technological capability to address or advance socioeconomic development. The most powerful and successful nations are those with, among other traits, developed scientific bases encompassing both the culture and practice of science.

The application of science to sustainable development is a function of national scientific capability. A society can realize the potential benefits of science only if its scientists are of a high quality and motivated to identify problems and promote solutions within the framework of that society's unique social and cultural traditions and environmental conditions.

It is unlikely that nations with small populations such as Guyana can have or afford a scientific infrastructure of any broad significance to impact on socioeconomic development without the effectiveness of the work of such institutions as IRRI. Thus, it would seem logical that the research efforts of developing countries with limited scientific resources must be channeled, of necessity, toward optimizing the benefits of scientific progress by the adoption of technologies developed off-shore and tailoring such technologies to fit their own special socioeconomic environment and resource base.

Rice has been cultivated in Guyana for almost 2 centuries, during which time it has expanded from a garden crop grown by slaves on the sugar plantations to an industry that now occupies more than 130,000 ha, and provides a livelihood for an estimated 25% of the population. Rice is a staple food of the nation. It also is an important earner of foreign exchange.

Expansion of the rice industry was greatest during 1950-77 when the annual acreage cultivated tripled and production increased threefold to fourfold. The yield per acre also significantly increased. These increases were largely attributable to the application of science and technology to the rice industry. For example, early attempts at varietal improvement involved introduction, selection, and hybridization. The selections made from these early introductions dominated the industry for several decades. It was not until the development of the semidwarf indica variety IR8 by IRRI in 1962, and the subsequent introduction of that variety and sister lines, that genetic materials with high yield potential were available for use in local hybridization programs. These materials were widely used with local varieties in crosses which eventually led to the release in 1974 of high-yielding, semidwarf, long-grain indica varieties that were widely accepted by farmers. They made a significant contribution to increased production and productivity.

Recently, a very ominous trend has begun to manifest itself in international behavior. A trend that signalled and now dictates that developing countries need to look more seriously at their agricultural development programs to satisfy, as far as possible, their own internal food requirements. Food security has become a most urgent priority. It is obvious that, given the advances in technological development, the application of science to agricultural development is one of the most important tools not only for bringing about the necessary transition toward food self-sufficiency but also for facilitating complementary socioeconomic changes necessary for the sustained application of science to development.

Science has been applied to Guyana's agricultural development from the time a concerned effort was made to organize such production. Seldom has it been applied as a pure science but more often as a complex mixture of science collectively called agricultural science. More particularly, the various sub-disciplines of agricultural science found greatest application in the characterization and understanding of Guyana's crop- and livestock-growing environment and in her capability to tailor technologies developed off-shore to satisfy, to some extent, her agricultural development needs.

Rice and sugar as export-oriented crops have traditionally received the greatest national attention. The history of rice in Guyana is an interesting example of the classic application of science to the development of the rice industry.

Further hybridization work using a wider range of genetic materials resulted in the development and release in 1977 of the extra long-grain, high-yielding, high-quality varieties, that currently occupy between 60 and 75% of the annual acreage cultivated.

Before the 1950s, land was prepared by oxen and harvesting and threshing were by human and animal power. Because of expansion and intensification of rice cultivation since the 1950s and difficulties in finding an adequate labor force to cope with the expansion in the industry, however, tractors gradually replaced the oxen and combine harvesters replaced manual labor. The commercial varieties grown at that time were not suitable for mechanical harvesting because they were tall, leafy, lodging susceptible, and did not mature uniformly. This resulted in intensification of efforts to develop higher yielding commercial varieties that were more suitable to mechanical harvesting.

Today, land preparation and harvesting are almost completely mechanized, making it possible to handle large acreages in a relatively short period.

The tall, leafy, weak-strawed, indica varieties which dominated the rice industry until the late 1960s did not respond well to fertilizer applications. However, with the increased use of introductions such as Bluebelle and Starbonnet, and the development of local semidwarf hybrids, the use of fertilizers, mainly nitrogen and phosphate, became widespread. This was accompanied by the use of pesticides to remove suppressive influences on grain yield and quality. It can be concluded that the increases and higher grain qualities resulted from applying improved technological practices.

Sugarcane can be used as another example in which science has had a remarkable impact on the development of the industry. The most significant impact has been the wide range of germplasm material of high-yielding, disease-resistant varieties available to the industry and the recent successful attempts to mechanize harvesting operations.

We continue to apply the science and the technologies already developed to make our sugar industry more efficient; to utilize the crushed stalks for fuel and later for paper and particle board; the filter-press mud as a soil ameliorant; and the molasses for making yeast, alcohol, and vinegar. We now export raw sugar, but plan to have our own factories refine and process this sugar into other consumer-finished products.

The application of science to the development of other crops has been dwarfed by progress in the sugar and rice industries. However, we recognize that to stay agriculturally competitive and to meet the increasing demand for food and fiber both locally and internationally, the most effective mechanism is the use of technologies including improved crop varieties and cultural practices such as those being developed here at IRRI. These technologies fit well within our socioeconomic and resource base.

Guyana, as a country with a vast potential agricultural base, has allowed herself to become apparently entrapped in technologies that make her dependent on imports to develop and sustain agricultural output levels. Seed is no longer imported, but fertilizers, limestone, and agrochemicals are. Machines, tools, and mills are also imported along with agricultural implements, packing materials, and fossil fuels. Even the technology has been imported. In fact, like so many other developing countries, it now appears that Guyana's agricultural production is on an import-oriented assembly line. This is a most unhealthy national position, because it has made us most vulnerable and susceptible to the vagaries of the international market.

Some of our scientists still have visions of our agriculture on large expanses of land with neat, clean rows of crops in monocultures cultivated by eight-row equipment, fertilized at rates that push the crop to its genetic potential, kept free of weeds and other yield-suppressing pests by agrochemicals, harvested by large combines, and transported in bulk to factories. There is nothing theoretically faulty with this vision because it epitomizes a concept of efficient, maximum production with a minimum involvement of the nation's work force. However, while one may argue about the efficiency of such production utilizing that kind of technology to spurn development, one should recognize that the system takes its toll on the national financial reserves and few developing nations have any control over the cost they must pay for such inputs and the price they obtain for the products derived therefrom.

Our scientific capability must, therefore, be strengthened and our scientists properly oriented toward recognizing most fully our natural endowments. The application of such scientific principles that will allow maximum production within our own capability is the single most important challenge for our scientists.

Several anomalies that reflect the training and orientation of our scientists exist in Guyana. There is an acceptance of, for want of a better term, development blunders as it were, that is manifested by a tendency to cling tenaciously to accepted norms of scientific application to agricultural development. These norms are relevant not only to other resource bases, but also to the scientific and environmental capabilities of developed countries rather than to our own. This is not a criticism of the science itself but only of the way in which it has been applied.

Questions arise as to whether Guyana, like many other developing nations, has optimized the case of scientific principles in agricultural development strategies in terms of utilizing the most appropriate, not necessarily the most available, technologies and approaches — given our natural resource endowment and our national socioeconomic climate. This leads one to question whether the way in which science is applied truly contributes to our development or to our bondage.

We have just reorganized our scientific infrastructure so that such questions should never arise in the future. We have established the national Agricultural Research Institute which serves not only to concentrate our slim scientific resources but also to provide the necessary critical mass of researchers to identify and address with relevancy the problems that are critical to our agricultural development. In this respect, we look up to the international research centers, such as IRRI, for assistance in developing production technologies — technologies that fit, or can be easily tailored to fit, our own conditions and which can be maintained without unduly straining our resource base.

We have inherited systems that are now economically difficult to maintain. Guyana's coastal plain has developed as the most populous, agriculturally advanced region but it lies 2-3 m below the mean high-tide sea level. It is an excellent example of environmental modification to permit the initial production of sugarcane and, later, rice in alternating land across the coast. A massive system of earthen and concrete dikes restrict the sea while inland, others create hundreds of square kilometers of irrigation reservoirs and swamps. There is an intricate system of canals — conceived by the Dutch, built by their slaves, maintained and expanded by the British, and passed on as a legacy to Guyanese. This system controls both the drainage and irrigation necessary to manage an annual precipitation in excess of 2000 mm. The canals also form an important transportation system for moving more than 3 million tonnes of sugarcane annually from field to factory. But these modifications have been and are expensive and drain the national coffers for maintenance. It should be pointed out that sugar was not introduced to increase national well-being but primarily to satisfy trade demands of the then colonial masters.

Guyana is now faced with recognizing the limits of her capabilities and the problem of screening, selecting, and/or breeding varieties of crops of interest for production as far as possible within these limits. Such varieties will obviously be more compatible with prevailing environmental conditions or with the level of environmental modification that is technologically and economically feasible within the given limits.

This is the accepted norm, but I wish now to present to your scientists other bothersome problem — an apparent void in the way scientific principles question and address environmental conditions.

It should be recalled that when the European colonists arrived in Guyana they found the indigenous people self-sufficient in food and fiber. We know now that their production systems were in close harmony with the environment, thus creating a minimum of natural stress and disequilibrium. This was the low-intensity, low-input (and low output) farming system often referred to as shifting cultivation. It is still practiced in some hinterland areas as the most appropriate farming system, given the prevailing set of socioeconomic conditions. The Europeans introduced a new set of technologies and crops — technologies that have evolved with a greater demand on science for increased yields per unit of land for crops cultivated.

Upland rain forests cover 60% of Guyana’s land surface. They are verdant and grow without human intervention. They seem to be in no danger of ravishment by insects and diseases. Yet there is a symbiosis and interdependency that allows such forests to grow well on acid, low-fertility soils. On the coastal plains, at the onset of rains, there is a proliferation of vegetation that covers the land with such ease that one wonders why we experience difficulty in growing cultivated crops. We have not looked at indigenous species — species not now utilized and often considered weeds that grow prolifically without intervention. We know these plants are well adapted to prevailing environmental conditions. Little attention has been given to ascertain their usefulness. Indeed there is a wide range of plants of known and unknown potential for food, fiber, and pharmaceuticals.

Focusing on environmentally compatible trends in realizing Guyana's agricultural potential, there must be greater exploitation of the concepts' natural ecological harmony and a greater use of biological systems for enhancing production.

Of the 15 or 16 essential plant nutrient elements required for crop growth, Guyana possesses only nitrogen (besides carbon, hydrogen, and oxygen from air and water) in any significant amount and in a form not readily available to the plant. There is an estimated 36,000 t of nitrogen over each acre of land surface. Few ways are available for economic exploitation of this vast natural resource. Current levels of technology suggest that biological fixation is the most inexpensive way (unless a cheap source of electrical power is developed). Such crops as legumes can symbiotically utilize this atmospheric nitrogen. Recent research in other countries indicate a high probability of utilizing azolla, blue-green algae, and other microbial species for nitrogen fixation in rice and other crops. Such approaches must be rapidly developed for farm application.

Scientists have made remarkable progress in protecting crops from insects and diseases. A number of chemicals are readily available for adequate protection of most crops. Some of the most effective pesticides are now being extracted from pyrethrums, and science is directed toward the search for other such plants and for natural predators for most insect pests. We must encourage this approach to biological pest control and exploit the allelopathic characteristics of some plants in production systems.

Guyana recognizes the role IRRI has played and is playing in the agricultural development of developing countries. The institute's plan for its third decade describes approaches that address some of the queries I have raised with regard to the appropriateness of technology being made available to such countries. IRRI has come to recognize limitations in crop growing environments, socioeconomic conditions, and the resource base of its information users. I do hope that this trend is seriously followed by other international research centers.

Notwithstanding all of this, there is the awesome potential impact of biotechnology on agricultural development.

Recently, the discipline of molecular biology has had its frontiers rapidly expanded and has given rise to such new areas as genetic engineering and the fascinating encompassing field of biotechnology. Developments in these fields, like those accompanying the silicon chip in the computer technology, have begun to revolutionize thinking in agriculture and food production. Tissue culture is the tip of this awesome technology. It permitted the rapid reproduction of uniform sets of genetic characteristics in crop materials. It appears that these advances in science have brought us to the verge of a new era — an era in which the scientists will be able to design and construct an organism from the pool of existing genes to perform any desired task in food production. Further, if this microbiological activity can be brought into the laboratories successfully for food and fiber production, then it seems likely that food production is destined to become factory rather than field oriented. If such is the case, and it is highly likely, then what will become of our traditional agriculture and our agricultural scientists?

With these thoughts, I extend heartiest congratulations to the Institute on its 25th anniversary and express the hope that its contribution to agricultural research will be of continuing excellence.

RABESA ZAFERA ANTOINE
Minister of Scientific and Technological Research for Development
Democratic Republic of Madagascar

RICE PRODUCTION IN MADAGASCAR

Rice occupies the most important position in the socioeconomic activities in Madagascar. It is the basic food of the population. About 70% of the people grow rice on almost half of the cultivated area — 1.2 million hectares.

I will not attempt to present the scientific and technical results of research in Madagascar, but will simply try to explain the development of rice culture within a certain time frame within the social structures in Madagascar.

Some information on the development and the present state of rice culture and production, and the historical and socioeconomic aspects in rice culture is included.

A summary toward the end of the paper explains our present efforts to attain the national goal of self-sufficiency in rice by 1990. The role of research is emphasized.

PRESENT SITUATION IN RICE PRODUCTION

Rice production has stagnated during the last decade after a rapid increase in the 60s, from 1.2 million tonnes in 1960 to 1.9 million tonnes in 1970 (Table 1). Although the area has irregularly increased, yields have decreased relative to 1967 yields (Table 2, 3). In the interim, population grew from 5.5 million in 1960 to 9.4 million in 1983, resulting in a chronic rice shortage.

Faced with this situation, the government resolved to increase rice production and attain self-sufficiency for Madagascar. In line with this program, several activities are being conducted.

Table 1. Total availability of local rice, 1960-83.

Year	Population (thousand)	Rough rice production (thousand t)	Per capita availability (t)
1960	5505	1229	1.2
1961	5616	1263	1.2
1962	5728	1330	1.3
1963	5842	1317	1.3
1964	5959	1520	1.4
1965	6078	1445	1.3
1966	6200	1603	1.4
1967	6342	1706	1.5
1968	6487	1873	1.6
1969	6636	1858	1.5
1910	6188	1865	1.5
1971	6943	1873	1.5
1972	7102	1687	1.3
1973	7265	1730	1.3
1974	7431	1844	1.3
1975	7604	1972	1.4
1976	7817	2043	1.4
1977	8036	2067	1.4
1978	8261	1922	1.3
1979	8492	2045	1.3
1980	8730	2109	1.3
1981	8914	2012	1.2
1982	9225	1970	1.2
1983	9484	2147	1.2

Source: Rice Sector Study, AIRD 1984.

1. Marketing
   - A price increase for both producers and consumers (Table 2), and
   - Easing of restrictions on collection and sales.
2. Production
   - Boosting of production operations either at the peasant level or through agroindustrial companies;
   - Some theories on production forecasts based on daily consumption to increase from 360 to 370 g/day per person, increase of up to 600 kg/ha in yield, increase up to 36,000 ha in area, a progressive decrease in rice import until the no-import level is attained in 1990.
3. Rice research. Rice research has support from the government as well as from international institutions and organizations.

SOCIOECONOMIC HISTORY OF RICE CULTURE IS MADAGASCAR

The introduction of rice in Madagascar

The origin of rice grown in Madagascar is still not very clear to us. According to some, it dates to the time of our first migrants from Africa and the Far East. It

Table 2. Development of rice production and producer and consumer price.

Year	Rough rice production (thousand t)	Area (thousand ha)	Yield (t/ha)	Producer price (FMG/kg)	Consumer price (FMG/kg)
1960	1.229	782	1.57		
1961	1.263	766	1.65	8.	
1962	1.330	799	1.66	9.0	
1963	1.377	826	1.67	9.0	
1964	1.520	854	1.78	11.0	
1965	1.445	849	1.70	11.0	
1966	1.603	883	1.82	12.6	
1967	1.706	901	1.89	13.0	
1968	1.873	913	2.05	13.4	
1969	1.858	913	2.04	13.6	
1970	1.865	935	1.99	14.2	
1971	1.873	943	1.99	15.0	
1972	1.687	1.008	1.67	15.0	
1973	1.730	1.055	1.64	15.0	
1974	1.844	1.134	1.63	25.0	65
1975	1.972	1.078	1.83	30.0	65
1976	2.043	1.064	1.92	35.0	65
1977	2.067	1.175	1.76	35.0	55
1978	1.922	1.1 33	1.70	35.0	55
1979	2.045	1.1 58	1.77	38.0	55
1980	2.109	1.178	1.79	43.0	60
1981	2.012	1.186	1.70	47.0	75
1982	1.970	1.188	1.66	60.0	140
1983	2.147	1.189	1.81		140
1984	2.1 12	1.163	1.82		

would seem that the introduction of rice started in the northwestern coast of Madagascar between the Mahajamba Bay and Antsiranana (Fig. 1).

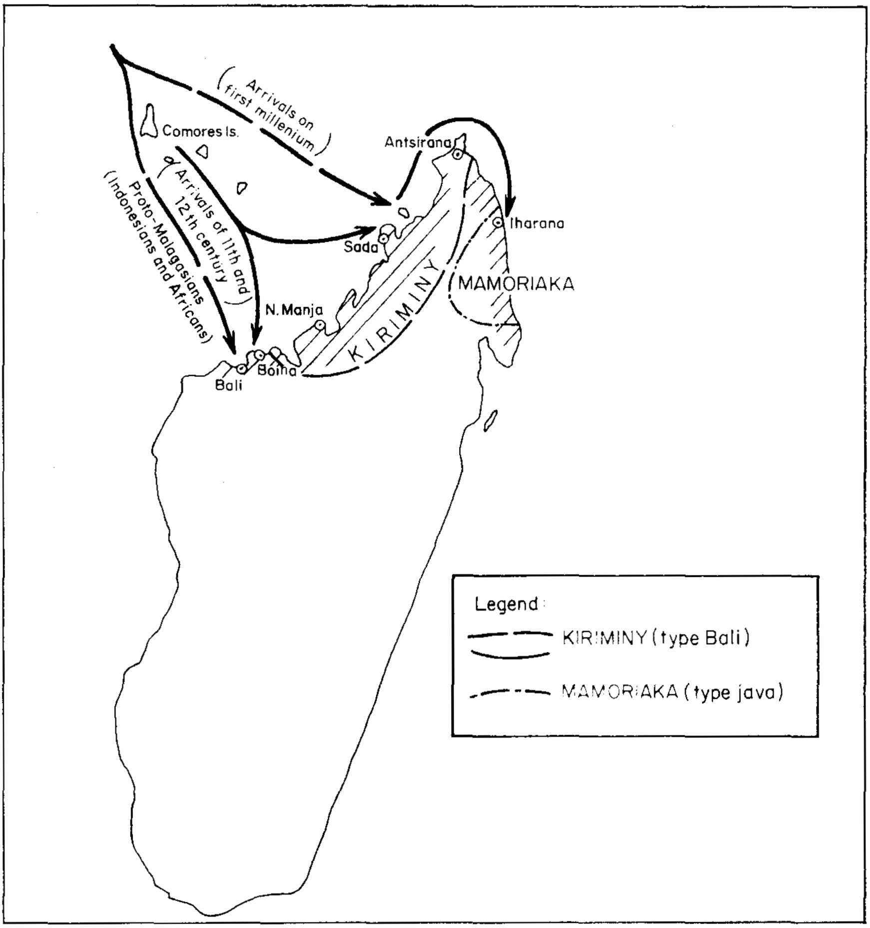
Later, toward the 10th century, migrants probably from Indonesia introduced more complicated rice techniques in the eastern coast (Fig. 2, 3). Since the 10th century, according to P. Martini, the Malagaches have had a well-established tradition of rice culture. In Antananarivo, Andrianampoinimerina already had initiated the development of the Betsimitatatra plain.

From then on, a veritable osmosis was established between the mode of life of the population and the farming systems and rice became a staple food.

Table 3. Annual rate of rice production.

	1960-70 (%)	197083 (%)
Total production	4.8	1.3
Yield	2.8	-0.5
Area	2.0	1.8

Source: Rice Sector Study, AIRD 1984.



1. Region of distribution of the two ancient rice varieties.

Sociocultural and economic value of rice

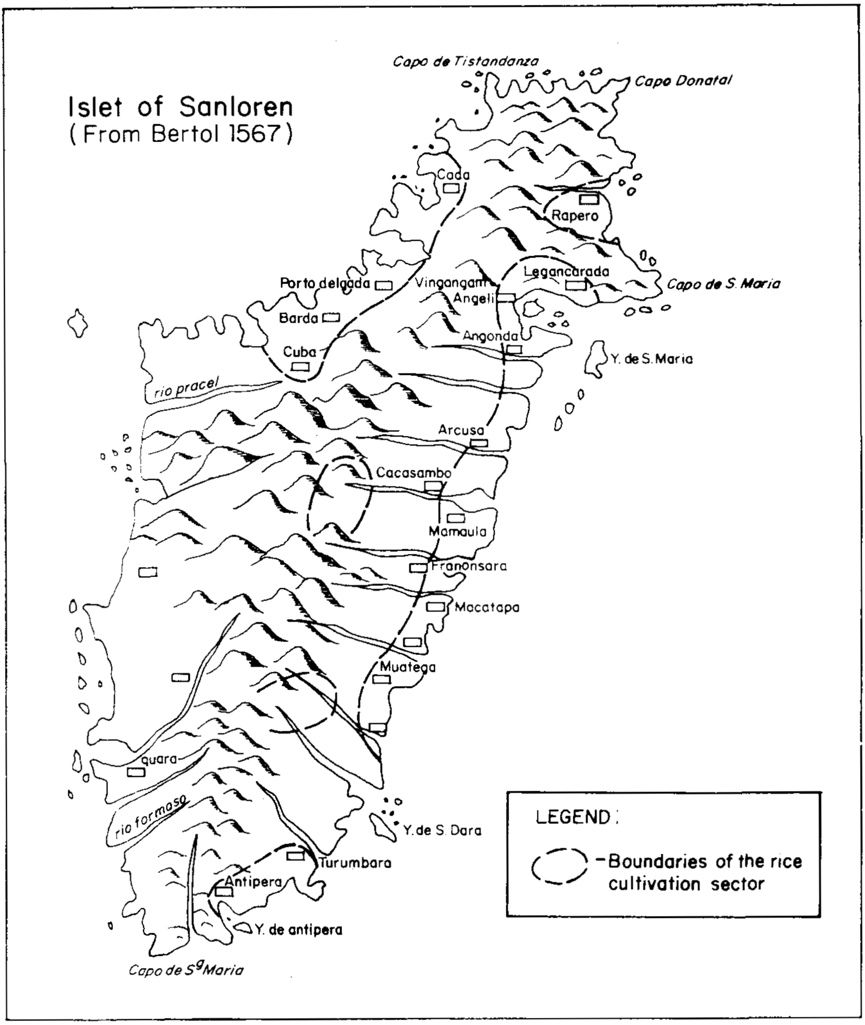
As rice invaded the rural milieu it became a veritable social link among the peasants. One of the most remarkable proofs of this link is the inter-aiding system among the farmers carried out through *Fokonolana.*

This practice of helping each other was in the form of assistance with farm work beginning with land preparation to harvest.

The *Sakafobe* offered by the farmer to all participants as a reward illustrates the social atmosphere at that time.

Spiritual value

A veritable rice cult came into being within the peasant and the urban milieu. This was manifested by a cascade of religious rites performed during farm work. For example, during sowing, the last handful of rice is reserved for the



2. Probable distribution of rice cultivation in the islet of Sanloren in the 16th century.

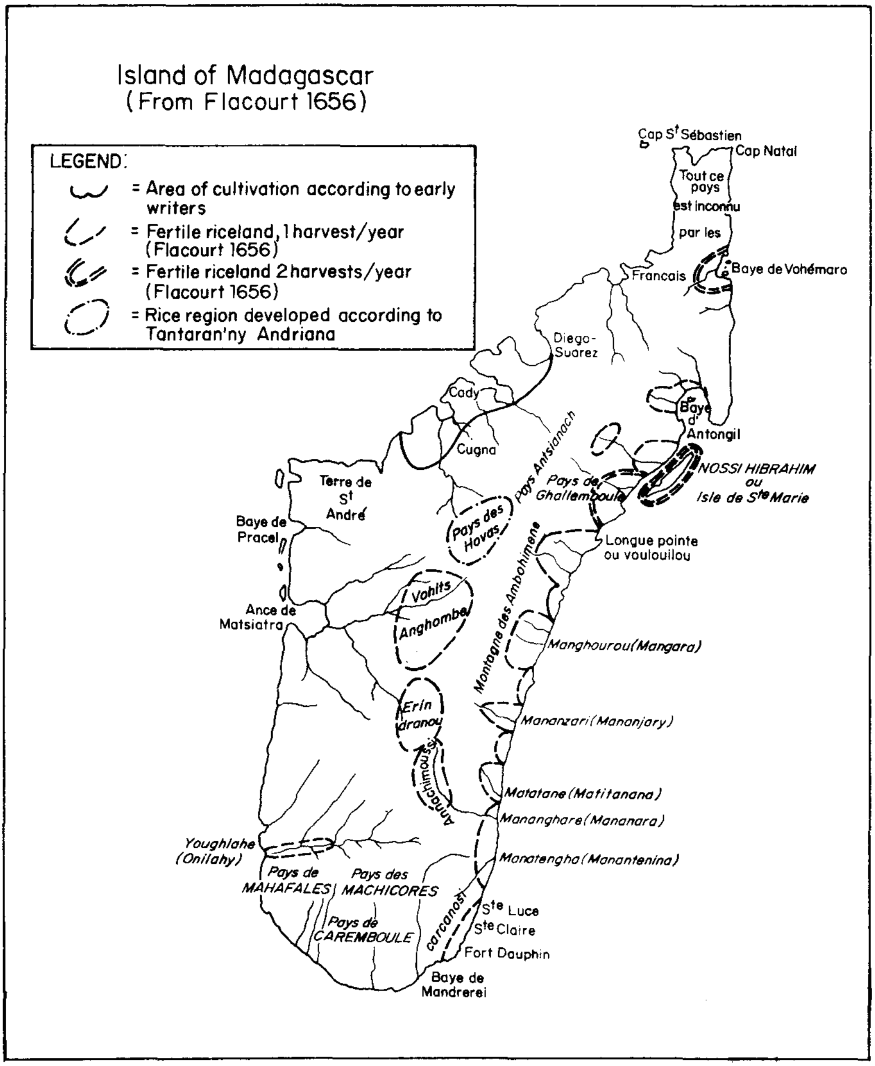
ancestors and is brought from the *Zorofirarazana* (northeastern section in the house).

In the home of some ethnic groups of the eastern region, a *Fadimbarry* ceremony is practiced consisting of offering to the elders of Tranobe the first ears of the harvest.

On the high-plateaux the *Santabarry* feast is held.

Material value

In economics, rice is important because it is a currency for trading purposes and is a secondary source of income for the farmers. Some examples prove this.



3. Probable extent of rice cultivation in Madagascar in the 17th century.

Agricultural work by persons from outside the village are paid in *daba* of the paddy during harvest.

Rice was used for barter in commercial transactions in the village and with Arab, Indian, and Portuguese merchants.

In some cases, rice serves as guarantee for cash (a part of the crop still to be harvested is reserved for payment of a debt).

At concessions and agroindustrial commercial companies, rice rations were given to the workers as incentive, in addition to their monthly or weekly allowances.

Cultural value

Because rice is important to the Malagaches, it has been the object of numerous proverbs used in daily conversation or in official ceremonies, as well as in social or religious functions.

Rice has also been used as a basis for all kinds of measurements used in trade or for giving rewards.

The following measurements are used:

vary = 120 liters

vata = 4 *fahefany* (1 fahefany = 1 gallon of white iron = 3.5 kg of rough rice)

daba = 12 kg of rough rice (1 oil can)

kapoka = 3.5 *kapoaka* = 1 kg of white rice (a can of Nestle milk)

fatam barry = a ration necessary for a father of a family, the mother, and the child

eran'ny tanan'olona = a handful of rice

In the Malagaches' daily life, rice is not only a product for consumption but also a coordinating element in the geographic, social, and economic structure of Madagascar.

Rice culture in Madagascar at the start of the 20th century; development of new zones for rice production

In 1895, Madagascar was under France with a new political and administrative organization.

Agricultural production flourished anew resulting from:

- the law of 9 March 1896 awarding land concessions to settlers under certain conditions such as by leasing, purchase, or free; and
- the division of the country by electoral sectors.

In 1904, the population of the island was estimated to be 2,700,000, considered numerically insignificant in relation to the land area of the island and insufficient to ensure its development. Thus, efforts were exerted to attract much needed private agricultural concern from the outside.

About 290,000 ha were developed and dense concentration of activity was observed in 2 centers: Tananarive and Fianarantsea.

The highlands were the most developed with an area of more than 100,000 ha.

Rice culture thus spread also in zones formerly occupied by other cultures such as, for example, in the far region of Tulear.

In January 1904,374 concessions over an area of 40,000 ha were awarded permanently, 3,315 concessions representing 149,000 ha were awarded temporarily and 5,000 ha were awarded to individual planters. This triggered off the proletarization of the peasants.

The establishment of a group of migrants traveling in a spontaneous manner accompanied by their families settling in the lesser populated areas contributed to the development of rice culture. The consequences of this European colonization and traditional migrations contributed to a generalized development of rice cultivation in the country as a whole and resulted in the coexistence of different customs and farming systems. Rice geography, therefore, was greatly transformed toward 1950 compared with earlier times.

At the start of the 20th century there was a rapid flourishing of rice production (Table 4).

RICE RESEARCH IN MADAGASCAR

Until 1974, most of the rice research as well as other agricultural research was carried out by the French Research Institute.

In 1974 the CENRADERU (National Research Center for Rural Development — FOFIFA) was created by grouping together all agricultural research, but rice research was entirely under the responsibility of the Institut de Recherche Agronomiques de Malagasy (IRAM) or the Institut de Recherche Agronomiques Tropicales et des Cultures Vivrieres (IRAT).

Beginning 1982, rice research was redynamized because of the government's determination to attain self-sufficiency in rice for 1990. The participation of the following institutions and international organizations in research and finance was sought:

- International Rice Research Institute (IRRI)
- IRAT
- International Board for Plant Genetic Resources
- Cooperation Suisse
- World Bank
- USAID, International Agency for Development
- Fund for Aid and Cooperation
- European Economic Community, and
- Food and Agriculture Organization.

Because this conference is taking place in IRRI, we believe we should talk briefly on the cooperation between IRRI and FOFIFA/CENRADERU.

We wish to emphasize that for the first time in the history of FOFIFA/CENRADERU, a national program for rice research has been established. The program is implemented by a multidisciplinary team including two IRRI researchers (an agronomist and a genetic expert residing in Madagascar).

Table 4. Area planted to rice and rice production, 1905-51.

Year	Area (ha)	Rice production (t)
1905	300,000	400,000
1906	350,000	500,000
1936	500,000	680,000
1944	540,000	640,000
1951	700.000	1,025,000

Research activities embrace the following disciplines, and are conducted with close cooperation between the national and expatriate researchers:

- plant breeding,
- crop protection,
- soil science and fertilizer management,
- cultural practices, and
- agricultural technology

embracing all types of rice cultivation systems.

Short-term or long-term consultancies are provided to reinforce the national program. This has already involved visits from an economist, entomologist, and a specialist in farming systems.

IRRI also provides training to our national specialists. Four trainees are currently attending study programs at IRRI and others will be coming.

In the first phase of the project which will take 30 mo, the USAID has granted total support of US$42,400.00. This amount covers about 90% of the funds allocated the national program for rice research.

The project concerns 4 major rice zones in Madagascar, namely, the Hauts-Plateaux covering about 300,000 ha of rice land, Lac Aloatra (90,000 ha), Marovoay (30,000 ha), and Samangoky (10,000 ha).

FOFIFA, incooperation with IRRI and IBPGR, is undertaking research on wild and traditional rice strains as well as food legumes in Madagascar. The project will be extended later and will include other species such as food tubers, fruits, and other species of legumes.

CONCLUSIONS

Through this brief overview of the history of rice cultivation in Madagascar, we attempted to show how and to what extent rice is involved in the daily life of the Malagaches. It is essential to appreciate the importance of rice production in Madagascar to achieve optimum results. For this very reason, our program for national rice research takes full account of the different regional problems.

P. A. C. MTENJE
Minister of Forestry and Natural Resources, Malawi

RICE PRODUCTION IN MALAWI

It gives me great pleasure to join in the conference commemorating the 25th anniversary of the International Rice Research Institute. Allow me to thank, on my behalf and on that of my government, the Government of the Republic of the Philippines for the kind invitation extended to me to join this celebration, and to express my sincere appreciation for the warm reception and kind hospitality accorded to us by the people of the Philippines. I would also like to sincerely thank the Director General of IRRI for the excellent conference facilities he has provided.

This symposium is significant to us, as it is, no doubt, to all the other delegations assembled here.

Malawi is, by world standards, a small producer of rice. At its independence in 1964, for example, the total quantity of rice produced in the country was about 3,600 t. But this belies the fact that the crop has been grown in the country for many many years by smallholder farmers to whom it has been, and still is, a staple food in the same manner it has been, and is, to millions of people around the world. At independence, therefore, the government decided to encourage an increase in rice production to meet the internal demand as well as to sell to neighboring countries. Thus, the government introduced several agricultural improvement measures which included the establishment of irrigation schemes throughout the country and of a Rice Research Station at a site agroecologically representative of the country's rice-growing areas. The mandate of the Rice Research Station was to develop endogenously agricultural technology.

The Rice Research Station has tested the performance of several improved varieties bred and developed elsewhere such as Blue Bonnet, Basmati, and Nilo II. As a result of these tests, Blue Bonnet has been released to smallholder farmers with technical packages formulated to help them increase rice production. To ensure expansion in rice production, as in all other major crops, the government has extended credit facilities to the smallholder farmers to enable them to procure much-needed agricultural inputs. These measures have significantly increased total rice production in the country. About 14 yr after Malawi's independence in 1964, as much as 31,000 t of rough rice (a tenfold increase from 1964's 3,600 t) was purchased by ADMARC, the nation's agricultural marketing and development agency. This figure represented only a proportion of the actual rice production in the country. If all the rice the smallholder farmer either keeps for his family's consumption or sells to parties other than ADMARC were taken into account, it would be clear that rice production has increased significantly since independence.

Blue Bonnet, because of its relatively short growth duration, is grown twice a year in the irrigation schemes. Fava, a local long-duration variety, is also widely grown by smallholder farmers because of its unique aroma. Farmers can only harvest one Fava crop a year. Rice ranks only second to maize as a staple food, so the government is keen to ensure that production expands.

It is in this context that Malawi attaches the greatest importance to the 25th anniversary celebration of IRRI. Malawi sees hope in the existence and work of IRRI. IRRI's experiences and achievements over the past 25 yr can only be of benefit to Malawi's efforts to increase her rice production. As already pointed out, the Rice Research Station established in Malawi has tested several rice genetic materials, including those from IRRI. We have had the opportunity to test the very early, early, and medium-maturing varieties which include IR1561-250-2-2, IR1529-533-2-3, IET 4094, and P2360-6-7-14 (yields of 5.3, 5.7, 5.6, and 5.8 t/ha) which performed particularly well under Malawi's environmental conditions. More agronomic investigations are being carried out to determine not only the optimum economic fertilizer requirement for each variety, but also other cultural measures required to achieve economic yield potential under Malawi's environmental and socioeconomic conditions. In saluting IRRI on its 25th anniversary, therefore, Malawi, under the wise leadership of His Excellency the Life President, Ngwazi Dr. H. Kamuzu Banda, who is also Minister responsible for agriculture and whom it is my privilege to represent at this symposium, wishes to extend her appreciation of the invaluable assistance IRRI has extended over the years, in her efforts to increase rice production through, among other things, the introduction of high-yielding varieties. We would like to thank the donors who have offered financial and other forms of support to IRRI for enabling the Institute to do the work it has done in the past 25 yr.

At the same time, Malawi wishes to make it known that she cherishes the hope that a much closer collaborative relationship will develop between IRRI and Malawi. We have been particularly pleased to learn during this visit that Malawi's scientists can avail themselves of the training opportunities at IRRI in the fields of genetic evaluation and utilization, which would acquaint our participants with new techniques of breeding and evaluating improved rice cultivars; the INSFFER training course in soil fertility and management; cropping systems training in on-farm research methodologies for crop intensification; and the machinery development and testing course.

I wish to assure you that Malawi will take advantage of any training opportunity IRRI may offer. This is because, being basically an agricultural country, we wish to develop our agriculture to the optimum.

Collaboration with IRRI can go further than the four areas outlined. We understand that a regional workshop on rice was held in April 1984 in Lusaka, Zambia, during which a framework for regional cooperation in rice research and development was developed. We also learned that an IRRI liaison scientist for east, central, and southern Africa has been appointed to work directly with national programs in the countries in that part of Africa. Malawi hopes that these measures will help strengthen collaboration with IRRI for the mutual benefit of the countries involved. Certainly, in Malawi, where it is the wish of His Excellency the Life President that people should grow more of every crop, including rice, there would be scope for exploring possibilities of additional areas of further closer collaborative relationship with IRRI.

Allow me, once again, to salute IRRI on its 25th anniversary and to thank the government and people of the Republic of the Philippines for the excellent hospitality accorded to us.

S. N. GWEI
Vice-Minister, Cameroon

RICE PRODUCTION IN THE REPUBLIC OF CAMEROON

Permit me first of all to express, on behalf of my delegates, the gratitude and thanks of the Government of the Republic of Cameroon to the Government of the Republic of the Philippines and to the Director General of the International Rice Research Institute (IRRI) for inviting us to participate in the 25th Anniversary Symposium. We bring greetings from President Paul Biya of the Republic of Cameroon to President Marcos and to IRRI.

The food problem in Africa is well known the world over. This problem has claimed several million lives and many more people are close to starvation. Yet Africa has the potential to produce more food than she needs. Unfortunately she is plagued and often overwhelmed by poverty; natural disasters such as drought and insect pests; lack of trained personnel in agriculture and related fields; and political, sociocultural, and economic upheaval. The oil boom has unfortunately contributed to these ills as some oil-producing African countries seem to have given up emphasis on agriculture.

However, it would be wrong to say or conclude that Africans are doing nothing to solve the food problem. A careful look at many African countries would show that much has been done since independence to promote agricultural development.

It is through such efforts that many African countries, including Cameroon, have discovered rice as one of the crops that can be grown in Africa and that can contribute to the solution of the food problem. Rice was considered in many African countries as a western crop eaten mainly by

Africans who were capable of importing it. It was a delicacy eaten only on feast days or special occasions like Christmas.

Rice cultivation in Cameroon started after her independence in 1960, about the time IRRI was founded. IRRI's 25th anniversary coincides with Cameroon's double 25th anniversary: independence and the introduction of rice cultivation. When the Government of the Philippines and the Director General of IRRI invited us to this 25th Anniversary Symposium little did they know that we were coming here to celebrate a triple anniversary.

Agriculture is a top priority in Cameroon. Food self-sufficiency has been our main objective since independence. And today, Cameroon is not only proving itself self-sufficient in food production but is also fast becoming the granary of central Africa. Many of our neighbors depend on food produced in Cameroon. The introduction of rice cultivation is very timely indeed.

Research has proved that rice can be grown and is in fact being grown in Cameroon's three ecological zones — the forest, the savannah, and the arid regions.

However, rice produced in Cameroon is still far below the total national annual consumption of about 200,000 t. The total surface area cultivated is about 32,000 ha — 27,000 ha by SEMRY, 3,000 by UNVDA, 1,000 by SODERIM, and about 1,000 by peasant farmers.

IRRI and the International Institute of Tropical Agriculture (IITA) have supplied more than 800 varieties for trials in various ecological zones from which we have chosen high-yielding, early-maturing, disease-resistant, and cold-tolerant varieties. Three varieties have been selected and tested for 4 yr, and results sent to IRRI. UNVDA is coming up with 10 promising varieties which will be distributed to farmers for trials.

Rice growing in Cameroon is plagued by many constraints:

1. The newness of rice growing is in itself a problem. Because many farmers are unfamiliar with the crop, they are unfamiliar with rice problems. Many Cameroons who have eaten rice have never seen a rice plant.
2. Lack of trained manpower to handle research, training, and extension. This and the problem of newness of the crop are handled by state corporations known as Development Missions. The objective of the Development Missions is to help farmers with problems connected with cultivating and handling rice.
3. Storage, processing, and marketing of farmers' rice are also handled by these Development Missions.
4. In the various regions where rice is grown there is the microclimatic problem. Currently planted varieties are not adapted to the various altitudes. Research to identify varieties adapted to these climatic conditions is being carried out with the help of IITA and IRRI.
5. Rice cultivation in the tropical area has many problems. The forests are thick and rains are too heavy. In the semiarid region water is a problem because wells sometimes go dry.

6. Yield per hectare is still very low (1.5-3.5 t/ha), even with the new varieties.
7. Locally grown rice costs more than imported rice, thereby making competition difficult. Farmers who cannot sell their rice quickly give up cultivation.

Because the Cameroon Government is determined to achieve self-sufficiency in rice, everything is being done to solve these problems. With the help of IRRI and other rice research institutes we hope the rice crop will be better handled for the benefit of Cameroon and her neighbors.

C. WALKER
Minister of Primary, Industries, Fiji

RICE PRODUCTION IN FIJI

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. This was a decade before the establishment of the Consultative Group on International Agricultural Research (CGIAR). Today, IRRI is supported through the CGIAR by several donors including the Asian Development Bank, the European Economic Community, the Ford Foundation, International Fund for Agricultural Development, the OPEC Special Fund, the Rockefeller Foundation, the UNDP, and the international aid agencies of a number of countries, which include some developing nations.

The CGIAR, an informal consortium of governments, international and regional organizations, and private foundations was established in 1971 to nurture agricultural research to improve quantity and quality of food production in developing countries. The CGIAR has grown from a core of 15 donors contributing US$12 million to 4 research centers in 1972 to the present 36 donors contributing US$164 million toward the support of 13 international agricultural research centers.

This shows the importance of agricultural research. Indeed, agricultural research is essential for the very survival of human population, which is increasing at alarming rates in some countries. Food is a basic need of man.

RECOGNITION OF IRRI'S CONTRIBUTIONS

IRRI has played a major role in rice research. It is not possible or intended to cover IRRI's achievements here. However, it would be grossly unfair if appreciation for IRRI's contributions was not recorded. This has been recognized a number of times. In 1970 IRRI shared the UNESCO Prize for Science with the International Maize and Wheat Improvement Center (CIMMYT) located in Mexico. IRRI received the award for its work on rice and CIMMYT for its work on wheat and corn. The address of the Director-General of UNESCO, M. Rene Maheu, stated, "These are the two organizations which have played and continue to play a major role in what we call the 'green revolution.' Actually, this revolution is the introduction of science into one of man's routine activities, which until recently remained the least developed and is now becoming more essential than ever: agriculture. In a very short time, the undernourished regions have made an extraordinary leap forward in the production of certain cereals."

In 1982, for the first time, the Third World Prize of the Third World Foundation was awarded to an institution, IRRI. The citation of announcing the award on 18 November 1982 states:

> Over the last two decades when so much else faltered in the struggle against hunger and poverty, IRRI's quiet, persistent, highly professional and wholly dedicated work touched the lives of millions in the Third World, improving the human condition in truly practical and lasting ways.
>
> While the war on hunger is yet to be won, the contribution which IRRI developed and stimulating rice technology has made towards ensuring that no child, woman or man goes to bed hungry, is a vital element in the battle against poverty, hunger, disease and early death.

The award was presented by His Excellency Premier Zhao Ziyang, Premier of the State Council of the People's Republic of China, on 4 April 1983 at Beijing. In his address, His Excellency Premier Zhao Ziyang said,

> Since it was set up in 1960, the Philippines-based International Rice Research Institute (IRRI) has attained a series of scientific achievements and won high prestige in the Third World. This Institute has developed many good rice strains to help developing countries increase rice yield and improve Its quality. These strains not only can increase the yield markedly, but also can resist plant diseases and insect pests, shorten the maturing period and save water. The Institute has made important advances in rice genetics, physiology, soil science, etc. Its achievements have been spread far and wide in the Third World.

THE APPLICATION OF SCIENCE TO AGRICULTURE IN FIJI

The application of science to agriculture is essential in both developed and developing countries, perhaps more so now in the developing countries, to feed the expanding population. A small developing country like Fiji is constrained by lack of skilled manpower, funds, and other resources in its efforts to develop elaborate national research systems. What is justifiably needed is a small research system consisting of a group of well-trained competent scientists in appropriate disciplines who are capable of carrying out applied and adaptive research.

Agriculture research in Fiji is carried out by two organizations. The Research Division of the Ministry of Primary Industries is responsible for research on all crops (except sugarcane) and livestock and the Fiji Sugar Corporation is responsible for research on cane, with support from the sugar industry.

The Research Division of the Ministry of Primary Industries has been working in close collaboration with international research institutes and has received considerable assistance from these institutes, especially IRRI and the International Service for National Agricultural Research (ISNAR). With assistance from ISNAR, the research system was reorganized and a long-term research plan was developed for major agricultural commodities. The Research Division is now better able to plan and carry out relevant research and adapt technologies developed abroad.

Fiji's collaboration with IRRI goes back to the very early days of the Institute. Improved rice strains developed at IRRI have been regularly introduced into Fiji and most of the high-yielding varieties released in the country are either varieties bred at IRRI or have genes from parents bred at IRRI. Several agricultural scientists from Fiji have received training at IRRI. The need for such collaboration and assistance for a developing country cannot be overemphasized. High-yielding rice varieties that have potential under local conditions to yield more than 7 t/ha, compared to the national average of about 2 to 3 t/ha, have been released. With greater research and extension efforts it is planned to significantly increase the national rice yield over the next few years.

The Research Division of the Ministry of Primary Industries now has eight research programs. These are in rice, root crops, tree crops (cocoa and coconut), vegetables, pulses, tropical fruits, livestock, and soils and soil management. Major emphasis of the programs has been in developing high-yielding varieties adaptable to local conditions through introduction and selection and through breeding; developing improved cultural practices and plant protection measures; and introducing appropriate mechanization.

Past research has provided valuable information for planning and implementing agricultural development projects. Apart from the rices, improved varieties of vegetables, root crops, fruit crops, pulses, and other grains like maize are regularly made available to farmers. Root crops are very important food crops in the Pacific. Through a small breeding program, Fiji has become the first country to breed and release a taro variety for commercial production. Fiji also has had highly notable successes in the biological control of the rhinoceros beetle, a devastating pest of coconut, and in the control of a serious weed, koster's curse (*Clidemia hirta* [L.] D. Don). Bacterial wilt-resistant tomato and potato varieties have been released, as have suitable varieties of English cabbage, which enable off-season production. This has given the farmers opportunity to produce over a longer period and reduce imports.

In sugarcane breeding, Fiji has pioneered some of the work on the use of tissue culture for developing new varieties. The country's very successful and efficient sugar industry is the result of concentrated effort in research for developing suitable varieties for different climate and soil conditions.

In forestry, especially pine, varietal research identified a suitable pine that is now grown on a large commercial scale on previously unproductive land.

All these have become possible through the use of science and scientific methods in agriculture. With intensification of agriculture and expansion into new areas, new problems arise which can be solved only by experience and by competent scientists of national and international institutes who work together to make the best use of available resources.

RICE AND RICE FARMING SYSTEMS IN A BROAD PERSPECTIVE

Ninety-two percent of the worlds rice is grown and consumed in Asia, which has 55% of the world's population. Rice is the major source of calories and protein for more than 1.5 billion low-income people in Asia and hundreds of millions in Africa and Latin America. Rice comprises a third of the area planted to cereals in developing countries. In view of these statistics, the topic of the seminar *The role of science and technology in rice production agricultural progress* is indeed a very important one.

Research on rice cropping systems is complicated by different types of rice culture including upland rice, rainfed wetland rice, and irrigated rice; various irrigation methods; different rainfall patterns requiring cropping systems suitable for flood-prone and drought-prone areas; and for areas located at different altitudes and latitudes. Indeed, research on rice farming systems, which includes many crops and environmental conditions, is a major undertaking. Nevertheless, a start has been made and must be pursued vigorously.

IRRI scientists have made remarkable achievement in plant breeding, plant physiology, soil and plant nutrition, development of appropriate technology for rice cultivation, and other research relevant to rice. Much of the credit for 60% increase in rice production and 40% increase in rice yields in Asia goes to IRRI. In rice farming systems a good start has been made. Triple-cropping of rice with total rough rice yield of more than 24 t/ha per yr has been demonstrated. IRRI has also done research in cropping systems involving crop rotation, intercropping, and multiple cropping, and related areas. Biotechnology will perhaps dominate future agricultural research.

This, however, cannot be equated with farming systems in a broader term, which involves other production-related aspects such as land tenure, manpower availability, allocation of time by the farmer, socioeconomic conditions, credit facilities, and marketing. Some of the aspects are no doubt investigated by the International Food Policy Research Institute, also a center under the CGIAR system. Nevertheless the total canvas must be prepared for critical examination. Agricultural research alone will not solve food production problems. Suitable environment must be created by government policies in capital development, land, credit delivery, marketing, etc., to uplift the rural population and national development.

Our natural resources are not unlimited and need to be managed properly to sustain production and development. Many have accused research institutions of developing and pressing for adoption of varieties which, although they provide high yields, require considerable fertilizers and agrochemicals, and have led developing countries to depend on imported fertilizers and chemicals instead of imported food grain. However, it must be noted that better and pest-resistant varieties are being developed, adoption of which, if combined with integrated pest management, will not adversely affect the environment. Research on farming systems must consider various factors including environment. It must be kept in mind that we have not inherited the earth from our forefathers but borrowed it from our children and their future generations.

RICE RESEARCH: CHALLENGES

E. F. WHELAN
President, World Food Council
and
Former Minister of Agriculture, Canada

THE GLOBAL FOOD SCENARIO AND ITS IMPLICATIONS FOR INTERNATIONAL AGRICULTURAL RESEARCH

Yesterday mention was made of the man who was the former Minister of Agriculture of the Philippines for 13 1/2 yr, I believe, and President of the World Food Council for 4 yr. I knew Arturo Tanco from 1972, whose death from cancer at the age of slightly over 51 was an untimely one. He was not scared of anyone who got in the way of trying to do something for those in the world who needed aid. He was not afraid to approach anyone, to ask them for assistance. We have lost in the world a man who will be missed by many, many who never knew him but whom he also helped.

My topic is *Global scenario and its implications for international research.* If it was not for people multiplying we would not even need research, would we? Let us look at the facts though. Since the beginning of mankind, what has taken place with population? From the year 0 until 1980, we have grown to 4.2 billion people. By the year 2000 we will have six billion people, nearly a 50% increase in population. Can we look after them? If we really want to, we can. Let us look around us. If the developed part of the world decides to go to war, we have the knowledge, the ability, the technology, and the resources to instantly mobilize war. The billions we spend every year! In 1984-85, the developed part of the world and the developing part of the world will spend nearly one trillion dollars on sophisticated weaponry — the scientifically destructive equipment that the world has never seen.

In my country, when I was Minister of Agriculture, our agriculture budget was 1.5% of our total budget, and defense was 14% because our allies accused us of not contributing our full share in the North Atlantic Treaty Organization. We were not, however, much different from many other countries spending little on food.

We spend a lot on health in Canada — 39% of our budget goes to social services. In Canada we live longer than most people in the world — average age expectancy now is 75.7 yr. Not bad for a land of ice and snow, referred to one time by the King of France, when he was abandoning Canada, as "that wasteland, who wants it anyhow?" They said "What about those settlers?" And he said, "Who wants that land of ice and snow, wasteland? Let them survive the best way they know how." And of course, some of us did. We survived. How? By sharing, cooperating, and working together. Otherwise, we never would have accomplished anything.

And where did we come from in Canada? We came from all over. In the part of Canada where I live there are 72 different ethnic groups — from India, Asia, Africa, Europe, South America — you name it, they're from all over the world. Some of them came without anything. My ancestry is Irish, French, Welsh, and Indian. My wife is a pure German Yugoslav. And I have a Finnish sister-in-law, a Romanian brother-in-law, a Hungarian sister-in-law, and two German brothers-in-law. I live in an Italian community, and they call me Gino all the time. I am using this as an example to show that by working together we can accomplish nearly the impossible if we want to.

When we talk about feeding the world, it is not impossible. We can turn the world into a productive area if we want to. I read what Dr. Swaminathan said about Africa, and I agree with him. If we really want to, in 15 yr we would not recognize Africa. We would not even believe this terrible tragedy that is taking place could take place. And we have people among us — world leaders in the UN organizations — who say "we did not know what was happening."This is a lie! We watch by satellite what is going on around the world. When any one of you starts to dig a hole we become alarmed because you may be putting up a missile or something. We know when you are reading a newspaper in the backyard, what day it is, and who published the newspaper. We know when the greenery is disappearing, when the trees are dying, or when the grass is growing. We know when the land is barren. We can even tell by satellite where the minerals are. People know, for instance, that Canada is the richest land in the world because it has every kind of mineral that you can imagine. We can tell where the water is by satellite — infrared, radar, all the different techniques. We know the temperature of every village in every part of the world every day. Every marketing system in the world has a satellite. But people are not concerned about people dying or anything. The sensitive equipment they have on the satellite is to tell them what the weather is going to be like and what the crops are going to be like and where they should concentrate the sales of their products. Research has done some tremendous things, but they could be better used for the good of mankind.

Every government goes through budget cuts. I never let our government touch research in Canada. We had the largest research budget, and we always had some bureaucrats say, “What do those farmers know about research in agriculture?” And those bureaucrats have the biggest branch of any department in all of Canada. They spend more than $350 million a year on research.

We’ve had people come from China, the Soviet Union, and all over to see how we produce in our land of ice and snow. We produce 55% of our food farther north than any other country in the world.

When I was a kid they used to scare us by saying “If you do not behave we will send you to Siberia.” And my god, we thought that that was the end of the world. But Siberia is just like the city of Regina, Saskatchewan, Saskatoon, Calgary, or Edmonton. Those places are as cold as Siberia, even colder. In the winter it is 50 degrees below zero, and in summer it is as hot as it is here — 33 degrees. It was 35-36 degrees in Saskatoon for 30 days straight last year. It cut grain production 22%.

So you see, when we talk about research, and we know the things that we can do, we can if we really want to. We can turn desert into productive land if we want to. All one has to do is go to the University of Arizona in Tucson. See what they have done around Phoenix, Arizona, in that horrible, rough, tough desert where nothing but creosote bushes and cactus used to grow. It is like you are in the Garden of Eden. You can go to Mexico and see what they are doing there in the desert. You can go to Israel, and see what the scientists have done there with wasteland, land that they said no one wanted.

We have an exchange agreement with scientists in Canada and Israel — we signed that 8 yr ago — I signed it. They work on projects, we work on projects — we work back and forth exchanging scientific knowledge. Look at Australia and the deserts there. Rapporteur Flinn knows more about that than I do, but I have read about it and I have been to Australia. And we know what you can do. I just came back from Africa — spending 3 wk visiting in Burkina Faso, Niger, Ethiopia, Somalia. I was in the Ivory Coast mainly because of the plane connections we made there, and in Kenya. But there were deserts where you see big trees, still alive, nothing but sand below, green on top. That tells you two things, there is moisture down below and the trees are too big for a goat to eat. The vegetation is all gone but there are thousands of goats and sheep, skinny cattle, and camels running all over the place eating every damn thing in sight. There has to be a whole change. Turn the scientists loose, turn the developers loose, and spend some money. Because that is how they did it in Arizona, California, and Israel, and that is how they are doing it in Mexico. With money and technology and scientists, you can do it in any place if you want to. And you will not have to spend as much as on a war that kills people. But here we are, killing millions of people because we refuse to assist them and help them. Millions of people are dying. Let us look at one country — Ethiopia. If Ethiopia was farmed right, Ethiopia could feed 240 million people. The Sudan, if farmed right, could feed all of Africa. Sure, with some soil conservation and water conservation, and all of these things involved — but you must stop the desert encroachment. That is the scientists’ job. You have to turn it around because if you do not have greenery, you do not have rain. You heard earlier today the statement of how seven trees are necessary for you stay alive and have life-giving oxygen. I remember when I was Parliamentary Secretary to the Minister of Fisheries and Forestry, and we knew one rotting tree in a forest took all the life-giving oxygen out of an acre of forest, of healthy trees, through its rotting process. So there has to be massive reforestation, massive drought-resistant grasses, too. We can do that with airplanes — we can bomb the deserts with seed and fertilizer, and moisture. You do not do anything until everything is just right, but you can bomb the whole desert. You have 20-50% chance of growth, if nothing will eat it when it comes up.

When we talk about the overall situation, let us ask what we are doing in our society. We are saying to some, "You can live," and to others, "you can die, because we are not going to spend any money on you." That is actually what we are saying. We spend about $15 billion a year on food aid, but we spend more than $900 billion on war material. We have to change some of our ideas, and our principles.

In Canada, we give more per capita to the Third World than anybody else and I am proud of it. Many Canadians did not have anything. Now we are rich and we share our resources. I was in Geneva 6 weeks ago when Vice-President Bush said, "I am proud of the citizens of the United States of America because they have given $70 million." I could not say anything because at that time, 25 million Canadians had given $50 million. So this is what I'm saying, it all depends on the attitude and what you are doing within your country.

I read Dr. Chandler's book. He talks about financing of IRRI. I could not believe we did so little, because IDRC which is totally Canadian funded is listed as if it was some foreign company. This year (1984-85), according to my latest information, Canada gave to IRRI $3.5 million. I turned right away to finances in the index and it told about how Canada, at one time, was going to be second to Rockefeller Foundation in supporting IRRI. It said that in 1969, there was some opposition in Parliament because the wheat farmers did not want Canada to give aid for rice research. And then it went on — and I really liked this part — "But in 1972 things changed, Canada became a big donor to IRRI." I became Minister in 1972. I can remember them saying to me, "Are you not concerned that you are giving so much for rice research?" (I think we were number two or three at that time). I said, "No, because the need for food is so great in the world. Even if we distributed it properly there would not be enough to go around. If everyone had proper diet, with proper nutrition, proper vitamins, proper minerals, — there would not be enough for them all with the production we've got." And Canada's land is very fragile. And look at the land base in Africa and South America, the potential for production is hardly being scratched. Argentina has a land base that would make any Canadian farmer envious. Canada has no land like that in Argentina, that can produce so much food.

The Fathers of Confederation in Canada established research stations and experimental farms before there were provinces. I can remember going to one of the research stations in Lacombe, Alberta, and I said "Gee, it must have been a lot of work to clear all the land here" (there were trees that big). They said "No, Mr. Whelan, the director of this research station, when it was first established in 1907, liked trees, and he planted trees. We have a research station in Canada where trees from Siberia, Mongolia, Asia, and Africa were brought in 1905, 1906, and 1907 in what was called the Northwest Territories, because they knew if they broke the land, they would have to have trees to protect it. We know these things have to be done — it is not that we do not know how to conserve our land and do all these things. It is getting that across to people. And if there is anything that is needed in the world, it is agricultural extension and education, so people can learn to read and write. The research that you do here at IRRI, or at any research station, is not any good if it does not go outside. It is obvious to me that it is going outside, but it is also obvious to me that not enough of it is going outside." I have visited research stations in South America, Asia, Africa, and around the world, and every time they think of Canada they say, "How do you get the extension?" And one of the things I have found is that research people are the same all over the world — they are there to help mankind have better life.

We had a researcher in charge of a station away down in one of our eastern provinces. They called him "Big Mac." There were a lot of new Canadians in the area who did not read and write English or French. Big Mac got up in the morning and went out in the orchards with them, at 3:30 in the morning, to show them how to use their sprayers, and how to spray before the wind come in the orchards. They wrote a petition when he was moving to another station, to have me stop him from moving, because they did not want him to go. Now you see, what he was doing in our country was contrary to the constitution because the constitution says that education is a provincial jurisdiction, not a federal one, and he was a federal employee. We do practically all the research in agriculture in the provinces and the provinces want us to do that kind of thing.

The world is as small as an island. We know what is going on. We should have the concern and the responsibility to make sure the terrible tragedy that is taking place in another part of the world does not continue.

In Ethiopia there are about 2 million mentally and physically retarded children, many ofthem orphans, a lot ofthem blind. Because of lack of Vitamin A their eyes collapsed and they will never see again. There is no one to take care for them. How in the hell can we let that take place in 1985? Are we not our brothers' keepers? We are supposed to share with one another. How can we be oblivious to what is going on? I submitted a report to my government in 1983, and I did not get what I wanted, but it made Canada the largest donor in the world to Ethiopia at that time. We said there would be a mass movement of people out of the hills. We wanted helicopters, we wanted armies to move in with their helicopters and airships, with their medical supplies, and tents and all these things, because we could foresee what was going to happen. My government said I was nuts. It makes me 50 sad when I read that report that we submitted in September 1983 about what was taking place. I would be glad if I had been wrong. It makes me sad that I was right and could make so few pay attention. There were people there from World Vision, Catholic Aid, International Red Cross. There were people from UN bodies who were not putting their information together and assimilating it. I was 10,000 miles away and I submitted a report, after I looked at satellite pictures of Africa. There was only a little green area across Africa — all that is left of the rain forest. At one time much of Africa would have been green in a satellite photo. There must be a massive movement of some kind to stop desert encroachment. When I came back from Africa I wrote every world leader who had money, and told them it is their responsibility, that we have no right to say "Our budget must be cut. We cannot have a deficit. You can die until we can get our deficit a little smaller." How inhuman can we be!

In Africa, there is nothing. I saw people I could not believe were still alive. Skin, and bones, and skeletons. But alive and dying. I was in the settlement camps one time and I could not believe what this AID person was saying. "We need 16,000 oxen in this resettlement area." And I knew the land was fragile. I knew they could only produce about 3 mo a year. And I said, "16,000 oxen? You're going to use them 6 wk a year. What are you going to do with them the rest of the time?" "Turn them loose," he said. And eat every damn thing in sight. Turn them loose! And I said, "Why don't you do like China, why don't you do like Zimbabwe, like some of the other countries that have shown how successful they can be — by providing infrastructure — roads, marketing, income, etc.?"

People produce all the food that they want if you give them a decent living and a decent chance in life. They are entitled to that. They are entitled to everything that you researchers can do. They are entitled to everything that the politicians can do. They are entitled to something more than they are getting.

J. C. INGRAM
Executive Director, World Food Programme, Italy

THE ROLE OF THE WORLD FOOD PROGRAMME IN AGRICULTURAL RESEARCH

It gives me great pleasure to participate in this symposium marking the 25th anniversary of IRRI, not least because of the opportunity to renew acquaintance with many old friends and to update my knowledge of the work of the international agricultural research community which is here represented by its most distinguished members. I would like to express my personal gratitude to you, Dr. Swaminathan, for inviting me.

When IRRI was created 25 yr ago, world artention focused on hunger in Asia. The news media was full of stories of famine and malnutrition in the region. The problems seemed so daunting that some eminent personalities of the time virtually gave up, so much so that some of the prosperous, largely food self-sufficient countries of this region were at that time being described as "basket" cases and bottomless pits.

Looking back over the last 25 yr, one can, therefore, justifiably congratulate IRRI for a job well done. IRRI provided the technological impetus which, together with the proper policy environment provided by governments and the accompanying tremendous investment in training and extension and in irrigation, resulted in the transformation of Asian food production.

Although much has been achieved, it is too early to sound the victory bell. Given the population pressure in Asia, the continuing existence there of many millions ofseriously malnourished people and the vagaries ofnature, IRRI and the other international agricultural research organizations cannot relax. As most of you would know, much better than I, rice diseases and resistant insect populations can reduce to naught past breeding efforts which laid the foundation for the tremendous increases which have taken place in rice production. As Dr. Swaminathan noted yesterday, there is a continuing need for *maintenance* research.

However, I am not going to talk about the technical challenge of rice research — I am not personally qualified nor do I come from an organization equipped to do so. Rather, I will address myself to the most urgent challenge that IRRI and the rest of the international agricultural research community will have to face in the future.

That challenge is not too difficult to discern. Over the last year or so we have been buffeted with pathetic photographs of starving children and emaciated women and men in Africa. A continent which only a decade ago was a net exporter of food is starving — unable to produce or pay for the food it needs. The African of today has 10% less food than 10 yr ago and the situation is worsening. The international community has been generous with food aid and other forms of emergency assistance. But I am sure we are all convinced that, valuable as emergency food aid is, the real solution to Africa's food problem lies in long-term development programs aimed at advancing the indigenous capacity of Africans to solve their problems.

In contrast to Asia, Africa has done poorly in food production. This is exemplified by rice, which tripled in production from 140 million tonnes in 1960 to 420 million in 1983. In Africa during the same period, rice production only doubled, from 4.3 million tonnes to 8.5 million tonnes. But African rice imports increased sixfold from 500,000 t to 3.2 million tonnes.

Moreover, whereas rice yields in Asia have doubled in 20 yr, Africa yields remained effectively stationary — they are now lower than Asian yields of 1960. Rice is, of course, not a major crop in Africa, but these figures dramatize the problems which Africa is facing, namely, how to cope with growing consumer preference for cereals that compete with traditional staples.

If, for a crop such as rice, which has been the focus of research attention worldwide, Africa is lagging behind in yields, it is not difficult to imagine how serious the situation is in relation to the traditional crops of the continent, which have received much less attention. Here lies the challenge to the international agricultural research community, namely, to develop appropriate technological packages adapted to the farming systems of Africa, for crops such as cassava, white maize, sorghum, millet, yam, cowpea, and for animal production. Technologies are required which will have such an evident impact on production that governments will be stimulated to evolve policies encouraging their adoption by small farmers while stimulating the donor community to commit the necessary resources required to develop the supportive infrastructure needed to launch and sustain a second green revolution, this time in Africa.

I do not underestimate the difficulties of doing this because the problems of Africa are many and complex and their interrelationships not well understood. They include old, eroded, leached soils; limited water resources; complex farming systems without clearly identifiable lead crops; trained manpower shortages; weak research and extension institutions; uncertain and sometimes counterproductive policies; and a failure to recognize the often critical place of women in the production process. Solutions to these problems are made more difficult in many countries by an accelerating desertification and rates of population increase never previously attained.

I would like to say a few words about how the World Food Programme (WFP), in conjunction with other donors, is playing an innovative role in relation to cereal marketing and pricing policies in the Sahel countries. Also, on account of their relevance to a proposal I will be making at the conclusion of this address, I shall make one or two comments about farming systems and the role of women.

In many African countries there is need to resolve the dilemma of a food pricing policy that increases producer prices to levels that encourage higher production while keeping prices low enough for poor consumers. Food aid and its counterpart funds can be used to resolve smoothly and gradually over time this dilemma. Unfortunately, if food prices are raised abruptly, the result is often public disorder that may lead to political instability. WFP and other donors are assisting a project in Mali to deal with this dilemma. WFP food aid is sold in Mali, and the proceeds are deposited in a common counterpart fund and used to support an agreed program for gradually raising cereal prices to consumers to a level high enough to stimulate increased local production. In Senegal, a similar approach is being developed with a group of donor countries and WFP under which funds generated from the sale of food aid commodities is used to support the government's policy decision to shift consumption away from imported wheat and rice toward locally produced cereals.

The assurance of regular supplies of program food aid over a number of years from a group of donors and the creation of a counterpart fund in which the proceeds of food aid sales from all participating donors are pooled provide a safety net for the governments in these countries, both heavily dependent on imported food, to launch these difficult but necessary reform measures.

There appears to be a fair agreement that even in Asia the direct transfer of western technology has met with limited success and the single discipline or commodity-specific research approach has worked well only in environment suited to specialized food production. Even in much of Asia the trend is in the opposite direction. In Africa the need for an understanding of current farming systems is much more important. This understanding must include not only the cropping systems but also their major interactions with other farm activities, many of which are the domain of women. I believe that this point cannot be emphasized too much because unless it is not only recognized, but also acted upon, progress in improving African farm production will continue to be disappointing.

Unfortunately, the process of agricultural transformation in Africa will be much more difficult and tangible results will be attained more slowly so that seemingly fruitless efforts will have to be maintained longer than was required to bring to near maturity the green revolution in Asia.

This is a challenge that the Consultative Group on International Agricultural Research, national research organizations. and the multilateral and bilateral financing agencies are called upon to take up with great purpose and energy. The WFP will be willing indeed to play its full part in this worthwhile endeavor, as I will explain in a moment.

The WFP came into being some 22 yr ago, at a time when much of Asia faced serious food deficits. It started as an experiment in the use of food aid as an investment resource to foster social and economic development. Since then, the program has grown to become the largest development program of the United Nations. Development projects valued at $6.8 billion have been completed or are in progress. All of this is apart from WFP's feeding of the victims of natural disasters, refugees, and other displaced persons. While this activity is more often the object of public attention and is of enormous importance, it does in fact consume only one-third of the resources available to the program.

WFP-supported rural development projects have focused mainly on employment creation in rural areas and on investment in hard infrastructure needed for agricultural development, i.e., irrigation, land development, and rural roads. A few examples of WFP's investment projects in Asia may be in order.

The program has participated in the Rajasthan Canal Project in India since 1968 in partnership with the Government of India and the State of Rajasthan. The program has committed US$42 million to this labor-intensive project which has as its main objective the construction of a 650-km main canal and an 8200-km distribution system to irrigate 1.5 million hectares of desert land by 1995. To date, more than 500,000 ha have been developed and put to productive use.

In Bangladesh, WFP has been involved in a food-for-work program in which wheat is supplied as payment of wages to seasonal labor, in conjunction with assistance from Canada, USA, the Federal Republic of Germany, the United Kingdom, and Australia, for the construction of flood control embankments, coastal embankments for the prevention of salt encroachment, canals, and field distribution channels for irrigation; and the construction and maintenance of rural roads. This program, which generates 72 million man-days of employment per year, has cost WFP US$250 million since 1975, and a new 3-yr expansion phase costing US$110 million was approved last week by our governing body.

It is a particularly interesting project to illustrate that the supply of a commodity, wheat, which changes consumer tastes, is not necessarily harmful. Throughout the life of this project in Bangladesh wheat and rice production have increased steadily.

A transmigration project in Indonesia which has so far settled 90,000 families on 200,000 ha of newly opened land has received support worth

US$72.5 million from the WFP, while in China resources worth US$200 million have been used in support of successful projects in irrigation, drainage and land improvement, soil conservation and reforestation, and aquaculture. Similar projects could be cited for many other countries in the region.

WFP's participation in the agricultural development efforts of countries in Asia has been a happy and rewarding experience. The positive results are there to be seen as the external evaluations made of them attest. Many of them show convincingly that food aid can be a very useful resource to promote rural development and that its well-known potential disincentive effects can be avoided with carefully planned projects which are well integrated with national development plans and which also receive appropriate technical and financial inputs.

The results of these and other projects have been positive because improved crop varieties and reasonably appropriate technologies were known to farmers so that they were able to realize the benefits flowing from improvements in water management brought about by irrigation, drainage, and land improvement. The countries concerned had relatively well-developed institutional infrastructures staffed by qualified scientists, planners, and administrators, and, where these were lacking, necessary institution-building programs were developed.

The WFP has for many years made similar investments in Africa. Indeed the value of current investment projects in sub-Saharan Africa is $1.3 billion. But the results have not been as good as in Asia. I am convinced that one important cause of this has been that African countries lack the requisite institutional infrastructures to support agricultural development. Many of these countries lack not only the institutions and the persons to run them, but just as importantly, the funds to cover the local running costs of existing services already benefiting from external assistance.

The WFP and the donor community must do more, much more, to deal with the real constraints that keep Africa from participating in the overall progress that has been made in food production worldwide. WFP is intensifying its support for African rural development along the lines of the Asian projects described; but because we attach so much importance to an intensified research and extension effort for Africa we wish to extend our support to African national research and extension programs, including outreach activities of the CGIAR centers undertaken in conjunction with national authorities.

In principle, what I would like to see is the monetization of some WFP food aid to assist those African countries that already are undertaking or are committed to undertake research and training programs related to farming systems. Budgetary constraints are a serious impediment to this in many African countries. As well as using the proceeds of food aid to support such national research and training, it would be desirable to support also national extension programs in the same countries and to encourage extension activities that pay particular attention to the place of women in farming systems. I am convinced, for example, that modest programs of multiplication of traditional vegetable seeds combined with some limited focus on cultivation methods could have a dramatic impact on an overlooked but important aspect of food production in many sub-Saharan countries.

Clearly, if WFP's governing body is to approve a project of this kind it will need to be convinced that monetization is warranted. For various reasons, this is approved on an exceptional basis only. To obtain that approval, such a project would need to be developed in close conjunction with the CGIAR and the World Bank and I shall be writing to both institutions to propose a way of proceeding, always assuming of course that they would be interested in such collaboration.

If I have digressed from rice, it is because the major agricultural research problems of today and the near future are related to a complex of crop and livestock problems in a part of the world where rice is but a minor crop with limited development potential — a part of the world where the gravity of the food situation today is such that a concerted effort is needed on the part of all donors to assist in the development of new technologies, to support the required institution-building, and to help meet some of the local costs. This places a great burden on the international agricultural research system not least on IRRI, not only in relation to rice production per se, but by adapting and developing fully the knowledge it has gained about how to increase production of a particular crop on small farms with diversified production. IRRI's understanding of how to help such farming systems should provide important insights into ways of helping African farmers, even those not engaged in rice production.

S. S. PURI
Assistant Director and Regional Representative for Asia and the Pacific, Food and Agriculture organization of the United Nations

THE ROLE OF RICE IN ASIA'S FOOD SECURITY

I feel greatly honored that I have been invited to speak at this symposium. I take this opportunity to congratulate IRRI on completing 25 yr of dedicated service to agriculture. As one of the cosponsors of CGIAR system to which IRRI belongs, FAO is naturally happy to associate itself with the anniversary celebration. On behalf of the Director General of FAO, and on my behalf, may I extend heartiest felicitations to the Director General of IRRI and his colleagues.

I shall divide my talk into three parts. In the first part, I shall talk about the importance of rice as food in various Asian countries. Then, I shall present a brief outline of the concept of food security. Finally, I shall deal with the role of rice in food security.

FAO recently completed the Fifth World Food Survey but its findings have not yet been issued. The food balance sheets are thus available only for 1979-81. During this triennium, the average per capita per day calorie intake varied greatly in different Asian countries. Bangladesh had the lowest intake — 1,837 calories. The other end of the spectrum was represented by the Republic of Korea where per capita calorie intake was 3,056.

The variation in different Asian countries is even more striking. Burma is the largest per capita consumer of rice. Rice accounts for 1,906 calories representing almost 78% of the total per capita calorie intake.

Besides Burma, in countries such as Bangladesh, Indonesia, Laos, Thailand, and Vietnam rice accounts for more than half of the total calorie intake. In some other Asian countries rice is of relatively marginal importance. For instance, in Pakistan, rice constitutes barely 14% of the total calorie intake. In Mongolia, it is as little as 2%.

In another group of countries, rice constitutes 30-40% of the total calorie intake. These countries include the two largest Asian countries, China and India. Our host country, Philippines, also falls in this category.

With these figures, Asian countries can be divided into three distinct groups: 1) those where rice does not have a significant share in the food basket of the average citizen of the country, 2) those where rice is an important element in the food basket but not a decisive element, and 3) those where rice obviously is the most crucial food. On the whole, for more than two-thirds of the Asian countries, rice constitutes a significant element of total food intake. Hence, rice has an important role in determining the status of food security of these countries.

The concept of food security continuously evolves. In recent years, an enlarged concept of food security, enunciated by the Director General of FAO, has come to be internationally adopted. This concept visualizes food security as having three components: 1) adequacy in food production, 2) stability in food supplies, and 3) physical and economic access to food by needy households.

In discussing the first component, adequacy in food production, it is appropriate to look at the situation in Asia during the 10-yr period ending in 1984. I chose this period for two reasons. First, in 1974 the World Food Conference was held and the world community adopted certain goals affecting food security. Second, food production in Asia cannot be properly appraised except in a broad historical perspective and the decade ending 1974 provides a suitable time span for this purpose.

As is well known, the phrase *food production* is a fairly broad phrase and includes products such as cereal crops, noncereal food crops, livestock products, etc. Because cereals constitute the staple food of bulk of the population of Asia, I shall confine my analysis to them.

In 1974, total cereal production in Asia was 482 million tonnes. This rose to 730 million tonnes in 1984. On a point-to-point basis, cereal production in Asia between 1974 and 1984 rose by as much as 51.5%. Taking 10 yr of the decade ending 1984, the annual compound growth rate was 3.8%. This is indeed a highly satisfactory growth rate.

Asia’s performance in increasing cereal production is highlighted if the following aspects are considered.

- Although during 1974-84, Asia recorded a growth rate of almost 3.8%, the corresponding figure for the rest of the world was only about 1.7%. This shows that Asia’s achievement was more than double that of the rest of the world.
- The compound growth rate of 3.8% is for Asia as a whole, including Japan. If Japan, which is a developed country, is excluded and only the developing countries of Asia are considered, the growth rate for the period 1974-84 is even higher, about 4%.

- What is most gratifying is Asia's performance in the last 5 yr. The relevant figures of cereal production in these 5 yr are as follows:

1980	590 million tonnes
1981	614 million tonnes
1982	630 million tonnes
1983	703 million tonnes
1984	730 million tonnes

If the 5 yr (1980-84) are taken into account, the annual compound growth rate for cereal production in Asia is 5.8%. I hope you will agree that all concerned, including policy makers, agricultural scientists, extension workers, and, above all, Asian farmers deserve recognition for this remarkable achievement.

During the decade ending in 1984, Asia witnessed an annual compound growth rate of 3.8% for all cereal crops. I think it is important now to consider what has been the contribution to this growth rate by individual cereal crops — rice, wheat, etc. Data show that the highest contribution was from wheat. In 1974, total wheat production in Asia was about 72 million tonnes. By 1984, it had more than doubled to 146 million tonnes, registering an annual compound growth rate of 7%. In 1980-84, the growth rate of wheat in Asia exceeded 10%. Another significant feature of wheat's contribution to food security lies in that in countries like Bangladesh, a new dimension has been added to food security as a result of the introduction of wheat crop.

I would now like to discuss the contribution of rice to adequacy in food production. Unlike wheat, rice is more widespread in different Asian countries and has a much greater weight in the index of cereal production. During 1974-84, rice in Asia witnessed an annual growth rate of 3.3%. This is a moderate growth rate and, by no means, as spectacular as that recorded by wheat. Furthermore, the performance of rice during the recent decade in different Asian countries has been extremely uneven. Countries such as Burma, Indonesia, and Sri Lanka, have had high growth rates ranging from 5.8'% to 6.9%. China, the Democratic People's Republic of Korea, India, Pakistan, the Philippines, Thailand, and Vietnam had medium growth rates ranging from 3 to 4%. Eight countries have recorded growth below 3%.

There is another way of looking at the unevenness among different countries in Asia. This is with regard to rice yields per hectare. There are 18 rice producing countries in Asia. Of these, China, Republic of Korea, Democratic People's Republic of Korea, and Japan, had 1984 rice yields ranging from 5.3 t to 6.5 t/ha. Burma, Indonesia, and Sri Lanka had yields from 3 to 4 t/ha. Malaysia, Pakistan, Philippines, and Vietnam had yields from 2.5 t to 3 t, and Bangladesh, Bhutan, Kampuchea, India, Laos, Nepal, and Thailand had yields below 2.5 t/ha.

I mention these details to highlight the fact that in several Asian countries, there are still numerous unresolved problems that continue to limit productivity growth in rice. I shall not go into the details of these problems because I expect many other speakers will deal with them.

I would like now to turn to the second component, namely, stability in food supplies. One of the important aspects of this component is food grain stock buildup and management. In recent years, a number of Asian countries have endeavored to build up food grain stocks as an important element in their strategy for food security. At the end of 1984, the total food grain stock with the countries in Asia exceeded 80 million tonnes. Of this, about 30 million tonnes was rice and 50 million tonnes was wheat. It would thus be seen that in the Asian situation, wheat plays a bigger role than rice with regard to food grain stock policies. This is presumably a reflection of two factors. First, wheat has a better storage quality, and second, wheat production is relatively more concentrated in certain parts of the countries and hence lends itself more easily to public procurement for food stocks.

The third component of food security, access to food by those who need it, is crucial. Its effective implementation depends a great deal on progress in the first two components — adequacy in food production and stability in food supplies. I need hardly point out that if, in a given country, the aggregate production of food is far short of the aggregate demand, then the task of providing access to food on the part of vulnerable sections becomes doubly difficult.

Among the developing countries of Asia, the per capita per day calorie requirement has been estimated by FAO and WHO as ranging from 2,160 to 2,360 calories. The per capita calorie availability is short of the estimated requirement in about one-third of the countries and exceeds the requirement in about two-thirds of the countries. This means that, in bulk of the developing countries, if all households had equal access to available food, there need be no undernutrition. But we know that in most countries, there are glaring inequalities in food purchasing power among various households. It is this factor that accounts for lack of economic access to food by a large section of the population even when physical availability of food in the aggregate is adequate.

I need hardly mention that there are no easy solutions to the problems of lack of equitable access to food. The most durable solution is to upgrade the income levels of the vulnerable sections of the population. While a number of medium- and long-term plans have been drawn up by different countries in this direction, several countries have also devised short-term special measures to improve physical and economic access to food of the needy households. These measures involve difficult questions of logistics and finances and questions of price policy in relation to food producers on the one hand and food consumers on the other. It seems to me that in the coming years much greater attention and effort will have to be directed toward agroeconomic research in these matters. So far, there has been preoccupation with biological and other agrotechnological aspects of rice and various other food crops. For food security in Asia, time has come when equal attention should be paid to the economic aspects of marketing and distribution of various food crops including rice.

K. HEMMI
Chairman, IRRI Board of Trustees

THE GLOBAL RICE SCENARIO AND IRRI'S RESEARCH THRUST

First, we must recall the food situation in Asia before 1960. At that time, population growth in Asia was accelerating. Leaders in and outside of Asia were very much worried that the increasing food requirements in Asia might exceed the increasing capacity of the rest of the world, especially of North America, to feed the Asian population. Nowadays we talk very often about the African food situation. However, almost no one questions the ability of the world to feed Africa. The Asian food situation at that time was much more serious than the present African food situation.

World rice production increased about 40% in the 1960s and about 30% in the 1970s. As you know, the increase in rice production in each of three major rice growing and consuming regions of the world — South Asia, Southeast Asia, and China — was very impressive. The food situation in Asia has improved significantly during the past 25 yr although there still are hundreds of millions of undernourished people. The rice growing countries were primarily responsible for these impressive developments in the Asian food and rice economy, which often is called the green revolution in Asia. However, the development of semidwarf strains of rice (and wheat) encouraged them to launch comprehensive rice (and wheat) production programs in the 1960s. In this sense, IRRI and the other international agricultural research centers contributed significantly to the world hunger campaign.

I admire the foresight of the Ford and Rockefeller Foundations, in establishing international agricultural technology transfer agents like IRRI.

When IRRI was founded, few had recognized the location-specific nature of agricultural technologies, and research needs for subsistence food crops were largely neglected in many developing countries. Moreover, rice was grown and consumed mainly in developing countries, hence scientific and technical knowledge about rice was rather limited. Locating a center of scientific excellence devoted to solving the rice problems of the developing world in the developing world fulfilled a keenly needed role in the world hunger campaign. I admire the Government of the Philippines which agreed to offer space and other services needed for IRRI's establishment.

Because of time limitations, I will not discuss IRRI's past achievements. I shall speak only on one point — IRRI's strategic research. Usually, international agricultural research centers (IARCs) work on research and training. Research is not basic research but is applied research or research related to developing specific technology such as plant varieties or farming systems. Training is not training of farmers, but is training of research scientists, policy makers, and trainers. Because rice is grown mainly in developing countries and research capacity concerning rice in developed countries is, and will be, rather limited, it was necessary for IRRI to work on pretechnology sciences — the application of basic science to particular scientific problems related to rice plant growth. This is strategic research located between basic and applied research, and not necessarily accompanied by the intent of developing a particular technology. In my judgment, our knowledge concerning the physiology of rice plant, especially under climatic and other environmental stress, and of the ecological system of biomass in rice fields is particularly rich and useful. The latter leads to development of integrated pest management. I am told that integrated pest management techniques have not yet been mastered even in developed countries.

There is no doubt that rice is, and will continue to be, the most important food crop in the developing world. The share of rice in total value of food and cereals consumed in the developing world was 21.5 and 58.4%, respectively, in 1978-80. There is no sign of a significant decline in this share in the foreseeable future.

According to the FAO, if past trends in demand and production continue, the annual gross import requirement of developing countries would rise from the 8.3 million tonnes of rice required in 1975-76 to 33 millions in the year 2000. Moreover, only 6% of world rice production is in developed and eastern European countries. Therefore, the future of food availability of the developing world depends largely on the ability of developing countries to increase rice production. IRRI's role in this connection is, and will be, crucial. For example, without IRRI's germplasm collection, preservation, and manipulation, future flow of new rice varieties will not be fruitful.

Many Asian countries are, or soon will be self-sufficient in rice. Increased rice production may lead to lower producer's price of rice. In such countries, a commercial rice surplus may coexist with a large undernourished population. Objectives of the rice program in these countries should be shifted from simple increased rice production to increasing the income of rice growers. In this sense *rice-based farming systems research* may become more important. The special demonstration program on *Prosperity through rice farming* may bring about similar benefits. In these countries quality of rice also should be improved.

Some of these countries will accelerate their industrialization process and may soon reach the same stage of development as in present-day newly industrialized countries. In these countries, mechanization and other labor-saving techniques of rice production will be needed. However, I wonder whether IRRI should be encouraged to meet this need. I have reasons for my skepticism. We are in the computer revolution. Computers and chips are becoming smaller, cheaper, and more versatile. The computers of the future will have tremendous impact on all aspects of agriculture and food economy. We should understand that present-day robots are rudimental ones, and that the future of mechatronics is vast. A single crop research institute like IRRI, in my judgment, cannot pursue the vast future of development and application of computers to agriculture and the food economy. This research may be carried out more effectively by other research institutes.

IRRI is increasing its research effort for rice grown in unfavorable conditions: rainfed dryland or upland rice, rainfed shallow water rice, and rainfed deep water or floating rice, and research on toxic soils is progressing. This is appropriate because the rice growers of areas with unfavorable growing conditions are economically more disadvantaged than rice growers in irrigated areas. In such areas, rice production, especially in Africa, should be sharply increased and stabilized. IRRI, under its global mandate, should continue its research effort on rice for unfavorable growing conditions.

At the same time, we must consider the potential benefits from research for different rice-growing environments, and the amount of rice research being done outside IRRI. An IRRI estimate of the value of potential benefits expected from research focused on each rice growing environment from 1980 to 2000 shows US$14,600 million from irrigated environments, US$4,600 million from shallow rainfed, US$1,770 million from deep water and floating, and US$840 million from uplands (2). These figures show it is undesirable to reduce IRRI's research effort for irrigated rice. Moreover, there should be considerable amount of what might be termed *maintenance research.* The possibility of IRRI increasing its research effort on rice under unfavorable growing conditions depends entirely on IRRI's ability to increase the productivity of its limited number of scientists.

There is no doubt that the potential benefits of rice research will not arise from IRRI research alone, but from the totality of rice research. My estimate shows that developing countries spent U$S160 million (US$123 million in Asia and US$37 million in Africa and Latin America) on rice research in 1976. IARCs under the Consultative Group System spent a little more than US$24 million on rice in 1983. IRRI spent US$12 million in 1976 and US$22 million in 1983. Moreover, we can expect that rice research capacities of developing countries will be substantially expanded in the future. IRRI's future role will be more and more in upgrading the quality of their rice research. Again, the germplasm collection, preservation, and manipulation will increase its importance in IRRI's activities. IRRI's role as facilitator for information and material exchange among rice scientists of the world will be more and more in demand, and the importance of IRRI training programs will be significantly expanded.

In this connection, we should note that a recent survey of plant research journals showed that only 3.9% of the articles were devoted to mechanisms of plant growth in unfavorable environments (1). IRRI's knowledge concerning the physiology of rice plants under climatic and other environmental stresses is particularly useful and rich. I believe that IRRI will continue to have a large comparative advantage in this area.

The following major scientific revolutions have occurred in recent years: 1) genetic engineering and biotechnology, 2) nuclear energy, 3) space exploration and development, 4) new raw materials, and 5) computer revolution. All these revolutions relate directly and/or indirectly to science and technology for agricultural research, and in turn to the future of world agriculture. For example, remote sensing techniques to determine changes in climate and land surface will be used increasingly in future agricultural research. However, very basic research is needed to carry out these scientific revolutions. Moreover, except for genetic engineering, all these revolutions need very large scale organized research. In my judgment, IRRI cannot participate in these four scientific revolutions, but I sincerely hope that IRRI continues to receive the various benefits from development of these revolutions.

I am an economist. I may be wrong in interpreting the characteristics of *biotechnology and genetic engineering.* In my understanding, biotechnology is not new to us. Many of the new technologies are actually techniques of conventional plant breeding and fermentation. What is new to us is the fact that the gap between basic and applied research is, through biotechnology and genetic engineering, being bridged. Some results of basic research find immediate application. The reason we can identify immediate application of basic biological research results is that we have accumulated biological knowledge and biological materials for centuries. We do not need any very large scale organized research in biotechnology and genetic engineering. IARCs can afford genetic engineering and biotechnology research. Moreover, private sector dominance of research and development in genetic engineering and biotechnology in many developed countries may create challenges for the IARCs. IRRI has a large collection of germplasm. There is no reason why IRRI should not utilize new techniques of biotechnology, such as genetic engineering and tissue culture, in its rice plant breeding. I expect that biotechnological and genetic engineering techniques make IRRI's plant breeding work much more productive and effective. Of course, we should not make little of the more conventional areas of plant breeding research.

My presentation so far did not cover the whole field of IRRI's research program. However, let me summarize what I said. First, the role of IRRI as an international agricultural technology transfer agent will continue to be crucial and keenly needed. Because rice research capacity in the developed world is, and will be, rather limited it is necessary for IRRI to work on pretechnology sciences, or strategic research.

Second, research concerning the physiology of rice plant, especially under climatic and other environmental stresses, and the ecological system of biomass in rice fields must be encouraged. The latter is useful in developing integrated pest management. The concept and methodology of integrated pest management has great potential for application in crop production in both developed and developing countries. The former is useful to the national rice research of developing countries. Because rice research capacities of developing countries will be substantially expanded, IRRI's future role will be more and more in upgrading their rice research. IRRI's role as facilitator for information and material exchange among rice scientists of the world will be more and more in demand. IRRI's training programs should be further encouraged.

Third, the objectives of rice programs in tropical Asian countries will be shifted from simple increased rice production to increased income of rice growers. In this sense, rice-based farming systems research may increase in importance. However, IRRI should not expand its machine development programs because it is a single-crop research institute.

Fourth, there is no reason why IRRI should not be encouraged to pursue biotechnological and genetic engineering research.

Let me conclude by saying that in my judgment, IRRI's present size in terms of number of scientists is beyond optimum. If IRRI increases its number of scientists, the efficiency of IRRI's research activities may decline. There are two ways to overcome this possibility of decline in efficiency of IRRI. One is by introducing newly developed communication media and improving communication among IRRI scientists. The other is to increase further the labor productivity of its limited number of scientists. This can be achieved by increasing use of techniques of scientific revolution; remote sensing, biotechnological and genetic engineering techniques, various kinds of computers, and so on. IRRI is proud of its past accomplishments. But the road ahead is not an easy one. I do hope that IRRI maintains and strengthens its scientific excellence for the welfare of rice farmers and consumers of the world.

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IRRI IN THE NEXT 25 YEARS: THE FUTURE

It was with mixed feelings that I responded favorably to Dr. Swaminathan’s invitation to give ,my impressions of the future role of the International Rice Research Institute (IRRI) and other international agricultural research centers (IARCs). On the one hand, this invitation gives me an opportunity to comment on the work of an institution and its staff with whom I have had close association and for whom I have profound respect and admiration. At the same time, it presumes that I can give an unbiased opinion and that my judgment is worthy of note by individuals who are far better qualified than I to make these judgments. Consequently, my comments are given with a feeling of humility and inadequacy.

During the past 25 yr I have had the unique privilege of viewing IRRI from 3 perspectives. First, I recognized the need for such an institution in 1953-55 when I had the privilege of spending 2 yr as a professor at the University of the Philippines College of Agriculture (UPCA). Through field trials I satisfied myself that improved technology was essential for increased rice production. I was completely convinced that the mere transfer of technology from the temperate, more developed nations of the world was not enough. New and improved technologies, appropriate for the tropical and subtropical climates of most developing nations, needed to be created. And research was the primary tool for this creation.

As you know, men wiser than I championed this view and took steps to create IRRI. I was pleased to observe the bold and courageous leaders of the

Ford and Rockefeller Foundations as they joined with the Government of the Philippines to establish this great institution. Jack Umali, then Dean of the U.P. College of agriculture, George Harrar of the Rockefeller Foundation, and Frosty Hill of the Ford Foundation were the conceptual and intellectual leaders of this innovative venture. Rice-producing countries around the world are indebted to these courageous leaders. I am most pleased that Jack Umali is here to receive our acclaim.

This great institution has used science to provide needed technology for agricultural and economic development in rice-growing countries, particularly in Asia. I observed the consultancies and negotiations which led to the selection of rice as the crop on which this pilot institution was to focus, and of Los Baños as the site for its headquarters.

I further observed and admired Dr. Bob Chandler as he assembled a remarkably capable international staff, who promptly generated research findings and technologies which, in part, laid the foundation for the "Green Revolution." His leadership, and his staffs unflinching dedication, stimulated accomplishments far beyond those envisaged even by the founders. I was also most pleased to see the role played by the University of the Philippines, IRRI's partner in educating and training thousands of rice scientists.

The second perspective was gained when I had the privilege ofworking at this institution for 8 of the most memorable years of my life. These years followed the remarkable first flush of success which had convinced the world of the essentiality of research to provide improved technologies. I witnessed first hand the dedication of a select group of scientists from diverse backgrounds and cultures sharply focusing their scientific talents on the rice plant and on the agricultural systems that depend on rice.

Additionally, I observed the symbiotic interaction between IRRI and its counterparts in national research centers and universities around the world. Further, I witnessed the impact of the technological products of IRRI and its national program partners on the agricultural institutions and systems in rice-growing areas in Asia, Latin America, and Africa. I saw the impact of IRRI's findings on national policies which influenced the profitability of using the new technologies and on the perception of the role that scientists can and should play in national economic development.

IRRI stimulated scientists to find satisfaction by focusing on problems and on scientific disciplines. It stimulated national leaders to support agricultural research and extension. It stimulated and encouraged farmers to look to and support national agricultural research and extension systems. Now there was some time to "extend" which led to farmer confidence in research and extension.

My third perception, and most recent and current one, has allowed me to view IRRI and other IARCs from the point of view of a donor, a donor which now provides one quarter of the financial support for IRRI and other international centers, and also helps support national programs which are trying to more effectively utilize the improved products and processes developed by and coming from the centers.

I found in this donor and in the two American foundations which helped establish this institute in 1960 a profound commitment to IRRI and to the other CGIAR-founded centers around the world. Although I have not checked the financial records in detail, I am certain that in the last 25 yr no less than 90 million dollars have been provided IRRI in unrestricted core funds, and about 20 million dollars in special project support. I know of no better way to demonstrate commitment than through this level of support.

But I also found in this donor, forces which were demanding consideration of the comparative priority of allocating funds to support research as compared with other development opportunities. As a donor representative, I am forced to continually assess the relative priority of support for IARCs as compared with support for agricultural production systems or for national agricultural research programs. Questions such as the following are constantly being asked by those who allocate support for IARCs:

- How long will it be necessary to continue to support the IARCs?
- Have they fulfilled their missions, and if so, is it not time to phase them out and concentrate on national programs instead?
- Have they become so strongly institutionalized as to be self-serving?
- Are they more oriented toward self-preservation than toward service to their constituents? The rationale for expensive conferences such as this one is being questioned.

From these three perspectives it is obvious that I am not an unbiased observer of the IARCs and especially of IRRI. Based on my own personal experience and observations, I have gained a profound respect for these centers, and have a sense of pride in their accomplishments. I know of no other comparable international endeavor, scientific or otherwise, which has accomplished so much for the world’s low-income people as these centers have.

Independent studies have shown remarkable economic returns from the financial inputs into these centers. Each year we learn of new varieties, improved technologies, and better farming systems emerging from the efforts of the IARCs and of the national programs with which they are associated. The centers are continually being asked to do more to accelerate agricultural production in the developing countries. This is evidence of the respect others have for these centers.

FUTURE OF THE INTERNATIONAL AGRICULTURAL RESEARCH CENTERS

From my three perspectives and with all my biases, I come to two very important conclusions with regard to the future of IARCs and especially IRRI. First, *by no means have these centers completed their missions.* They continue to play a significant and vital role in enhancing agricultural production in the developing countries. They will likely play as significant a role in the next quarter century as they have in the past 25 yr. The progress in overcoming the obstacles to rice production is only the beginning of that which must be done if the future food requirements of rice-eating countries are to be met. IRRI has a key role to play in meeting this requirement.

My second conclusion is that the *the role of the IARCs in the next 25 yr will likely be markedly different from that which prevailed in the past 25 yr.* In fact, if that role does not change, the likelihood of continued support for these institutions may well be in jeopardy.

Three factors make it essential that the future role of IARCs be modified. First and foremost is the fact that national agricultural research programs are much stronger and are better able to accommodate national needs than was the case in 1960 when IRRI was organized. Well-trained national scientists with years of experience working alone or in cooperation with IRRI are capable of developing their own improved varieties and their own pest control and soil and water management technologies. Although national institutions will continue to benefit from collaboration with IRRI and with scientists in other countries, they can function effectively on their own. This means that IRRI's programs will need to be oriented even more than they have in the past toward those activities which cannot be carried out easily by national programs. *IRRI must focus on those activities for which it has a comparative advantage.*

Second, growing donor resistance to increased budgets for the centers will force decisions as to which activities can be continued and even expanded, and which will need to be reduced or eliminated. This contention that constraints on donor funding exist has been made for 6 to 8 yr, but only in the last 2 yr have the centers seriously suffered from lack of financial resources. Although some centers, including IRRI, have obtained a measure of relief as a result of variations in foreign exchange rates, in general program levels have actually been reduced in most of these centers during the past 2 yr.

Even with some general relief from stringent donor budgetary constraints, there is no anticipation of sharp increases in budgetary support for the IARCs. Foreign aid worldwide generally is at best remaining steady. The pressing food and medical requirements for Africa are competing with other developmental activities for donor resources. Action programs to help African nations increase food production using existing technologies will also take high priority for donor resources. Thus, competition for scarce foreign aid resources will continue to place constraints on increased funding for the international centers.

Third, new genetic, physiological, and biochemical research tools are emerging that offer remarkable potential for the solution of food production problems in developing countries. In the past 5 yr new biotechnology approaches have been utilized to make some significant breakthroughs, particularly in human and animal health. Already, new vaccines for measles, malaria, and leprosy as well as animal foot-and-mouth disease have come from these efforts and are now being field tested. New simple diagnostic techniques for human diseases have been developed. The rate of progress in the past 5 yr far exceeds that of the previous 15 yr.

Preliminary findings of agricultural researchers suggest that in the long term these modern biotechnology tools may have even greater impact in agriculture than in health. Already we find that through genetic engineering desirable traits are being incorporated into microorganisms and even into higher plants. Interspecific crosses have been achieved and host resistance to an herbicide has been incorporated into a crop plant (soybeans) using modern genetic engineering.

THE FUTURE ROLE OF IRRI AND OTHER IARCs

These three factors are among those which will determine the role of IRRI and other IARCs in the decades ahead. The centers will likely respond in many ways to these, but one common response will most certainly prevail — *the centers must focus even more sharply than in the past on priority programs for which they have truly comparative advantage.* In this way they will more effectively complement and underpin national programs while minimizing competition with them. In short, the evolution which has characterized programs at IRRI and sister IARCs during the past decade will continue but most certainly at an accelerated rate.

I will not attempt to identify specific priority areas on which IRRI should concentrate in the future. However, I think some general programs should receive priority attention. Included are those programs which permit IRRI to most effectively backstop, coordinate, and serve national research scientists. For example, *IRRI should continue its excellent work in rice genetic resource conservation and utilization.* The Institute is the world's primary center for rice germplasm storage and characterization, and it should remain so.

This germplasm storehouse should continue to be free and open to rice scientists around the world. The collection, characterization, and maintenance of these genetic resources should continue. Central to rice germplasm utilization is the unique *Genetic Evaluation and Utilization (GEU)* program which IRRI has perfected during the past decade. It is essential to characterize and combine rice genetic resources and to make these resources available to cooperators around the world. The GEU program or a modification of it continues to have much to offer to national programs.

IRRI and other IARCs are also playing another catalytic role in collaboration with national programs. This is the *initiation and coordination of international research networks.* These networks are not only channels for the exchange of information, genetic materials, and improved technologies, they also provide an organized mechanism for joint attacks on common problems. The International Rice Testing Network is a good example. It provides a rational mechanism for uniform field testing of the best genetic materials coming from national programs and from IRRI. The network provides effective information exchange among rice scientists worldwide. It encourages the rapid exchange of genetic materials and helps in the prompt identification of materials that are resistant to insects and diseases. This network provides regular opportunities for national scientists to keep abreast of research at IRRI, and provides a mechanism for these scientists to help IRRI identify high-priority research areas.

Other valuable networks should also continue to receive attention. The International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) has helped scientists design and test means of improving fertilizer utilization efficiency. The network also includes work on azolla and other nitrogen-fixing systems. The Rice-Based Cropping Systems Network and the so-called “Constraints” network have helped determine how improved component technologies can be integrated into practical field systems. Likewise, the farm machinery network has much to offer. IRRI could well continue to provide leadership in these areas, with the development of research methodologies being a primary priority.

IRRI has a comparative advantage in certain aspects of economic and social science research. For example, it can coordinate intercountry research networks concerned with rice policies. And it can use modern social science tools to better understand how farmers and their families can be motivated to adopt improved technologies. Special attention may need to be paid to the role of farmers in this decision-making process. IRRI should be able to develop research methodologies that could be used by cooperating scientists in national programs.

APPLYING MODERN RESEARCH TOOLS TO UNFAVORABLE RICE ENVIRONMENTS

During the past 25 yr IRRI has focused primarily on increasing rice production in more favorable environments. This focus was appropriate because it gave the greatest immediate yield enhancement. Furthermore, much is yet to be done to help achieve respectable stable yields of rice under these favorable conditions. During the next 25 yr, however, considerably more attention must be given to increasing yields under less favorable conditions. Included will be areas of high insect and disease infestation, areas with infertile soils, and toxic soils high in acidity, alkalinity, or salinity. Tolerance for drought, low and high temperatures, and floods must also be sought. People in areas with these characteristics are poor and disadvantaged. Research to help them move above the poverty level is essential.

Fortunately, IRRI and other IARCs may be able to use modern biotechnology and especially genetic engineering to develop rices which resist or tolerate these adverse environmental conditions. The potential for accomplishment is most heartening. The progress IRRI scientists have made through cell and tissue culture gives a hint of the future potential for these methods. The future will likely provide successful crosses between cultivated rice and related species. It will permit the incorporation of genes which give resistance to specific insect and disease pests, and tolerance of other environmental stresses. And it will greatly speed up the crop improvement process.

Comparable progress will likely be made in chemical and physiological research to create a better understanding of the basic processes of growth and development of the rice plant. Likewise, new and innovative methods to increase the efficiency of fertilizer use must be sought. And the biochemical basis for host resistance to insect and disease pests must be determined. IRRI scientists can play a critical role in making these discoveries.

It is likely that during the next two decades basic research in the more developed countries will create new tools to transfer desirable genes into crop plants. Such research will develop through monoclonal antibody technology diagnostic reagents to ascertain viral infections in crop plants. Although IRRI should not be involved in such basic research, it should be ready to apply the new methodologies to the removal of rice production constraints.

LINKAGE POSSIBILITIES

To effectively utilize these emerging technologies, it is essential that IRRI develop effective linkages with scientists in industrialized nations on the one hand, and with counterparts in developing countries on the other. The type of linkages I have in mind already exist to a degree between the IARCs and some universities and research institutes in industrialized countries. Focusing on a topic of interest, scientists in cooperating institutions develop a general plan of action which commonly involves research activities at both institutions, training opportunities on new methodologies, and the short-term exchange of staff. Research here at IRRI on pheromones and pest management carried out cooperatively with scientists from the Tropical Products Institute in the United Kingdom is an example of this type of cooperation. Cooperation on nitrogen research among IRRI scientists and counterparts at the Boyce Thompson Institute is another good example.

Cooperative research should be proposed as a sufficiently long-term activity to optimize the potential for significant accomplishments. Short-term, ad hoc cooperation can be helpful, especially in relation to such activities as methodology and testing. But a well-conceived, long-term scope of work which provides for continuity of cooperation over a period of several years and which spells out, at least in general terms, what is to be accomplished is essential. The potential for this type of cooperation should be carefully considered by institutions in both developing and more developed countries, and by all donors interested in supporting such research. I would hope that within the next 5 yr significant linkages could be established to permit the IARCs to promptly utilize research tools coming from scientists in the industrialized countries.

CONCLUSIONS

IRRI has been and is now a remarkably productive institution. It has met the highest expectations of its founders, and has become an honored byword wherever rice is grown and eaten in the world. With appropriate leadership and adjustments to today's scientific, social, and economic environment, IRRI has many productive years ahead. I trust that these years will be used as effectively as have the past 25.

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EDUCATION AS KEY TO PROGRESS

Whenever the question of why one country is developing and another regressing is raised, one of the factors sure to be considered is education. From Strumilin's first attempt in 1925 to quantify the role of education in economic development to the rise in the fifties and sixties of econometric measurements of residuals and rates of return on education, the linking of education with development has been well established. The wonder is that the link was not established sooner.

Productivity is human productivity, regardless of the level of technology. The wealth of ideas that promote development — be they ideas of more efficient forms of organization and cooperation or of machines and their uses — springs from the human brain. And the rate of output of such ideas is directly proportional, I would think, to the degree of training that the brains in question have had in sustained and rational thinking.

Even in the age of assembly-line production, human intelligence continues to enjoy a premium. Note the Japanese who have been stereotyped as robots to explain their high productivity; it is not mere coincidence that they are well-educated. Even in the most mechanical process, there is a critical juncture where human discretion must be exercised and it is better if informed by education. And then, of course, in a fast-changing world, there is a constant challenge to improve on techniques. Here, success turns on the level of intelligence that is called on to size up the challenge and meet it.

We need intelligence not only in the discovery, comprehension, and use of material techniques, but more importantly in the organization of human wills and in the appreciation of those ends that best inspire their fruitful collaboration. In short, we need intelligence in the economy and intelligence in politics.

What I shall make here is a plea for establishing a cult ofcritical reason in developing societies. I shall call for the cultivation of that habit of critical and inquiring thought that finds its highest expression in science and urge its application in every aspect of the life of a young nation.

The first universal expectation of education is that it should develop the knowledge and skills that promote material progress.

The second expectation, and equally important, is that education, as an instrument of socialization, should train future citizens by inculcating the cultural values, norms, and ideas which form the basis of a civic culture that will be the foundation of a social and political order whose objective is the personal development of its members as individuals and as citizens. Thus, schools are expected to raise not only the income-earning capabilities of individuals but also their capacity to relate their personal interests to those of the community and the country.

Decidedly, these expectations exist among the Filipinos, who place education on the level of a basic necessity. Filipino families will go to any length to send, if possible, all the children through school. They will forego the most basic needs of the family for that purpose. From sprawling campuses in suburbs and high-rise universities in the congested heart of cities to three-room, prefabricated structures in barrios, schools are an integral part of Filipino communities. But they are integral for the wrong reason.

Local communities look to these schools as the gateway to another world they hope will be radically different and better than the difficult world in which these communities exist. Most of these communities are in the countryside and the hope there is that schools will enable their children to escape permanently from the harsh and hopeless condition into which they were born. The farmer sees his child go off to school and there is hope in his heart that eventually his child will never have to return to the hard lot that produced him. He hopes he will become an accountant, an engineer, a doctor, a lawyer or an entertainer, but, God willing, never a farmer. This is the tragedy of Philippine education — all its achievements point our children away from our country's basic requirement.

The Philippines is an agricultural country and so it will always be either a rich agricultural country or a poor agricultural country. Land is our greatest natural resource; the others are negligible. Logically, the national effort should be exerted in the direction of its most efficient exploitation. Instead, the greatest efforts are made to escape from what is popularly called its "bondage." Why is this so? Why is there such a low regard for the agricultural vocation? How can we reverse the popular opinion about it? How can we redirect the national effort to the land?

Our agricultural productivity is low and returns on that activity are meager. I will not say which causes the other, but undoubtedly both factors feed on each other. It is a vicious circle and the circle is closed by the double-lock of technological ignorance and political impotence.

Philippine agriculture needs a massive infusion of technology (not necessarily of machines but of techniques), of the kind that has permitted Japanese and Taiwanese farmers to produce national bounty out of small plots of rural earth. This will not happen until the land is finally regarded by the Filipino people as the highest challenge to their intelligence. It must cease to be the object of nostalgia or regret, or the subject of political rhetoric, but the target of Filipino scientific ingenuity. It must cease to be merely the concern of sociology; it must become the premier subject of our science.

The high regard hitherto enjoyed by commerce, industry, and the professions must be transferred to agriculture. Those sectors enjoy high respect because they are seen as the only arenas where a man can triumph by the power of his intelligence. Success in those sectors measures his stature. On the other hand, success in agriculture, when it comes, is usually meager and attributed to grace.

The problems of commerce, industry, and the professions are seen as intellectual puzzles that invite solution and promise publice steem. (This is true also of the problems of government.) But the problems of agriculture are seen in a different light. They are seen as intractable not because of their complexity but because of their idiotic simplicity. They are seen as not really problems but merely facts of nature: the weather, the distance from thriving centers of human community, soil infertility, the lack of basic comforts. It does not take brains so much as grace to solve them. And grace is a question of prayer. It is this attitude that must be broken. And it will be broken only by applying the scientific attitude to agriculture.

If the weather is a given, the schedule of agricultural activities is not. If you cannot change the first, you can do something about the second, not only in the matter of timing but also in the quality of agricultural activity so that more is produced in the time and with the land you have. If surplus will affect prices, silos are the answer. If distance from markets is the problem, roads and transportation systems are the answer. If infertility is the problem, then irrigation and fertilizers will relax the earth's grudging hold on its fruits. All this has been said before, and by others with qualifications I do not possess. And, unlike the great puzzles of science and technology, these problems can be solved without too much difficulty. Or they could have been before the present economic crisis. Why weren't they? The knowledge was there — in texts and in the schools, in agri-research institutes and on the lips of experts. Still nothing was done. Why?

Because one major factor is missing. A farming sector with implicit faith in the power of human industry and science to overcome the problems of agriculture that appear as immemorial and permanent as nature. Periodic visits by agricultural extension workers, when and if we finally produce enough of them, will yield nothing unless the scientific spirit that informs these workers infects the farming population as well. Outside workers cannot anticipate all the problems that may arise in a particular farm. A farmer with the scientific spirit, however, should be able to handle them or provide against them. Faced with a natural calamity to his crops, such a farmer will not resign himself to the event. He will know what he must do, and if the means are not at hand, then he will include them among his demands on government as an enlightened citizen. He will be enlightened as to his true interests, specific in his requirements for their protection and therefore reasonable about his expectations of the government's response. He will stand no nonsense, but, being informed, will expect no miracles.

I believe that men are more productive when they are aware of their circumstances and know exactly what they are doing. They are less prone to paralyzing disappointments when they are not raised through ignorance with false hopes. They are more creative when they combine the full knowledge of their limitations with a clear idea of their potentiality. They achieve a greater rate of success when they stop the habit of meeting problems head-on and sitting down in despair when they fail and, instead, cultivate the scientific habit of breaking their problems down to more manageable parts. This requires faith in the ultimate efficacy of reason. That faith produces the patience to work out the gradual solutions that reason invariably prescribes.

Members of this distinguished audience are devoted to the discovery and development of scientific techniques that promote agricultural productivity. As an educator, I thought to devote the time allotted me to argue for the spread of the scientific attitude that is the foundation and moving spirit of your endeavors. That attitude must be shared by the lay population which you expect to use your discoveries. The achievements of science and technology are not self-implementing and they do not provide against every contingency in the areas they service. The more sophisticated these achievements are, the higher the demands they make on the intelligence of those expected to use them — not only mechanically but creatively as well — to meet unforeseen contingencies.

Before laymen will turn to the products of technology, they must first believe in it. Before they can believe in it, they must understand it — or, at the very least, share with its originators and proponents the scientific attitude that produced them.

COOPERATIVE RESEARCH: NEW DIMENSIONS

COOPERATIVE RESEARCH: NEW DIMENSIONS

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NEW DIMENSIONS OF COOPERATIVE RESEARCH: AN INTRODUCTION

IRRI came into existence just 15 yr after the greatest global conflict the world had ever experienced — World War II. Although it is not pleasant to recall that terrible disaster, it is important to realize the state of the world — the misery, the turmoil, the uncertainty, and the hopes and aspirations of nations after the war. In 1960, a decade and a half after the war, many of the principal rice-producing nations were just emerging as newly independent states. With several notable exceptions, these nations whose economies were highly dependent on rice did not make much headway in modernizing their rice production and utilization systems. Many were receiving external help from multilateral and bilateral donors.

Our distinguished colleagues/speakers in previous sessions have noted IRRI's establishment during that critical period and have highlighted the challenges and accomplishments over the quarter of a century of its existence. To put it simply and to the point: *IRRI did those things that had be done but which most rice-producing nations had been unable to do for themselves — singly or collectively!*

Of course, in 1960, it was first things first: get established in the Philippines and establish relations with national rice programs, begin to develop superior/high-yielding rice cultivars, and begin training and information programs. In 1960, when IRRI was established, disillusionment with agricultural research was beginning to creep into ministries of planning and finance. Confidence in agricultural research as the panacea for ailing agrarian economies was waning and automatic financial support for previously unchallenged agricultural research budgets was being questioned, In a few years after its establishment IRRI helped restore confidence and credibility to agricultural research. Together with CIMMYT and other international centers, IRRI did just that and directly and indirectly gave a tremendous boost to national agricultural research programs and systems.

Once established and a highly visible success, IRRI was able to move with dispatch to do more of what needed to be done. With growing financial support from donors and with the active participation of rice-producing nations throughout the world, IRRI's programs evolved and expanded to meet continuing changes and challenges: in effect, IRRI continued to do those things that needed to be done on a much larger scale. (At this point, I would like to note that it was Nyle Brady who recognized that although IRRI had been a tremendous success, the magnitude of effort was nor commensurate to the problem and he proceeded to increase the effort. His success in increasing the capacity of IRRI had a ripple effect throughout the CG system and thus had a salutory effect on the level of support to other international commodity research.)

Over the past 25 yr there have been dramatic and far-reaching changes in the world, especially in Asia where most of the rice is grown. I can see that the changes which have been occurring and have occurred are such that IRRI's role has been continually evolving. For the past decade or so IRRI has been moving more and more into a partnership mode - cooperative-collaborative research relationships with rice-growing nations. This trend stems from the increasing growth and strength of national rice programs. Because of its importance now and in the future, this session has been organized to discuss what new, if any, dimensions are likely.

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RELATIONSHIPS IN COOPERATIVE AGRICULTURAL RESEARCH

It is a great honor and privilege to be invited to speak on this memorable occasion to so distinguished an audience. Those who recall the history of the Rochdale pioneers and the cooperative movement will realize the significance of my being asked to open the discussion on cooperation. I was born at the intersection of Robert Owen and Holyoake Streets in a house owned by the cooperative society where my father was employed throughout his working life.

It is curious that the word "cooperation" did not appear in English until the late 16th century although the verb *co-operari* meaning "to work together" had been used in Latin for many centuries. Perhaps my English ancestors took longer than their Latin cousins to appreciate the value of cooperation.

That be as it may, cooperation is fundamental to the concept and conduct of the Consultative Group of International Agricultural Research family. Its founding fathers fully recognized that providing a secure food supply for all people calls for resources far greater than those available to any single nation or international organization. The original architects of IRRI might well have found their inspiration for cooperation in George Santayana's quotation: "Unselfishness consists in sharing the interests of others.''

Earlier speakers have paid tribute to the spirit of international cooperation in which the Government of the Philippines provided IRRI with a home, fully recognizing that IRRI would become an international scientific cooperative, its intellectual property and good works being available to all who would seek them. Clearly, IRRI's founders accepted Chekhov's dictum: "There is no national science, just as there is no national multiplication table. What becomes purely national is no longer science."

IRRI has well demonstrated the many facets of cooperation essential to the style and purpose of the CGIAR family of research centers.

Most important has been its valuable cooperation with many rice-producing nations. During the 12 yr I was privileged to direct the Agriculture, Food and Nutrition Sciences Program of the International Development Research Centre (IDRC), we supported and cooperated in more than 600 research projects in close to 80 developing countries. No one of these has left me with a greater sense of satisfaction than IRRI's Asian Cropping Systems Network (ACSN) to which we made a modest contribution particularly during its early years. The Cropping Systems Program, which began in the early 1970s as a special project with a staff of one agronomist and one agricultural economist, is now a major and vital component of IRRI's program. In addition to having first defined and continually refined an exemplary systems research methodology, the ACSN has convincingly demonstrated how an international agricultural research center can stimulate scientists and technologists in many national research systems to cooperate and to share their knowledge and experience for common benefit. The custom of bringing all the 12 participating countries together each year in a different country well demonstrates how to pursue a path of progress through cooperation. The growth of the network program from 6 experimental sites in 3 countries in 1975 to 194 sites in 12 countries in 1984 is a spectacular achievement, one of which IRRI can be justifiably proud. While attending this conference, 1 learned of the probability of a most important 13th country soon to be added.

The essentials of the IRRI cropping systems methodology have been adapted in many other projects and networks supported by the IDRC and by other agencies. Most important, IRRI has demonstrated through the ACSN the essentials of true cooperation. First, the ability to listen sympathetically and comprehend the resources, opportunities, and constraints of farmers before seeking to produce changes for the better. The work, as in the ACSN, has demonstrated that cooperation calls for sensitive communication in both directions.

This conference has brought before us IRRI's successful cooperative ventures in many countries, countries as far distant as the People's Republic of China, Bhutan, the Malagasy Republic, and Egypt. The significant increases in rice production in many Asian countries bear testimony to the benefits derived from such cooperative undertakings.

A complementary means of cooperation demonstrated by IRRI is through subcontracting components of its research program to universities and other national research institutions. Several years ago IRRI contracted with the Philippines Institute of Plant Breeding at the University of the Philippines at Los Baños (UPLB) for the selection of phenotypes of various food crops particularly suited to different rice-based cropping systems. This program has assembled an impressive germplasm collection particularly of legume types with growth patterns suited to various agroclimatological conditions.

Cooperation through subcontracting offers many advantages. First, it helps strengthen national research institutions. Where a university is the cooperating partner, the subcontract can support graduate students and research fellows at that critical stage of their professional formation, and the type of research they undertake can influence the manner in which they will dedicate the rest of their professional lives. Subcontracting serves in an economical manner to strengthen the bonds of cooperation between the IARC and national institutions, expanding the IARC's overall program without increasing its in-house costs or the size of its establishment. As donor purse strings tighten, as they very well may in the near future, cooperative subcontracting deserves careful consideration by all IARCs.

Recently, IRRI developed cooperation with the Institute of Animal Science at UPLB to expand the cropping systems program to include livestock; animals are vital components of many small farming systems throughout Asia. The UPLB team will concentrate on determining the feed value of various natural forages and crop residues: a pragmatically wiser course than the pursuit of exotic microbial protein through fungal lignocellulytic conversions.

IRRI has also demonstrated the necessity and benefit of cooperating with other IARCs.

IRRI and the Centro Internacional de Agricultura Tropical (CIAT) have cooperated in rice research for Latin America since CIAT's establishment. The IRRI variety IR8, released in Colombia in 1968, was the first of a series of semidwarf rice varieties which the IRRI-CIAT cooperation delivered to Latin America. Similarly, in Africa, IRRI continues valuable cooperative programs with the International Institute of Tropical Agriculture (IITA), Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT), and West Africa Rice Development Association (WARDA). The Inter-Centre Coordinating Committee, with representatives of CIAT, IITA, IRAT, WARDA, and IRRI, appears as a useful mechanism for strengthening cooperation among the partners toward their common goal of increasing rice production in Africa and Latin America.

IRRI has also cooperated with other research systems and networks related to but outside the CGIAR.

In 1974, Sir John Crawford, Chairman of the Technical Advisory Committee, requested that a study be made of the needs of postharvest research in Asia and Africa. A study led by a Filipino agricultural engineer at UPLB, greatly assisted by IRRI's Agricultural Engineering Department, led to the Asian Post-Harvest Grains Network which for the past 8 yr has been serviced by an international advisory team. The team, based in the Philippines, is cooperatively supported by Australia, Canada (Canadian International Development Agency), The Netherlands, the U.S. Agency for International Development, and IDRC, with inputs from other donors including the Federal

Republic of Germany. Its concentration on threshing, drying, transporting, storage, and milling of rice and other grains has benefited from and complemented IRRI's agricultural mechanization program.

The Asian Post-Harvest Giains program closely parallels the ACSN in that both serve to stimulate cooperation among national programs, to ensure that significant improvements in one rice-producing country are made known to and can be adapted by others. We must extend and enhance the means and opportunities by which national institutions can cooperate with one another for their common benefit.

The Asian Post-Harvest Grains Network began a style of cooperation among groups of donors different from but complementary to the classical pattern of an international research center as exemplified by IRRI and the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). Subsequently, we have witnessed the emergence of the International Council for Research in Agro-Forestry (ICRAF), International Board for Soil Research and Management (IBSRAM), International Irrigation Management Institute (IIMI), and International Institute for Bananas and Plantain (INIBAP), each with unique characters but complementary to the existing IARCs. These are for the advantage of being financed by groups of donors largely from their bilateral rather than multilateral pockets. These and other new modalities of donor cooperation deserve serious examination as we look for economical means of further strengthening national agricultural research systems.

For those of us who took part in its first meeting, the foremost task of the CGIAR was and is to strengthen the resources and capabilities of national agricultural research systems. This remains fundamental to the group's activities and we consider it the most urgent responsibility of every IARC. Consequently, training at all levels remains an essential component of IRRI's and all other IARC programs.

Is it not equally important that after training, the international centers make provision for the trainees to continually maintain contact with one another, to share experiences, difficulties, and accomplishments for their common and individual benefit? It is our firm belief that many of the developing countries' difficulties could be overcome and their opportunities more quickly realized, if they could meet and cooperate with one another more frequently and more systematically. The IARCs have a vital role to play in stimulating such cooperation as indeed IRRI continues to do through the ACSN.

During the United Nations' Conference on Science and Technology for Development (UNCSTD) in 1978, two events occurred relevant to our subject of scientific cooperation. One was a decision of the Government of Canada, the other of the International Council of Scientific Unions (ICSU).

The Government of Canada announced its intention to provide IDRC with a special budget to encourage and support cooperation between scientists in developing countries and scientists in Canada. This action enabled IDRC to expand an existing but modest program of cooperation between scientists in the IARCs and scientists in Canada.

Canadian support for such cooperation began in 1971 in two programs. In one, several Canadian universities and government laboratories cooperated with CIAT and IITA in research to improve cassava production and utility. In the other program, other groups of Canadians cooperated with CIMMYT in the development of triticale. One of the products of the Canadian research almost a decade ago was the production of disease–free cassava from infected plants by apical meristem tissue culture. Equally important, the project demonstrated that Canadian scientists could make a useful contribution to cooperative research on a tropical root crop that never has and most certainly never will be grown in Canada.

Other Canadian cooperative projects randomly selected from a list too long to present in detail include:

- allelopathic interactions between intercropped species, with IRRI;
- yellow dwarf virus in barley and weevil resistance in maize, with CIMMYT;
- Faba bean pathology, pollination, and rhizobia1 carrier systems, with ICARDA;
- chemo-taxonomic classification of several food and forage crops, with CIAT; and
- other legume and oilseed breeding projects which will take advantage of improved anther culture techniques developed in Canada.

Research in British Columbia on fish pituitary gonadotropins made possible the first induced spawning of gravid milk fish at the Southeast Asian Fisheries Development Center (SEAFDEC) in Iloilo. This cooperative work has since been extended to several other Asian fresh water and marine species and to the cryogenic preservation of male fish milt.

Dr. Nyle Brady emphasized the necessity of a more efficient sharing of the research load between the international centers and scientists in many other countries. We believe cooperative programs such as those established in Canada help spread the essential work load and relieve scientists in the IARCs for activities which they are uniquely equipped to carry out.

At the same UNCSTD Conference at which Canada announced its scientific cooperative program, ICSU established an International Commission on the Application of Science to Agriculture, Forestry and Aquaculture (CASAFA). The Commission is composed of eight members including Dr. M.S. Swaminathan, together with representatives of all the international biological and related scientific unions. It is also supported by 25 complementary committees and correspondents in National Academies of Science throughout the world. It is thus able to be in communion with virtually all the natural and physical sciences throughout the world.

The purpose of CASAFA is to stimulate cooperation between applied- and basic-research scientists for the overall benefit of agricultural development. Particularly it seeks to attract the attention and talents of many scientists in disciplines little exploited for the benefit of tropical agriculture. CHEMRAWN II illustrated the contribution which chemistry can make to food and agricultural development. A great deal of imaginative research in cell biochemistry and physiology is needed if cell and tissue culture are not forever to rely on empiricism. A sizable increase in biological engineering research is necessary if animal vaccines, growth hormones, and other necessary veterinary biochemicals are to be developed and the processes of production adequately and efficiently scaled up. Although IARCs such as IRRI and the International Laboratory for Research on Animal Diseases (ILRAD) cannot conceivably undertake all of the necessary basic research, such research needs to be planned and conducted with their cooperation.

Dr. Swaminathan and Dr. Brady have brought before us some of the difficult decisions which IRRI will have to make in balancing its upstream and downstream activities. It would appear essential that a good deal of cooperation in the upstream segment of the spectrum with scientists all over the world is essential if the full benefits of science are to be realized in IRRI and other IARC programs.

CASAFA is fortunate because most of its meetings have been attended by Dr. Guy Camus and Dr. Donald Plucknett. Its next meeting in Wageningen will begin with a symposium by Netherlands scientists on land and water management and biological nitrogen fixation. The meeting, to be attended by representatives of several agencies which support research, including the Australian Centre for International Agricultural Research (ACIAR), Board on Science and Technology for International Development (BOSTID), German Agency for Technical Cooperation (GTZ), NUFFIC, Swedish Agency for Research Cooperation (SAREC), United Nations University (UNU), WINROCK, and IDRC, will specifically address cooperation in agricultural research and how the means and resources for cooperative research can be increased and improved. While remembering Cardinal Newman's Obiter dictum "Living movements never arise from committees,'' it is our hope that CASAFA will make some useful contribution toward more productive international scientific cooperation particularly between the IARCs and other scientific institutions throughout the world.

One of the Psalms instructs us that without vision the people perish. The future of the CGIAR and its family of centers calls for an exceptional manifestation of imaginative vision if many in the developing world are not to perish from hunger and malnutrition. It calls for international scientific cooperation on a scale never previously imagined, let alone brought about. It requires such vision and dedication as Dr. Swaminathan and his predecessors, Dr. Brady and Dr. Chandler, brought to the direction of IRRI. Thoreau might well have had any one of them in mind when he wrote "He is not a true man of science who does not bring human sympathy to his studies and expect to learn by behavior as well as by application."

The Directors General of IRRI have all combined scholarship with compassion, scientific vision with sympathetic concern for those in need, and the consummate manner in which they have guided IRRI's destiny continues as a splendid example to us all.

It has indeed been a rare privilege to take part in this silver anniversary. I hope and pray I shall be present when IRRI scores its golden fifty.

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COLLABORATIVE RESEARCH: PAKISTAN'S EXPERIENCE

Pakistan has been associated with IRRI since IRRI was established. In the very early days of this association the introduction of rice variety IR8, as IRRI-Pak, initiated a transformation in agricultural production, which has often been called the "Green Revolution." The impact on rice production was so phenomenal that IRRI soon became a household term in Pakistan and now, even in remote rice-growing areas of the country, it is known to farmers, literate or illiterate, male or female. As I participate in the celebration today, I bring very warm greetings from the rice growers and the Government of Pakistan, for this very fruitful collaboration with IRRI, spread over the last 25 yr. I intend to describe some of the salient features of this collaboration. It may not be possible to give all the details of what we are doing in rice research and production development, but I will try to highlight those aspects of our collaboration with IRRI that have had significant impact on our rice production development.

THE AGRICULTURAL ECONOMY OF PAKISTAN

Pakistan has a predominantly agricultural economy. With large areas of deep, rich soils, the world's largest man-made irrigation system, and favorable climate, the country is blessed with vast potential for agricultural production. The Indus basin, with 20 million hectares under cultivation and 100 million acre feet of irrigation water at farm-gate, is capable of producing an annual 100 million tonnes of food grain. But presently, we produce only about 20 million tonnes of total grains, which indicates the vast potential for increasing production. The realization of this potential, however, requires strong support from appropriately focused basic, applied, and adaptive research. The country's agricultural research system should be adequately geared to promptly respond to these research needs. Besides, a properly organized extension service for an effective transfer of technology developed by the research system and an excellent management system at the farm, are needed to fully realize the production potential.

Despite all the favorable production factors, including a good irrigation system, one cannot be assured of an optimum harvest unless the weather cooperates. For instance, for the last 2 yr we have been in deep trouble because of insufficient rain, which has drastically lowered the water level in our two major dams. Never before had we thought of water as a limiting factor at least, for rice production, in Pakistan. But this year there is scarcity and we are more concerned with efficient water management even for our monsoon crops. All this has brought a number of pertinent messages to the attention of rice researchers in the country.

RICE IN PAKISTAN'S ECONOMY

Rice is the second most important food grain crop after wheat in Pakistan and has gradually become the country's major export commodity. Area under rice increased from 968,000 ha in 1950 to 1.5 million hectares in 1970 and to almost 2 million hectares in 1984 (Table 1). Similarly total production rose from 864,000 t in 1950 to close to 3.4 million tonnes in 1984. The introduction of high-yielding, short-statured, fertilizer-responsive IRRI varieties was one of the dominant factors contributing to this twofold increase in rice acreage and fourfold increase in total production. The introduction of these varieties along with a package of improved production technology increased rice yield from 876 kg/ha in 1960 to 1.7 t/ha in 1983.

The consistent increases in total rice production in the country from the 1960s onward created exportable surpluses. As a result Pakistan's rice exports rose from almost nil in 1948 to 0.2 million tonnes in 1970 and then increased progressively to touch an all-time record figure of 1.2 million tonnes in 1983. The value of the 1983 rice exports amounted to about four billion rupees

Table 1. Area, production, and yield of rice in Pakistan.

Year	Area (thousand ha)	Production (thousand t)	Yield (t/ha)
1950	968	864	0.9
1970	1503	2200	1.5
1983	1999	3340	1.7

Source: Agricultural Statistics of Pakistan, Planning Unit, Islamabad, 1983.

Table 2. Rice export (quantity and value) of Pakistan.

Year	Quantity (thousand t)	Value (million rupees)
1951-52	86	34
1961-62	130	122
1971-72	196	271
1980-81	1244	5602
1981-82	951	4128
1982-83	905	3683

Source: Agricultural Statistics of Pakistan, Planning Unit, Islamabad, 1983.

(approximately 250 million dollars) and constituted a substantial component of our total export earnings (Table 2).

The introduction of high-yielding IRRI varieties, particularly IR8 and IR6, played a significant role in the development of rice production. The yield potential of these varieties motivated farmers to use inputs such as fertilizer and pesticides and apply other components of improved production technology. The shorter maturity of these varieties led to wider adoption of more intensive cropping systems in the rice belts of the country. The increased rice production necessitated expansion of several related activities such as rice milling, processing, and marketing and all this resulted in a considerable economic uplift in rice-growing areas.

To realize the potential of the new high-yielding varieties and to tackle problems brought about by a massive development effort for rice production, rice research in the country was appropriately strengthened. In addition, the government created a National Rice Board to advise her on policy matters concerning rice production, marketing, and processing. It also established a Rice Export Corporation to handle the increasing quantity of rice exports and to regulate processing and procurement of rice for a proper quality check.

STRENGTHENING RICE RESEARCH

The two Rice Research Stations at Kala Shah Kaku in the Punjab and Dokri in Sind were upgraded to the level of institutes and provided with necessary facilities, i.e. manpower, laboratory equipment, and operational funds. Collaboration with IRRI made a singular contribution in this upgrading of rice research in the country. With a few exceptions, almost all professional manpower employed by our research institutes have been trained in collaboration with IRRI. To date, 135 scientists have gone through various types of training. Of these, 25 have received their MS and Ph D degrees from the University of the Philippines at Los Baños, about 100 have participated in IRRI nondegree, short-term training courses, and 9 have worked in IRRI laboratories on postdoctoral fellowships.

A continuous inflow of breeding material as different nurseries and advanced breeding lines provided a sound genetic base for the variety evolution programs at these institutes. Continuous participation of senior rice scientists and planners from Pakistan in IRRI-sponsored International Rice Research Conferences provided opportunities for exchanging views with IRRI scientists and has helped broaden their vision for a more judicious planning and implementation of their research programs. IRRI has been compiling and publishing extensive scientific literature on various aspects of rice improvement and production management. These publications have been of tremendous value to the rice scientists in the country.

NATIONAL COORDINATED RICE RESEARCH PROGRAM

To put the total rice research and development effort in a national perspective, a Coordinated Rice Research Programme was initiated by the Pakistan Agricultural Research Council (PARC) in 1976 with the following objectives:

1. Strengthen rice research in the country,
2. Optimize rice production and thus increase farmer income,
3. Identify agroclimatic regions and develop production technology for each, and
4. Train technical manpower in rice research and production.

Previously the provincial rice research institutes in Punjab and Sind, our two major rice-growing provinces, conducted research at their respective stations almost in isolation. Through the Coordinated Rice Research Programme, the total rice research and development effort in the country was coordinated by holding regular program planning and monitoring conferences, national seminars, and in-service training courses. These conferences provided an opportunity to jointly assess the problems in rice research and development, plan suitable approaches to solve these problems, identify manpower and infrastructural requirements for these problem-solving efforts, and plan on mobilizing necessary resources to implement programs. Our association with IRRI became more intense in 1977 when IRRI scientists were located in Pakistan to help structure the national rice research program and establish an agricultural machinery institute. These scientists were very useful in initiating a number of activities under these programs.

YIELD GAP AND PRODUCTIVITY CONSTRAINTS

Despite the impressive gains in per acre yields of rice and total production, there still remained a large gap between actual and potential yields. Data in Table 3 compare the national average with the highest yield obtained in experimental planting, and clearly demonstrate the unexploited potential. Similar high yields have also been reached by several progressive farmers. The causes of the low yield in farmers' fields are biological, physical, and socioeconomic.

Biological constraints

Among biological constraints are the low yield potential of varieties like Basmati-370, suboptimum plant population, inefficient use of fertilizer, lack of plant protection measures, and inappropriate postharvest operations. Physical and socioeconomic constraints include problems in the availability and supply of inputs, lack of credit facilities and, in some cases, lack of effective dissemination of improved production technology.

Low-yielding varieties

One major reason for low national average yields in Pakistan is the low yield potential of Basmati-370. This variety continues to be the sole fine aromatic rice grown in the country, even though it yields low. It has a tall plant stature and is not suited to high input technology. It lodges severely with high doses of fertilizer. But, because of its aroma and fine grain quality, it fetches a premium price both in the domestic and international markets. Efforts of rice scientists to reduce its height and thereby increase its yield potential have had no significant success. Among medium fine/coarse rices, IR6, introduced 15 yr ago, continues to be the predominant variety. The yield potential of IR6 in Pakistan has been demonstrated to be about 9 t of rough rice per hectare and that of Basmati is 4.5 t/ha, while national average is about 3.2 t/ha for IR8 and 1.8 t/ha for Basmati, about 33% of the demonstrated yield potential. Our major emphasis, therefore, is to bridge this gap. We consider this a top priority item for our research and development program.

Varietal improvement work has been going on since 1950 at the two Rice Research Institutes. Despite the best efforts of our rice scientists it has not been possible to replace Basmati-370 with a similar fine aromatic variety of high yield potential. The quality characteristics in Basmati-370 remain a mystery and incorporating them in a short statured variety is an uphill task. In coarse and medium-fine rices, however, it has been possible to evolve and introduce a number of new varieties using the material received from IRRI's International Rice Testing Program (IRTP) nurseries and advanced breeding lines. Recent introductions include KS-282 in the Punjab, and Lateefy, DR-82, and DR-83 in the Sind area. Although only slightly superior in yield than IR6, they mature earlier and fit well into the intensive cropping systems. These varieties are somewhat more flexible in their planting time.

Table 3. Unachieved yield (t/ha) potential in rice in Pakistan.

Potential yield (highest actual yield obtained under experimental conditions) (t/ha)	9.5
National average yield (1982-83) (t/ha)	1.7
Gap between potential and national average yield (t/ha)	7.8
Unachieved potential (%)	82

Source: Agricultural Statistics of Pakistan, Planning Unit, Islamabad, 1983, and Coordinated Research Programme, PARC.

Suboptimum plant population

Another major constraint to high rice productivity is inadequate plant population per hectare. This happens primarily because specialized labor engaged for transplanting rice is paid by the total area transplanted. They are, therefore, keen to cover as much area as possible in a shorter time and do not care much about the plant population. As a result farmers' fields usually end up with about 150,000 plants/ha as against the recommended number of 250,000. Thus by following only one recommended practice, i.e., ensuring optimum plant population, it is possible to increase rice yields substantially. But this will be possible only if a suitable rice transplanter is developed. We have been trying to solve this problem for many years and have tried Japanese, Korean, Chinese, and IRRI transplanters but we have not found one that would give us the breakthrough. Now here is a problem for research.

Harvest and postharvest operations

A similar situation exists in harvesting operations. Harvesting is by hand, with hired manual labor. However, due to increasing labor constraints in the production areas, harvesting rice is becoming a problem, more so because all of it ripens within a very short period. In many cases, the crop overripens in the field and this adds to harvest losses, which sometime run as high as 5%, as against the normal 1-2%. We have undertaken research to develop a suitable reaper that can be used to harvest wheat and rice efficiently and reduce harvesting cost. Our efforts have resulted in the development of a front-mounted wheat-rice reaper. The reaper is becoming popular with the farmers because it can be attached to an ordinary farm tractor, is inexpensive, and harvest losses are very low.

Threshing is still largely by hand or by bullocks, and 3-4% losses usually occur in these operations. The use of power threshers, however, is gradually increasing.

In general, total harvest and postharvest losses (including those in storage) range between 10 and 15%. If we can reduce these losses even by 5% by appropriate harvest and postharvest machinery and suitable storage techniques, we will have a very impressive gain.

Fertilizer and pesticide use

The expanded use of fertilizer in cultivating the short-stature varieties has been a major contributing factor toward increased productivity, as well as to total rice production. However, the doses applied often correspond to very general recommendations and in many cases are less than optimum. The continuous high yields have created problems of nutrient deficiencies and imbalance, both of macro and micronutrients, in the soils. To tackle the problem of micronutrient deficiency, the application of zinc sulfate has been practiced for some time with good results. However, for full realization of varietal potential, optimum fertilizer use based on site-specific recommendations will have to be adopted. These recommendations should be worked out, keeping in view the soil type, moisture availability, and crop rotations. Due consideration will have to be given to the application of micronutrients other than zinc.

Insect pests have been a major constraint in rice production in Pakistan. Although the use of pesticides has increased considerably over the years, a matching effort to monitor its quality has not been made. In many cases farmers underdose in the use of pesticides, which gives low protection against pest attacks and increases insect tolerance to the chemicals. For efficient production management, these aspects of pesticide use will have to be effectively taken care of.

Physical and socioeconomic constraints

Physical and socioeconomic constraints are as real as biological constraints. Once a package of improved production technology has been developed and extended to the farmer, its use is possible only if facilities and necessary inputs for its adoption become conveniently available. The usual constraints in this operation have been the very cumbersome process to obtain credit, interruptions in the supply of irrigation water and electricity for tube wells, and unavailability of fertilizer and pesticides etc., of the right quality, at the proper time. If any of these production factors becomes unavailable or inoperative, the technology will be ineffective. There may be cases where the effective communication of improved production technology and proper motivation of farmers to use it have been lacking. Therefore, today our biggest problem is to be able to use this available knowledge efficiently.

It is generally assumed that once the technology has been generated and extended to the farmer, everything else from there on will happen automatically. However, knowledge by itself will not produce results — it is the proper use of knowledge that produces results.

Realizing that improved production technology for rice cultivation is available and its potential has often been demonstrated on farmers' fields, one wonders why the farmers have not picked it up on a mass scale and adopted it in their own fields. Many of these farmers have visited the frequently laid out on-farm demonstration plots and high yield trials in the production areas. A discussion with the farmers on these issues revealed that although the majority of them were aware of the components of improved production technology, many of them were not convinced of the feasibility or actual potential of these. With most others, a number of constraints concerning the availability of inputs required for high yields were the major problem. It was, therefore, necessary to become part of the farm life for a while and to get to know in detail the reasons for low productivity. We, therefore, decided to go right to the farmers in the village, stay there, and work there to see and learn.

For this purpose, a collaborative rice program was developed in 1977 by PARC and IRRI. The first phase of the program was to develop a package of technology at farm level through adaptive research. Experiments on efficiency of N-application methods, various fertilizer sources, response to NPK in various paddy soils, studies on zinc response, plant population density, varietal adaptation, and trials on insecticide use and levels of management were conducted from 1977 to 1979. A package of technology was thus developed based on results obtained from these experiments. The second and third phases were carried out to confirm and test the new technology on a large scale on farmers' fields. For this purpose an operational rice production project was implemented in Gujranwala District of Punjab.

Operational rice production project. The Operational Rice Production Project was organized to identify major constraints for the low productivity of rice and to demonstrate, at the farm level, the potential of improved production technology. The program was implemented in summer 1981 in a predominantly rice growing area of 4047 ha covering 12 villages and 900 farm families.

As a first step, 30 applied research trials were conducted on farmers' fields to identify constraints and standardize the production technology evolved at the research stations for various agroecological conditions. The following year the results of the applied research trials were confirmed through further verification trials.

The project was implemented based on the philosophy of bringing all actors in the game together. A Planning and Coordination Committee consisting of representatives of PARC, Rice Research Institute, Kala Shah Kaku; Agricultural Extension Services; Irrigation Department; Punjab Agricultural Development and Supply Corporation; National Fertilizer Corporation Cooperative Department; Water and Power Development Authority; and various credit-giving agencies was constituted. To increase the effectiveness of this committee, the local civil administration, i.e., the Deputy Commissioner of Gujranwala District, was made its chairman. This Coordination Committee played a vital role in streamlining the supply of inputs and services by coordinating the activities of various nation-building departments. All the needed inputs and services became available to the grower at the right time, at the right place, and in the desired quality.

Before the actual implementation of the program, an extensive educational campaign was launched to ensure maximum participation of farmers in the project. Several village-level meetings and contacts with groups of farmers were jointly arranged by research station and extension staff, in addition to 25 field days which were attended by a large number of farmers. Material on rice production consisting of wall posters, handbills, and leaflets containing detailed instructions on the various components of the production technology were distributed to the farmers in the project area. Radio, press, and other media were used extensively to educate and acquaint the growers with the program and to urge their participation.

The main components of the rice production technology consisted of an optimum plant population (250,000 plant/ha), careful fertilizer use, application of zinc in deficient areas, and proper pest management. Nitrogen fertilizer was incorporated in the dry soil, contrary to the prevalent practice of applying fertilizer at the puddling stage which results in considerable nitrogen loss. Incorporating fertilizer in dry soil resulted in 10-15% increase in rough rice yield compared with the farmer's practice. Applying zinc sulfate at 15 kg/ha increased rough rice yield 10%. Similarly a yield increment of more than 10% was obtained by insect pest control through the use of appropriate pesticides.

The motivation of the farmers in the project area received a further boost by frequent visits of important people including Provincial and Federal ministers, who during their visits appreciated the farmers' efforts to increase agricultural production. They impressed upon the farmers that such an increase in production would not only lead to their own economic betterment but would also have a favorable impact on the overall economy of the country. The visits of such important personalities reaffirmed, to the farmers, the government's commitment to modernize agriculture and make it more efficient. All this kept the farmer's morale high and his sense of dedication firm. Realizing that the government is alive to their problems and would do everything possible to solve them, the farmers felt enthusiastic in adopting improved production technology.

The magnitude of yield increase obtained through the project created a tremendous impact on farmers and national policy makers. A summary of the dramatic impact of project and its cost effectiveness is given in Table 4. It is apparent that average rough rice yields for Basmati-370 increased from 1.9 t/ha in 1980 to 3.0 t/ha in 1981, a 59% increase. IR6 yield increased 106%, from 2.8 t/ha in 1980 to 5.7 t/ha in 1981. These yield increases in the project area were the result of 45% of the farmers fully adopting the recommended technology, 35% adopting it only partially, and 20% not adopting it at all. In terms of individual components of production technology, the average plant population in project area increased from 150,000 plants/ha in 1980 to 190,000 in 1981,

Table 4. Impact of operational research and production project on rice in Gujranwala District in 1981.

A. *Project description*		
Location:	Sadhoke Union Council District, Gujranwala, Punjab	
Area;	4047 ha	
Number of villages:	12	
	Basmati-370	*IR6*
Average rough rice yield (t/ha), 1980	1.9	2.8
Average rough rice yield (t/ha), 1981	3.0	5.7
% Increase	60	106
Average yield (t/ha) from PARC demonstration plots (66)	3.4	6.6
National average yield (t/ha), 1980	1.8	3.2
B. *Cost effectiveness of project*		
Promotional expenditure by PARC (educational campaign, demonstration/ applied research trials)	0.17 million rupees	
Additional paddy produced over 1980	3342 t	
Additional income	8.00 million rupees	
Cost-benefit ratio	1:46	

Source: National Rice Coordinated Research Programme.

fertilizer use from 30-35 kg NP to 5040 kg NP/ha, zinc application from a total of 1530 kg to 2829 kg, and insecticide use from 3 1,805 kg to 53,021 kg.

The following conclusions can be drawn from this operational research and production development approach

1. Developing countries can obtain dramatic and quick yield increases under farmers' conditions through careful application of the existing crop production technology.
2. To bridge yield gaps between national average yields and yields obtained under experimental conditions, the agricultural production system must be managed more efficiently. To achieve this, the agencies providing guidance on improved crop production technologies and services to farmers must be mobilized in a coordinated manner.
3. The operational research/production project should be implemented under the leadership of highly capable and motivated management. The project leader should have the responsibility to improve crop yields substantially within one or two seasons. To achieve this goal the implementing agencies should provide necessary staff, funds, and authority to the project leader for successful implementation of the project.

FUTURE RESEARCH THRUSTS

Despite several impressive achievements made in the development of rice production technology and its adoption by the farmers, there are as yet a number of constraints that prevent the realization of full biological production potential of varieties, as well as various production factors involved in rice culture. We are, therefore, trying to revise our research strategies and reorient our rice research programs to focus more on the following aspects:

- Breeding for stress environments such as soil salinity, water stress, and low and high temperatures;
- More efficient soil and water management for increased productivity per unit area;
- More efficient techniques for nursery raising including its suitability for mechanized transplanting;
- Efficient and reliable screening techniques to develop insect- and disease-resistant varieties;
- Research on the chemistry of submerged soils to increase fertilizer use efficiency;
- Research in microbiology for maintaining proper soil health and utilization of renewable energy;
- Research to maximize productivity of rice-based cropping system;
- Research on marketing bottlenecks to ensure ready and remunerative prices to the grower;
- Research in quality characteristics of Basmati and other aromatic rices;

- Development of integrated pest management techniques, including biological control measures, to minimize the use of chemical pesticides; and
- Development of appropriate farm machinery for mechanizing rice production.

COLLABORATION WITH IRRI

Our future collaboration with IRRI will have to be redefined in the context of the above-mentioned research thrusts. Manpower development will still be an urgent need to bring the scientific cadres at our Rice Research Institutes to the desired level of competence. Whereas we may still need participation in some of IRRI's formal training courses, our future manpower training will have to be at postdoctoral level or through research fellowships for on-hand experience. This will provide our rice researchers, who have acquired some background in their field of specialization, an opportunity to work, for a reasonable length of time, with top IRRI scientists. Production-type training courses will preferably be held in-country, and we would certainly require IRRI's assistance in the organization and conduct of these.

We would very much like to benefit from the expertise of IRRI scientists in the planning and monitoring of our rice research and for this purpose would suggest participation of IRRI scientists in our regular program planning and monitoring meetings. This would ensure, with IRRI's involvement, development and implementation of research programs relevant to the various research thrusts that I have outlined. We would, of course, be drawing heavily on the rice germplasm being developed at IRRI and would continue to participate in the IRTP.

I would like to conclude by emphasizing that with the position that rice occupies in my country's economy and with the priority that the government assigns to research and development in rice, our interface with IRRI will be long lasting.

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Director General
Indian Council of Agricultural Research, New Delhi India

INTERNATIONAL COOPERATION IN AGRICULTURAL RESEARCH AND EDUCATION IN INDIA: NEW DIMENSION

It is fully recognized in India that the application of science and technology is imperative for attaining the goal of self-sufficiency in agricultural production, which alone can ensure sustained development of the country.

The Indian Council of Agricultural Research (ICAR) is India's apex body responsible at the national level for promoting and coordinating agricultural research and higher education in the various branches of agriculture and allied sciences including animal science, fisheries, soil science, and agricultural engineering. ICAR's role in evolving high-yielding varieties and new production technologies suited to different agroclimatic conditions has generated new confidence in India's capabilities to feed its vast population. The combined efforts of dedicated agricultural scientists, committed administrators, and hardworking farmers have made it possible to raise food production from 52 million tonnes in 1951-52 to 151.5 million tonnes in 1983-84. Similar achievements have been made in several varieties of fruits and vegetables, animal products, and fisheries. In its endeavor, ICAR benefited greatly through the cooperation of several developed and developing nations as well as international institutes.

HISTORY

ICAR was set up in 1929 on the recommendation of the Royal Commission on Agriculture as the Imperial Council of Agricultural Research. In 1946, the

Presented by Dr. M. V. Rao, deputy director general (crops), Indian Council of Agricultural Research.

name “Imperial” was changed to “Indian“ without affecting its acronym ICAR.

In the past 55 yr, ICAR was reorganized twice. The first reorganization was in 1965 as recommended by the Agricultural Research Review Team, an expert committee set up in 1963. Earlier, ICAR had been a coordinating body engaged largely in financing selected ad hoc research schemes, and its control was restricted to the schemes financed by it.

After its reorganization, major changes were made in its rules and by-laws. The governing body was reconstituted to make it preeminently a body of scientists. All the centrally managed research institutes and stations conducting research in agriculture and allied subjects were transferred to the administrative control of ICAR. In addition, ICAR was entrusted with the responsibility of supporting the growth and development of agricultural universities. A scientist was appointed director-general, the chief executive. Four positions of deputy directors-general were created to look after 1) crop science; 2) soils, agronomy, and agricultural engineering; 3) animal science; and 4) agricultural education. Recently, a fifth post, that of deputy director general (agricultural extension), was filled. These changes greatly enlarged the responsibilities and powers of ICAR.

The second reorganization was in 1973. The major developments included the establishment of the Department of Agricultural Research and Education (DARE), with the ICAR director general as secretary; the recomposition of ICAR as a business-like body with restricted membership; the restructuring of the governing body with the ICAR director general as chairman; the abolition of the standing committees; the establishment of scientific panels; and the establishment of regional committees for eight agroecological regions of the country to review the status of agricultural research and education and to examine in depth the location-specific problems of agriculture in the respective regions. Management committees were set up to rationalize the decision-making process at the national level. New personnel policies included classification of staff under various categories, creation of the Agricultural Research Service (ARS), and establishment of the Agricultural Scientists’ Recruitment Board to conduct the recruitment and assessment of scientific and technical posts as per the requirements of ICAR.

Provisions were made for direct recruitment of posts at the higher level, for contractual appointments to managerial positions, and for invitation to distinguished scientists by the ICAR director general, to work in desired disciplines at all the institutes of the ICAR. These developments, especially in the second phase of reorganization, raised the status of agricultural scientists and that of ICAR in the country.

RESEARCH NETWORK OF ICAR

To achieve its objectives, ICAR has developed a vast network of 39 research institutes and its 200 research centers, 11 national research centers, 5 project directorates, 66 All-India coordinated research projects, 19 agricultural education schemes, and 9 extension education and other schemes spread all over the country. In addition to this, ICAR provides financial assistance to 530 ad hoc research schemes which are in operation at various institutes, universities, and colleges all over the country.

In agricultural education, ICAR plays the same role as the University Grants Commission for general education. Since 1960, when the first Agricultural University was established at Pantnagar, ICAR has helped establish and develop 23 agricultural universities in 17 states of India. Two of the national institutes, the Indian Agricultural Research Institute (IARI) and the Indian Veterinary Research Institute (IVRI), which have been granted "deemed-to-be university" status; and three other institutes, the National Dairy Research Institute, Indian Agricultural Statistics Research Institute, and Central Institute of Fisheries Education, have educational functions in addition to their research mandates. In addition, ICAR grants hundreds of fellowships at different levels of education and research.

Because agricultural production technology is highly location-specific, ICAR has launched a National Agricultural Research Project (NARP) to strengthen the regional research capabilities of agricultural institutes. In this project, 116 distinct farming system zones have been identified and it is planned to establish a multidisciplinary regional research station in each zone to undertake location-specific research to improve productivity of local agriculture.

ICAR also plays a significant role in transfer of technology programs through its Extension Education Network of National Demonstrations, Operational Research Projects, Krishi Vigyan Kendras (Farm Science Centres), and Lab to Land programs.

ICAR has a massive publications program and has published several scientific and semitechnical periodicals and a large number of books for the benefit of its users. ICAR also supports the publication activities of the institutes and agricultural universities so as to disseminate information to the user community. ICAR also operates an agricultural research information service in various Indian languages and supports the production of instructional and extension films. It contributes information to the AGRIS (FAO) for users in India and abroad and is willing to extend cooperation in copublication for mutual benefit of users.

The vast infrastructure and the present functions combining the management of agricultural research, education, and extension make ICAR a unique organization.

The large infrastructure of agricultural research and education in India is manned by about 30,000 well-trained scientists, supported by adequate technical, administrative, and other staff working on a variety of subjects, covering all disciplines under the mandate of ICAR. As such, on one hand, ICAR is capable of adopting and absorbing the advanced technologies suited to its needs, and on the other, it can offer and share its rich experience with friendly developing countries of the world.

Because of the importance of international cooperation for the advancement of agriculture, ICAR is entering into agreements with various governments and international agencies for cooperation and mutual assistance. Activities under these programs include exchange of scientific literature, scientists, and specialists; symposia and training programs on subjects of mutual interest; and collaborating in other areas of mutual benefit.

CHALLENGES AND PRIORITIES

With a massive application of science and technology, Indian agriculture has been transformed from a subsistence type into a commercial farming system. The impact of research and development efforts is reflected in the achievement of self-sufficiency in food grain production. Similar achievements have been made in potato, apple, cotton, tobacco, sugarcane, milk, poultry, fish production, etc. The country has now one of the largest research and training infrastructures in the world devoted to problems confronting agriculture to meet the growing demands of food, feed, fiber, and fuel.

Despite its achievements, Indian agriculture continues to face serious challenges. Its food grain production has to be raised to 225 million tonnes to feed an estimated population of 1 billion by 2000 AD. Demands projected for other commodities are equally high. Naturally, emphasis will have to be given to improving and stabilizing crop and animal productivity. New crop varieties with wider adaptation, improved harvest index, and short duration to fit into multiple cropping systems under irrigated and varied rainfall situations are required. Under intensive agriculture, problems of water, plant nutrients, pest management, and pesticide residues are becoming complex. Postharvest conservation of produce and production of value-added products and by-products are essential to improve availability of food materials and assure better dividends to growers. Social justice demands greater focus on backward areas and weaker sections of the society. Selective mechanization is essential for increasing productivity, stabilizing it, removing drudgery, and imparting dignity to agricultural operations. Agroforestry and desertification are emerging new areas of vital importance. Because of the increasing energy shortage, it has become important to decrease the dependence on commercial energies, and supplement or substitute them with new and renewable sources of energy. Efficient communication and transfer of technologies to farmers remains its most crucial problem to be achieved without losing much time.

The identified priorities and thrust areas of ICAR for the Seventh Five-Year Plan (1985-90) are the following:

1. conservation and planned exploitation of germplasm resources of plants, animals, and fisheries to broaden genetic base for improvement;
2. enhancing production by evolving new varieties and hybrids of crops and animals, incorporating multiple resistance against insects and diseases, and tolerance for saline and alkaline soils, drought, floods, etc. Emphasis would be on basic and fundamental research and on the use

of advanced biotechnologies to produce new plant types and micro-organisms ideal for higher production;

3. improving nutrient management system through increased emphasis on biological nitrogen fixation, input use efficiency, and weed control;
4. complete inventory of natural resources using remote sensing and other advanced techniques for their planned management and exploitation;
5. improving dry-farming technology, with emphasis on developing suitable crop-weather relationships including trees and livestock as essential components under different agroclimatic situations, and on-farm water conservation and management;
6. energy management in agriculture with special reference to the use of animal power and other renewable sources;
7. postharvest technology with emphasis on on-farm storage, processing, and marketing of agricultural produce;
8. improving information and communication systems for strengthening transfer of technology programs;
9. fostering excellence in research and education programs; and
10. human resources development with special emphasis on weaker sections of the society and for advanced training of young scientists in new and advanced technologies.

COOPERATIVE RESEARCH

With the overall world food situation continuing to be serious, as evident in the widespread food crisis in Africa and in other countries, it has been a consistent stand of India that the international community should cooperate with United Nations agencies in solving food problems and abolishing hunger and malnutrition. Self-sufficiency in food is the key element in the economic and political independence of a country.

In their drive to achieve self-sufficiency in food, the developing countries could gain significantly from each other's experiences. India is already cooperating with a number of developing countries to foster the growth of agriculture.

The types of collaborative programs in which ICAR/DARE has been a signatory or participant can be broadly classified into four categories:

1. Agreements and protocols with developing and developed countries;
2. Agreements between ICAR and international institutes;
3. Project-based agreements at the government level with international agencies; and
4. Scientist-to-scientist interaction.

AGREEMENTS IN AGRICULTURAL SCIENCE AND TECHNOLOGY

The ICAR/DARE has signed memoranda of understanding with several countries such as United Kingdom, United Soviet Socialist Republic, Australia, Mexico, North Korea, Mozambique, Bangladesh, Philippines, Iraq, Vietnam, and Egypt. Protocols with The Netherlands, France, and Pakistan are under consideration. ICAR/DARE is participating under protocols and agreements signed by other departments like the Department of Culture and the Department of Science and Technology. ICAR has also signed agreements and memoranda of understanding with international organizations like the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), South East Asian Fisheries Development Center (SEAFDEC), Ford Foundation, International Development Research Centre (IDRC), Swedish International Development Authority (SIDA), Danish International Development Agency (DANIDA), IRRI, Centro Internacional de la Papa (CIP), and West Africa Rice Development Association (WARDA).

The essence of cooperation under different agreements is reciprocity and mutuality of interests. The actual mode of implementation of the collaborative programs is oriented to suit the broad objectives for which such agreements of cooperation are concluded. The mode of collaboration has normally followed the pattern of 1) exchange of germplasm of plant and animal origin, 2) exchange of scientific and technical information, 3) visits of scientists and experts, 4) training of scientists and academicians, and 5) infrastructure development.

Agreement between ICAR and counterpart international institutes

Agreements of cooperation between ICAR and international institutes have generally been limited to commodity-based research activity like rice research with IRRI, potato research with CIP, and maize and wheat research with CIMMYT. In recent years, a broader perspective has been introduced while signing agreements with BARC, PARC, ACIAR, ICARDA, ICRAF, and others.

Project-based agreements with international agencies

In agreements with foreign agencies like USAID, World Bank, and UNDP, the primary thrust has been to supplement national research efforts through funds made available by these agencies and through supply of material and equipment. These are primarily broad-based agreements.

Indo-U.S. collaboration

The Indo-U.S. collaboration has been very valuable in the development of agricultural education and research in India. Recently, a new dimension was given when an agreement was signed between our late Prime Minister, Smt. Indira Gandhi, and U.S. President Reagan to initiate major cooperation in science and technology. The emphasis was to embark upon a program of cooperation in a few well-identified specific fields which would be supported adequately by both sides and where tangible results could emerge for mutual benefits. As a result, the Indo-U.S. Senior Scientific Panel (Science and Technology Initiative) was set up for determining the priority areas of collaboration between both countries. In agricultural research, the panel identified two major programs, namely, biological nitrogen fixation and nitrogen fertilizer efficiency. The cooperation program provides, among other things, for visits by U.S. scientists to India and Indian scientists to U.S. laboratories, in addition to workshops and training programs.

Training foreign students

During 1984-85, 181 foreign students from Afghanistan, Burma, Bangladesh, Bhutan, Kenya, Nepal, Sri Lanka, Solomon Islands, South Pacific, Tanzania, Uganda, and other countries received training in Indian agricultural universities and ICAR institutes. Because Indian experiences are more relevant to situations in the developing countries, India is very well-equipped to play a significant role in the institutional development and manpower training for the developing countries of the world. Under the TCDC program of the FAO, some of the institutions in India can be identified to take up this responsibility.

NEW DIMENSIONS IN COOPERATIVE RESEARCH

Cooperative research has to continue to achieve the intended goals of the linkages. However, the food issue is so vital that any amount of effort does not seem enough to meet the challenge. Issues that deserve greater attention and initiatives include the following:

1. Nature has endowed this planet with tremendous diversity in germplasm of plants, livestock, and fish. We need to optimize this natural asset to full advantage. Every nation should build up its gene banks and share the germplasm for mutual advantage.
2. Biotechnologies should be developed and applied for improving biological materials, their propagation, and use.
3. In many developing countries there are management constraints. As a result, new ideas do not spread easily. Exchange of experts to build up indigenous expertise and execution of high-priority tasks demand priority consideration.
4. The current status of science and technology needs to be assessed to identify areas where assistance can be given to or solicited from a country. It is important to develop local manpower for undertaking such studies.
5. Cooperative research strategies should foster growth of local talent and infrastructure. Emphasis should be on the development of research and development of a nation.
6. Appropriate engineering inputs to agricultural and rural living are important to increase production, productivity, and net profits, and to improve the quality of life. Although some countries have successfully

mechanized their agriculture, many continue to use traditional equipment. In some, useful designs have been developed but have not reached the farmers. These designs should be popularized.

7. Energy management is important to agriculture. In many countries, dependence on commercial energy should be reduced by supplementing or substituting with alternate renewable energy sources.
8. Appropriate postharvest technologies and produce-management techniques are needed to assure the growers of due dividends.
9. Knowledge and management expertise need to be pooled in every country to disseminate new technologies.
10. Proven technologies need to be exchanged for adoption and exploitation among needy nations through bilateral and tripartite agreements and through international bodies.
11. Sharing knowledge through exchange of publications, films, tapes, etc., and communication techniques used for effective dissemination of scientific information to different levels of users needs to be given a high priority.
12. International programs should be complementary to national programs and directed toward improving national capabilities.

Starting with our first agreement signed with IRRI in 1974, the scope and content of collaborative research have been gradually enlarged. Currently, it covers manpower and institutional development and all aspects of basic and mission-oriented applied research aimed at improving and stabilizing rice production in the country.

I hope in the coming years our linkages will be further strengthened keeping in view our immediate and long-term research strategies and priorities.

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COLLABORATIVE RESEARCH IN BANGLADESH

The Bangladesh Government recognizes and deeply appreciates the special support and assistance it has received from IRRI.

It is with great pleasure that I extend to the IRRI Board of Trustees, administrators, and scientists special greetings and best wishes on their 25th anniversary on behalf of the Bangladesh Minister of Agriculture and the entire community of agricultural research scientists. We look forward to the continuation of the mutually helpful, productive, and effective relationship that has developed between IRRI and the various Bangladesh agricultural research programs and scientists, particularly with the Bangladesh Rice Research Institute (BRRI).

In the mid-l960s, IRRI scientists helped plan and organize a special rice research-team with Ford Foundation’s support and assistance. By 1970, BRRI was operating at its present site, initial laboratory and office buildings were completed, and a minimum set of scientific equipment was in place. Most of the scientists were provided short-term training at IRRI. This special relationship has continued in recent years with the support of the Ford Foundation, the Australian, Canadian, and United States Government overseas assistance programs. Many scientists have now completed professional training programs at IRRI at both masteral and doctoral levels. Several cooperative research projects have been developed and implemented by BRRI and IRRI scientists whose acquaintance and common interests began with graduate training programs. This personal and professional relationship will surely continue leading to additional cooperative efforts in the future. We particularly welcome such professional linkages and will continue encouraging and supporting them.

Several special challenges and opportunities for cooperation and collaboration seem to be emerging in the future for BRRI and IRRI, and these may also be of interest to other national rice research programs.

POPULATION GROWTH AND RICE PRODUCTION

During the early 1960s annual increases in Bangladesh rice production of 3.5% exceeded the population increase of 3% but in the early 1970s during the post-independence period, production increases fell and stagnated. Since then annual increases in rice production have about equalled the annual population growth now estimated at 2.8%/yr. At this rate population may easily double again within 35 yr. The major concern then is to develop a stream of technology, support services, and public policies that will encourage rice farmers to increase production and per acre productivity at least 3.5%/yr to achieve and maintain rice self-sufficiency. We believe that such per acre yield increases should and can be achieved while recognizing that seldom in the history of agricultural development has such a goal been achieved.

Use of modern varieties with associated production practices, including chemical fertilizer and irrigation, are expanding at a most encouraging rate. Irrigated hectarage is about 3 million hectares and should increase to 4 million within this decade. These recent developments have provoked a general feeling ofoptimism that for the immediate future Bangladesh may succeed in growing enough rice to meet national needs except in those years when unusual floods or droughts destroy major crop hectarage. Wheat imports may continue for some time primarily for use in food for work development programs in building hundreds of miles of rural access roads.

Most ongoing IRRI networks and special cooperative projects contribute either directly or indirectly to the achievement of such long-term growth of rice production. The ongoing BRRI-IRRI cooperative irrigation and water management and crop production research is a good example of such a project. It focuses on improved yields of individual crops and increasing the number of crops grown each year. Although we achieve considerable improvements in irrigation and water management, crop yield improvements fall short of our expectations. There is a special opportunity and challenge to develop feasible yield improving practices. Soil management practices to maintain long-term soil health as land use intensity increases will become more important. If we are to obtain such yield increases over a long span of years, means must be found to mobilize and integrate all available means for increasing yields while controlling production costs. Management of the overall farm resources to adjust to changing price relationships and available production technology while protecting the environment offers a special challenge. Perhaps IRRI can help devise a system approach for undertaking such long-term research efforts that organize and incorporate contributions from multidisciplinary oriented research efforts.

VARIETAL DEVELOPMENT

BRRI has released 19 high-yielding rice varieties with broad, general environmental adaptability. They were planted on about 20% of the rice hectarage and yielded about 36% of the total rice harvest in 1983-84. That means high-yielding varieties produce 6 million tonnes of the total rice harvest of 16 million tonnes. Farmers' use of these varieties is increasing slowly but steadily with each seasonal crop. To obtain a major increase in farmer adoption, modern varieties are needed to meet the unique agroecological conditions in different regions of the country. Development of a group of such varieties is a major goal for the existing five regional stations. Through 21 IRTP nurseries that are planted each year, a worldwide collection of varieties and elite breeding lines are directly tested in such target agroenvironments. Publication of standard descriptions of such environments last year was helpful in setting variety development goals and in facilitating management of collaborative plant breeding activities. High priority concerns are the direct-seeded upland crop planted at the beginning of the rainy season; shorter field duration for all seasons; photoperiod sensitivity and tidal submergence tolerance in some lines for the second rainy-season crop; salinity tolerance in the seedling stage of first rainy-season varieties; and floating rice varieties for depths up to 3 m.

While recognizing and appreciating the valuable support provided through IRTP and special assistance of individual IRRI scientists, would it be worthwhile to also consider organizing additional international working groups of scientists interested in specific environments to jointly plan research and share findings and breeding materials? Perhaps such network activity would help focus attention on additional environments that may be of relatively minor importance when considered on a worldwide basis.

Collaboration among national research programs can improve access to hot spots for screening and to support development of new screening methods. BRRI has a nematode-infected area where screening for ufra resistance is under way using methods developed by a BRRI scientist undertaking graduate studies. IRRI and Vietnam have sent lines to BRRI for either initial or confirmation screening.

Such collaboration should become easier to arrange as benefits are recognized.

FARMING SYSTEMS RESEARCH

Climatic conditions permit production of a large assortment of crops throughout the year in Bangladesh. Soil characteristics, elevation, and water availability add to the complexity of the farmer decisions about crop selection and production methods. But farmers are ingenious in selecting crops for each season that fit their farm conditions and offer the best income-earning potential with acceptable levels of production and price risks. BRRI is studying existing farmer cropping systems and introducing into those systems modern technology generated through the national research programs.

Microenvironments have been classified and those occupying major national acreage have been selected for priority research attention. The goal is to develop cropping patterns and production practices that offer the farmer an opportunity to increase the annual harvest with improved income potential without unduly increasing production and price risks. BRRI has been collaborating with the Department of Agricultural Extension (DAE) in conducting multilocation verification trials for 3 such microenvironments. Both the extension staff and the farmers are responding enthusiastically. Results have been so attractive that pilot production-programs are under way this year in three districts where 2 modern varieties can be grown under rainfed conditions. Full-scale production campaigns will be mounted in these areas next year using the BRRI-developed patterns and component technology.

There is a special challenge for the future in further developing and refining this research and technology transfer methodology so that it may be converted into a true farming system research effort. Special challenges may also emerge in devising means to train extension workers adequately to effectively deal with such a diverse set of enterprises. BRRI accepts this opportunity to undertake rice farming systems research as a special challenge for the future.

CONCLUSION

The examples of cooperation and collaboration cited earlier demonstrate the many emerging opportunities for planning and implementing mutually helpful activities. BRRI staff competency has improved over the years through various in-service and graduate training programs both at IRRI and other reputed institutes, and is, therefore, better able to collaborate with IRRI.

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COOPERATIVE RESEARCH: NEW DIMENSIONS IN INDONESIA

During the last 10 yr Indonesia's agriculture has changed from being heavily dependent on rice imports to having rice surpluses and exporting to other countries. In our rural areas, the situation was critical 15-20 yr ago. There were substantial underemployment and severe food shortages. Now in those areas the people are well fed and the opportunities for off-farm employment are expanding. Problems still exist but their magnitude is not as serious as in the late 1960s. One of the main reasons for this turnaround in agriculture was the role agricultural research played in providing information to policy makers and improved technologies to the farmers. Indonesia is very grateful for the role IRRI has played in strengthening rice research by training our scientists and providing the initial technical advances. Indonesia is also grateful to USAID for its long-term support of the USAID-IRRI program, making available skilled foreign scientists to work with Agency for Agricultural Research and Development (AARD) while our scientists were in graduate programs abroad. Other donor countries I would like to mention here are Japan, Australia, The Netherlands, and Canada. With their assistance, Indonesia overcame the serious problems that confronted the nation in the early and mid-1970s.

I will describe the goals and directions of AARD in the next few years; review past, present, and future collaborative programs of IRRI and AARD; and suggest some new dimensions for the future.

With the changing economic situation and increasing population pressure in rural Indonesia, AARD recently decided the time had arrived to reassess the research strategy of the agency. The first step in this process was to redefine our priorities.

AARD has set priorities for our agricultural research program. First is the continued expansion of food production. Second is the expansion of agricultural export commodities, third is the promotion of commodities for import substitution, and fourth, is the utilization and conservation of our land and water resources. All these efforts should simultaneously support the aim of increasing farmers' and fishermen's incomes.

To achieve a continuous expansion of food production, research should emphasize food crops, particularly rice, corn, and grain legumes. One of the government's main concerns is to create a stable and sustainable increasing level of rice production which keeps pace with the increase in the population and with the increase of demand of 4-5% annually. Rice production in Indonesia has substantially increased from 11.28 million tonnes of milled rice in 1968 to 25.8 million tonnes in 1984. Yet, for the future of the nation it is essential that this major achievement be maintained and the level of increase sustained. Corn, the second major food crop in Indonesia, has not yet received as much attention as has rice in our research program. Thus, one of the major research goals of AARD is to contribute to the expansion of corn production and its utilization. AARD will also put major stress on the expansion of grain legumes because it is essential to meet the growing domestic demand and the improvement of people's diet.

To expand export commodities for more foreign exchange for Indonesia, we continue to emphasize research on rubber, palm oil, coffee, tea, and cocoa. We will also give major importance to the expansion of shrimp production, both capture and culture, and to the capture of tuna by our fishing fleets. The government is placing special importance on commodities that are produced by traditional fishermen and commercial enterprises.

To conserve foreign exchange, the government is also promoting the expansion of import substitution commodities. Fifteen years ago many persons and organizations, including the World Bank, thought Indonesia would have very serious food problems in the mid-1980s. Instead we have achieved a surplus in rice production and are prepared to export rather than import rice. Thus, AARD's research program, to support this import substitution effort, will give increased attention to the production of sugar, coconut, cloves, cotton, fruits, vegetables, livestock, and fish. To increase the value added to these commodities, research on postharvest handling and processing will be expanded.

To utilize and conserve land resources, AARD has initiated a major research program to support watershed management. Scientists will be actively involved in a major research and development program to develop an integrated package of agricultural technologies for upland farmers in these watersheds. For too long, programs have assisted only the farmers in the well-irrigated lowland areas. It is essential that the poorer farmers working on the steep slopes in these critical upland areas be given the same level of support as their more fortunate brothers in the lowlands of these watersheds. Another part of this effort is AARD's research assistance to Indonesia's transmigration areas, and to opening up new rice fields and new agricultural lands for export commodities on the islands other than Java. At least one million hectares will be opened during the fourth Five-Year Development Plan (1984-89).

ROLE OF AGRICULTURE IN CREATING EMPLOYMENT

On Java, where the density of the rural population is as high as anywhere in Asia, the main issue for development is the creation of employment opportunities. Agriculture has played and must play in the future a major and active role in creating rural employment. Food crop production is entirely by small farmers and thus is extremely important for employment. The capture and culture of fish, shrimp, and other aquatic commodities are done almost 98% by small-scale fishermen and pond farmers. Estate crop production is at least 85% by smallholders. Obviously, the creation of rural employment in the nation's fifth Five-Year Development Plan will still be greatly dependent on these agricultural activities.

ROLE OF AGRICULTURE IN NATIONAL DEVELOPMENT

In Indonesia, the agricultural sector has made significant contributions to economic development during the first three Five-Year Development Plan periods. Annual rice production more than doubled between 1968 and 1985. Indonesia has achieved self-sufficiency in rice production and it is expected that the target of 28.6 million tonnes by 1989 will be achieved. Third-generation problems of storage of buffer stocks and export of excess production now confront the government. Production and export of commodities such as rubber, coffee, palm oil, tea, cocoa, shrimp, and fresh fish have also increased substantially.

Agriculture accounted for 29.2% of the Gross Domestic Product in 1983-84, which was the last year of the third Development Plan. This success in agriculture (especially in rice production), which has been a major factor in sustaining the economy, has been the direct result of agricultural research.

However, on Java it must be recognized that agriculture can only partially support the rural population. Most farmers with small holdings and agricultural laborers with very few resources must supplement their incomes with off-farm jobs. It is important to realize that agriculture is a subsystem of the national economy with important forward and backward linkages between agricultural production on one side and industry and trade on the other. One of the research goals will be to examine these linkages and develop research programs that will strengthen this interrelationship between industry, trade, and agriculture. Thus, agriculture will continue to contribute to employment creation, especially on Java. A simple diagram illustrates these linkages (Fig. 1).

One of the directions of our research on forward linkages is to develop ways for processing industries to increase the value added to the products by performing more postharvest handling and processing before export abroad or substituting for import commodities. In this way agriculture can contribute more to the gross domestic product and to employment in these agroprocessing industries. Another one of our new dimensions is initiating research on social and economic innovations for employment creation, income improvement, and marketing efficiency.

A country like Indonesia with a population of 165 million people and a large agricultural base, spread over a vast area which consists of 13,000 islands, must have a well-developed, efficient agroindustrial sector. AARD is actively exploring ways to cooperate with private industries to stimulate the expansion of agroindustries. This will take the form of cooperative research arrangements, transfer of knowledge, and exchange of personnel.

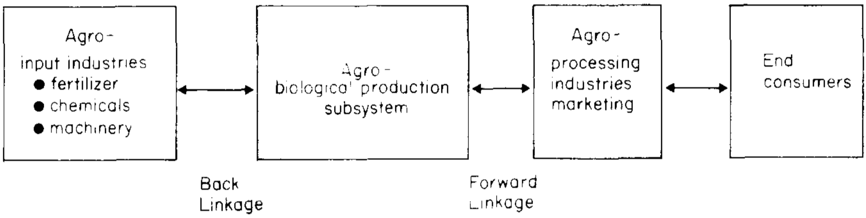
To support the biological production system the back linkages are with industries producing the necessary inputs for the improved varieties. A good example of this type of industry is Indonesia's major investment in fertilizer production which is capable of meeting our needs and exporting the surpluses. In addition, Indonesia is rapidly developing the capacity to produce agricultural machinery. Research to support these back linkages includes fertilizer formulations for rice and other crops, improved nutritive value of feeds, insecticide formulations, appropriate agricultural machinery, and benefit-cost ratio analysis.

For the biological system, AARD is continuing the development of technological innovations and exploring the possibilities of biotechnology as part of its new directions. This bioecological production system can be integrated with industrial development only if the system is healthy and not harmed by pollution or environmental degradation. Consequently, the direction of AARD's research must be to support the system and help to integrate it with the industrial development of Indonesia.

COOPERATIVE AND COLLABORATIVE RESEARCH WITH IRRI

In 1960-75, Indonesia's national agricultural research system was weak and most of the research was carried out in the five Directorates General for Food Crops, Estate Crops, Forestry, Fisheries, and Animal Husbandry. IRRI provided research findings and staff to Indonesia while AARD senior scientists were training abroad, primarily at IRRI, the University of the Philippines at Los Baños, in the United States, and in Australia.

Obviously, this was a very critical period, with the country's senior agricultural scientists training abroad. Thus, it was necessary to invite IRRI to provide substantial support for research in Indonesia on agricultural problems.



1. A diagram of the linkage between industry, trade, and agriculture.

Indonesia is grateful for this support which provided breathing space to train our scientists.

AARD was established within the Ministry of Agriculture by a Presidential Decree in 1974. This decree provided the authority for centralizing all the research activities of the Ministry of Agriculture within one organization. Two years later, in 1976, AARD was sufficiently organized to receive its own budget and to assume responsibility for managing the research institutes of the Ministry of Agriculture.

AARD had to maintain and improve research output while upgrading the manpower base through staff recruitment and training. In 1975 there were only 700 university graduates in the Ministry of Agriculture's various research institutes. Today, the number of scientists is 2000. By the end of 1988 it is expected that the number of Ph D holders will exceed 350.

A collaborative research program between Indonesia and IRRI has been in operation for the last 12 yr. A major aspect of this program has been the long-term collaboration in cropping and farming systems research among Indonesia, IRRI, and other South and Southeast Asian countries through the Asian Rice-Based Farming Systems Network. In addition, there has been a major thrust in varietal improvement implemented through the Genetic Evaluation and Utilization (GEC) program in which scientists of various disciplines are involved. This includes GEU collaborative research and training activities comprising International Rice Testing Program (IRTP) trials and the IRRI GEU training program.

More than 30 IRTP trials are conducted annually in Indonesia. These consist of observational and yield trials, problem soils tolerance tests, and disease and insect screening trials. More than 50 people have participated in the rice improvement program's 4-mo GEC training course at IRRI.

The IRTP nurseries are an important component of the GEU program. The nurseries have provided the national program with varietal information on diseases, insects, and problem area tolerances which is vital to the GEU program.

Since 1970, more than 50 rice varieties have been released in Indonesia. These consist of 36 varieties developed by the national program and 14 varieties introduced from IRRI. Some of these varieties developed by the national program are being released in other countries. The IRTP nurseries continue to be a valuable source of new germplasm and many entries have been used in the hybridization program. New genetic sources of resistance to diseases and insects and soil problem tolerances have been and are continuing to be introduced through the IRTP program.

Brown planthopper (BPH) was a major problem in the mid-1970s and remains a potential threat to the rice crop in Indonesia. Three BPH biotypes have evolved and resistant varieties have been released. Varieties resistant to BPH biotype 1 include Brantas, Serayu, Asahan, and Citarum, developed by the national program, and IR26, IR28, IR29, IR30, and IR34, introduced from IRRI. Among the varieties possessing resistance to BPH biotype 2 are Cisadane, Ayung, Cimandiri, Cipunegara, Barito, and Krueng Aceh, and the IRRI introductions IR32, IR36, IR38, and IR42. Varieties resistant to BPH biotype 3 include Singkarak from the national program and the IRRI introductions IR46, IR50, IR54, and IR56. IR46 and IR56 are also resistant to what has been called the North Sumatra biotype.

As Indonesia's rice research capabilities improved and developed, the working relationship between AARD and IRRI evolved from one of cooperative technical assistance into a collaborative relationship covering all phases of the research process. A basic characteristic of the current working relationship is a more formal annual discussion and development of work plans for research, training, and other activities.

As proof of the role of research, during this period average rice yields increased from 1.5 t milled rice/ha in 1968 to 2.6 t/ha in 1984. The use of fertilizer expanded from 247,000 t in 1968 to 4,000,000 t in 1984. Integrated pest control concepts have been gradually adopted by the farmers as the most appropriate method in preventing rice yield reductions.

NEW DIMENSIONS FOR COLLABORATION WITH IRRI IN 1985-90

A number of activities for the first year (1985-86) were decided at the AARD-IRRI Research Collaboration meeting in March 1985. These activities reflect the need for strengthening collaborative research on upland and rainfed lowland rice. During the next 5 yr several hundred thousand hectares of additional land will be developed for swampy and rainfed lowland rice and new areas will be opened for upland rice.

For the GEU program, collaborative research will concentrate on further work on developing resistance to BPH, tungro, and blast. Collaboration on hybrid rice will continue on new combinations and new CMS lines will be developed using Indonesian varieties identified as maintainers for the hybrid work. Special attention will be given to improved varieties with superior grain quality. Because Indonesia is likely to have surplus rice for export in the coming years, some varieties suitable for the export market need to be developed.

At present, no separate program on rainfed lowland rice improvement exists in Indonesia. Materials developed for the irrigated program are evaluated under rainfed situations and some promising improved varieties are widely grown in rainfed lowland areas. However, improved varieties for unfavorable rainfed lowlands such as drought-prone, submergence-prone, and stagnant water areas are needed. Collaboration for developing improved materials for these conditions will be implemented and IRRI will supply the parents, elite lines, and composite populations.

Indonesia has the largest area of tidal swampy lands of any country in Asia. These lands are affected by varying levels of salinity, acidity, and peaty conditions, and the water regimes are influenced by the tides. Only a small proportion of them is planted to rice but it is estimated that up to 10 million hectares can be developed for rice cultivation if suitable varieties and management practices are developed. Collaboration on developing varieties for these swampy lowlands will be continued.

Besides these activities, the collaborative GEU program will include upland rice improvement, continuation of the IRTP, and further work on the germplasm collection.

Machinery development is the second major area for collaboration in the next few years. This is due to the dramatic expansion of rice production and the need for selective mechanization of agriculture.

Collaboration will continue for farming systems, water management, soils and crop management, and postharvest technology.

As part of the new directions, AARD in collaboration with IRRI will establish a Regional Research and Training Center for Upland Rice Farming Systems. This institute will use the existing research infrastructure at the Sukarami Research Institute for Food Crops (upland, high rainfall areas) and at the Maros Research Institute for Food Crops (upland, low rainfall areas). In addition, the facilities available at the Sukamandi Research Institute for Food Crops will be utilized. Emphasis will be on research and training. Every effort will be made to increase training opportunities for candidates from other rice-producing countries. Evidence of the potential for this program is in that several Indonesian breeding lines entered in the IRTP performed very well in upland trials in Africa and Latin America. The Sukarami area provides an excellent hotspot screening location for upland rice under relatively low temperature which resembles the conditions in parts of Africa. Maros in South Sulawesi is a very good area for screening resistance to tungro virus infection. Thus, training in Indonesia will be very useful for candidates from Africa, Asia, and Latin America.

NEW DIMENSIONS FOR COLLABORATIVE RESEARCH

The infrastructure for commodity and disciplinary research in agriculture has reached a satisfactory level of development for the present and near future. However, for AARD to make direct contributions to regional development in Indonesia, our scientists have continued and will continue to carry out watershed management and conservation and develop appropriate farming systems in various places as needed and as opportunities arise. One such program will be in collaboration with USAID in the Upland Agriculture and Conservation Project. Through this project, AARD expects to develop a research program that will rapidly provide results which can be used in the three major targeted watersheds in Java. This research will develop technologies that can be applied in development projects throughout the country.

To assist regional development in the swampy lands, AARD is undertaking a major research program to support the transmigration programs in these coastal areas. With support from the World Bank, the government, in the Swamps II Project, is opening a 30,000-ha site for tidal swamp rice production in South Sumatra and AARD will provide the required research support for the project. The results will be applicable to farmers in the tidal swamp lands throughout the country.

AARD will give increased attention to agricultural problems in eastern Indonesia. This includes the development of a Farming Systems Research and Development Project to be partially funded by the World Bank to strengthen agriculture in these drought-prone areas of Indonesia.

AARD, in collaboration with IRRI, will also establish a Regional Research and Training Center for Upland Rice Farming Systems. This institute will use the existing research infrastructure at the Sukarami Institute which is concerned with upland, high-rainfall areas, and the Maros Research Institute which is concerned with upland, low-rainfall areas.

Supporting this new institute will be the research in the newly developed transmigration areas in West Sumatra and Jambi which provide excellent hot spot screening locations for upland rice under relatively low soil fertility conditions and ample rainfall. These conditions are similar in many aspects to the situation in parts of Africa and South America. The upland areas in South Sulawesi have been identified for research on upland rice-based farming systems where rainfall is limited. In addition to these research activities for upland rice, the Maros Research Institute presently has facilities at the Lanrang Station for screening lowland rice varieties for resistance to tungro virus infection for the Indonesian and the IRTP. Thus, as our research capabilities expand, AARD not only will serve Indonesia but also will develop technology and experience that will be useful for scientists from Africa, Asia, and Latin America.

Although AARD has carried out research on the basic agricultural commodities and has conducted research that indicates the benefits of new technologies and production systems, there are still two basic problems, especially for upland agriculture. First, the farmers are financially weak and have essentially a subsistence economy. Second, as in upland agriculture everywhere, but particularly in the tropical uplands, soil conservation and production sustainability are major research issues. AARD has initiated long-term fertilizer efficiency and cropping systems studies to examine some of these problems. The farming systems research programs being initiated will help broaden the farm production base and help increase the economic and biological stability of the farm systems. However, these are long term and the research and development efforts will require much administrative support and research collaboration to fulfill these new directions.

Besides the already identified collaborative program that is part of our new dimensions, AARD will continue work on germplasm with emphasis on utilization for the breeding program, place more attention on biological control programs, and stress the importance of postharvest handling and processing to increase the value added to our agricultural commodities.

AARD will also explore the possibilities of biotechnology and its potential for Indonesia. AARD must decide what should be initiated in the next few years to develop a base for a major thrust into this scientific activity. Biotechnology can provide important breakthroughs in the future. IRRI should conduct initial and basic research in this field. Then, IRRI should prepare guidelines and training programs in the application of biotechnology for national breeding programs. As with the GEU program, IRRI can make a major contribution by doing the initial work, and then training the scientists in the national programs to use these techniques.

D. L. UMALI
IRRI Liaison Scientist to the People's Republic of China

FOSTERING COOPERATIVE RESEARCH AND TRAINING

On this 25th Anniversary of IRRI, it is perhaps significant to note that the University of the Philippines at Los Baños (UPLB) marks these rites, too, as an occasion for appreciative remembrance.

For 25 yr, there has been a close and productive association between these two unique and evolving institutions.

Both institutions have shared physical and intellectual facilities and resources, on a complementary basis so that each reinforces the other.

UPLB gratefully acknowledges the significant contributions of IRRI in strengthening its graduate program by making accessible and available to its students IRRI research and library facilities. I am told that two-thirds of the users of the IRRI library are students and professors of the university.

In the formal training program of IRRI, its scholars take their graduate courses at UPLB, do their thesis research at IRRI, and receive their degrees from UPLB because IRRI is not an academic institution.

There is no doubt that the 25 yr of association between the two institutions has been most enlivening and enriching.

IRRI's role in strengthening the rice research capability of the Philippines is well recognized. Today, there are more than 500 Filipino rice research workers who received training from IRRI. Through the years UPLB and IRRI have had and are still undertaking joint research projects.

Thousands of Filipino farmers can trace their enhanced technological capabilities to IRRI. By developing appropriate packages of technology from the scientific findings of IRRI and applying them to their farms, they were able to prove that rice farming is both a satisfying and lucrative enterprise.

Simple historical record indicates that only after the advent of IRRI did Filipino farmers report yields of 8-10 t/ha. The outstanding rice farmers, during their dialogue with the Philippine press yesterday, declared that IRRI is a temple of science. The scientists, on the other hand, consider Los Baños as the science Mecca. If one has not been to Los Baños, then he has not arrived.

I would be remiss if I failed to mention the laudable roles played by the first and second directors general of IRRI, in the development of the university as one of the centers of excellence in Asia.

The first was Dr. Robert Chandler. He had the knack and intuition for selecting young people with intellectual capacity and qualities of leadership. Most of the key officials of the university, from the chancellors to the department heads, are the people Dr. Chandler hand-picked for graduate training abroad under the Rockefeller Foundation Scholarship program.

The second director, Dr. Nyle Brady, came to Los Baños more than 20 yr ago as a visiting professor from Cornell University. At that time, Cornell had a contract with Rockefeller and Ford Foundations and USAID to help rehabilitate the University, which was destroyed during World War 11. He was the last project leader of the Cornell group of professors who cast their lot with us in building the university. As project leader, he saw to it that they worked themselves out of the job. From Dr. Brady I got intensive training, as a professional beggar, in raising funds for the University.

Both former IRRI directors were unselfishly involved with the Rockefeller and Ford Foundations in helping us tap other sources of funds to enable the university to rise from the rubble of war to what it is today.

So anywhere you go on the campus — from the experimental fields, to the laboratories, to the classrooms, to the many homes of the professors — you find their imprint.

Under the able leadership of Dr. Swaminathan, who gives an invaluable human dimension to IRRI’s program, there is no doubt that the productive relationship between IRRI and UPLB will continue to flourish.

The winds of change are now affecting the whole realm of biotechnology and genetic engineering, molecular biology, microelectronics, and computer science. IRRI finds itself with a new challenging role in perceiving, interpreting, modifying, and transferring the ideas and techniques associated with these new scientific fields to developing countries.

Dr. Swaminathan dealt substantively on the upstream collaboration in his paper *Strengthening collaborative research,* I shall limit this paper to practical approaches in fostering downstream collaborative research and training. The downstream phase is accomplished with a mix of research and development, service, and training.

TRAINING

IRRI's training program complements national efforts in human resource development to strengthen national research systems.

Perhaps, the time has come for IRRI to embark on some aspects of training on a network basis i.e., training to be conducted not by IRRI alone or bilaterally with a university but multilaterally with two or more research institutions or scientificgroups with resources and expertise complementary to that of IRRI.

For instance, nonformal training in micropropagation in vitro for germplasm conservation, production of disease-free plants, and rapid multiplication of selected genotypes can be jointly undertaken by IRRI, the University of the Philippines, and the Institute of Botany of Academia Sinica of China.

This network training program could be carried out among training institutions of developing countries or between developing and developed countries. For graduate training, accreditation of universities involved will have to be established.

Building national research systems depends, to a considerable degree, on decisions of public officials and general administrators, some of whom have not had personal experience in research programs and do not realize what is necessary for such programs to succeed. Even scientists themselves, who have had years of experience conducting research, may not be knowledgeable in planning and conducting a total research program. Now that activities of research institutions have grown in magnitude and complexity, there is need to train people on how to improve research agency performance by promoting professional growth, providing incentives for more efficient performance, creating a more appropriate pattern of organization, and improving skills for planning and programming and management of research.

IRRI'S SUPPORTIVE RESEARCH SERVICE

National research institutions have been appreciative of the supportive research service of IRRI. This service enables cooperating research institutions without sophisticated equipment to undertake advanced scientific research at IRRI. Others request IRRI to do the research phase that requires use of modern equipment. The technical backup or advice of IRRI scientists is readily available to cooperators.

This unique supportive research service should continue and be given more support because it provides cooperating institutions in less affluent countries opportunities to take advantage of recent advances in science.

ANNUAL RICE RESEARCH CONFERENCE

IRRI's collaboration with national research systems can be further strengthened through regular national rice research conferences. In countries where no such conference has been held, the IRRI liaison scientist can help initiate one. This provides national rice researchers the opportunity to learn from scientific activities of other researchers. The annual conference is a useful mechanism for identifying priority problem areas of research; organizing and coordinating research activities; preparing a comprehensive and unified research program of short and long-term duration; and providing the framework for the mobilization of assistance from external aid organizations.

With this framework, IRRI's participation in the national research program can be identified and integrated. This arrangement will also prevent the impression that IRRI imposes on national programs.

ANNUAL PLANNING MEETING

When national programs have progressed to collaborative working relationships, joint planning meetings need to be undertaken regularly as IRRI does in a few countries. Scientists and administrators from IRRI and collaborative institutions should participate in these meetings. In countries where IRRI's activities have expanded in several areas of research in collaboration with several institutions, there is need for preplanning meetings of institutions involved in each area of collaboration. For instance, it is desirable that the coordinator of the International Rice Testing Program Network in a country call a meeting of the network leaders to agree on the workplan for the coming year to be discussed in the annual planning meeting. If funds for holding such a meeting are limited, then the coordinator can consult with each cooperator and work out practical alternatives.

THE ROLE IRRI CAN PLAY IN FORMULATING A RICE PRODUCTION STRATEGY

IRRI is a research institute. It is not a development institution. Its role in the overall strategy of development is to produce new ideas, scientific information material, and manpower to help countries intensify their rice production.

If highly productive farming is our goal, then what farmers do and how agricultural activities are conducted are strongly influenced by a host of factors. These include: weather conditions, and national policies on land tenure, incentives, support services, and tax policies.

One lesson is obvious. The food problem is exacerbated when one grapples with it as a purely technical issue without reference to people caught in a complex way of social, economic and even political milieu. Often the issue is not technology, important though it is. It is who controls the productive and market forces and who benefits from them. Inequality in the control of these forces is a major constraint. To underscore my point, the Philippines, despite the infusion of technology and funds, imported 200,000 t of rice last year. This year it has negotiated initially for the importation of 250,000 t.

As a research institution, IRRI can catalyze and help, directly or indirectly, in organizing concerned ministries and national research systems, with technical assistance and support, if needed, from UN specialized agencies and nongovernmental organizations. These groups will work together in formulating a comprehensive and unified rice production strategy and program for a rice-producing country, with established goals, objectives, and policy framework in mobilizing manpower and financial resources.

The unified program can bring about better coordination and complementarity among various programs and projects, either planned or under implementation by the different ministries and with foreign aid.

Because the program will provide a policy framework for the mobilization of short- and long-term foreign aid, the kind of assistance it will request from technical agencies and bilateral donors can be precisely determined. This approach ensures there will be less *adhocracy* — the peddling of projects, either by local ministries or foreign aid donors, on an ad hoc basis.

Given the framework of reformed policies, a restructured system, and a unified program backed up by a strong political will, a country's commitment to food self-sufficiency can be translated to practical achievements.

COMPLEMENTARITY OF RESEARCH ACTIVITIES OF NATIONAL RESEARCH INSTITUTIONS AND IRRI

Because of their similar objectives, IRRI and national research systems sometimes have overlapping research activities. This overlapping can be minimized by more frequent consultations. Better coordination and complementarity can be brought about among various programs and projects, either planned or under implementation, during the annual planning meeting.

International donors sometimes go directly to national institutions or even to individual researchers, which could result in duplication of efforts and even confusion within national research systems. This situation can be minimized if services are rendered in consultation only with an office or group with a coordinating or planning mandate, not through it. Coursing it through an office can cause delay. We know how bureaucratic red tape can demoralize individuals or institutions.

STRENGTHENING ADAPTIVE RESEARCH

There is unprecedented opportunity to achieve new production advances by translating into practice, on the farms, the new knowledge IRRI has generated by the basic and long-range research of its scientists. Such opportunities impel IRRI to make special collaborative efforts to help national research systems strengthen their adaptive research programs.

Technology must continuously be updated. Much, if not all, of IRRI's adaptive research and field testing gave rise to packages of technologies most appropriate to the realities of the farmers' environment and institutional setting.

However, success in adaptive research programs calls for a new breed of scientists trained to assess local environment and socioeconomic and human resource constraints; analyze and interpret existing farming systems; and learn from the farmers before they teach them.

As Dr. Brady stressed yesterday, socioeconomic research should go in tandem with adaptive research, if technology packaging is to be humanized. The need for and importance of socioeconomic research in food and agricultural problems are increasingly recognized in judging the appropriateness of technological advances in a given socioeconomic environment, in identifying the constraints in technology transfer, and in assisting decision-making in agricultural policies.

Social science research can cover three levels. The first is at the farm and village level. Here we seek to understand the conditions under which farmers adopt or reject new technology, identify socioeconomic constraints, and offer solutions to overcome them. The second is at the national policy and planning level. At this level, we need to investigate the interrelationships between planning bodies and research and development institutions in matters concerning public and socioeconomic policies. The third is at the international level relating to problems with global significance, such as trade and security.

PRIORITY AREAS FOR DOWNSTREAM COOPERATIVE RESEARCH

Dr. Brady, Dr. Hemmi, and other speakers have suggested priority research areas for IRRI to undertake. May I make additional suggestions of down-to-earth research problems as articulated by the outstanding rice farmers at their press conference yesterday.

Few of us recognize the impending impact of resource constraints. The high fossil energy subsidy to modern agriculture cannot endure. In the Philippines, for instance, the government subsidy to fertilizer was abolished last year. The agricultural output of developed nations has been closely tied to the availability of fossil fuel inputs. Many varieties of crops developed are highly dependent on industrial energy inputs — fertilizer, pesticide, irrigation, and mechanization. Cost of land, water, energy, seeds, fertilizer, pesticides, and machinery will continue to go up. Means of increasing productivities per unit resource input, per unit time, and per unit area will command priority for the 21st century. New high pay-off agricultural technology for the future will not only be those that result in stable production and high yields, but also those that are sparing of resources. The shift from the mechanical technology pathway to a biological one may be a wise step since there is an abundance of low-cost resources in developing countries.

TRADITIONAL AND ADVANCED TECHNOLOGY

Traditional technologies are often the source of cultural pride. They constitute the backbone of socioeconomic activities in most developing countries. They are used because they have low energy requirements and low cost inputs, are environmentally compatible, require simple management, and are well adapted to subsistence conditions. However, traditional agriculture often has the disadvantage of low productivity, unavoidable drudgery, and susceptibility to field and storage losses.

Although advanced farming techniques have not been widely adopted in developing nations, they have some obvious advantages. Among them are higher productivity, efficient and diversified labor use, and sustained high yields. But they also have disadvantages, such as high capital input demand, specialization, vulnerability, and higher mechanization, that lead to unemployment and damage the environment. The challenge is to find appropriate ways of integrating and applying traditional and emerging technologies that combine the strength of both while avoiding their weaknesses.

There will always be problems on rice for IRRI to solve. I have no doubt that the Institute will solve them in due time. As an organic unit, IRRI has always been flexible and ready to reorient its objectives and restructure itself so that it could be of greater service to the rice-growing world. With continued dedicated leadership and the sense of service of its staff, it will prevail.

W. T. MASHLER
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Former Assistant Administrator
United Nations Development Programme, USA

THE ROLE OF THE INTERNATIONAL AGRICULTURAL RESEARCH CENTERS IN COOPERATIVE RESEARCH

The establishment of the International Rice Research Institute by the Ford and Rockefeller Foundations 25 yr ago resulted from the convergence of two critical trends: a stagnation of food production and a rapid increase in population in the Third World. The combination of the two forces seemed sure to mean widespread hunger and possible famine in the developing countries.

Despite the world donor community's increasing efforts to provide funds and technical assistance to the emerging, independent countries, there was neither the experience nor clear direction to channel such assistance for maximum payoff. In most cases, the necessary infrastructure for agricultural development did not exist; where it existed, it was weak. Providers and recipients alike, despite their good intentions, were not capable in the early 1960s of building such an infrastructure. Those of us who were then entering the field of international development learned by experience. We are still learning. Progress is being made, although the process is slow, and is aggravated by politics, frustration, and often, wasteful decisions. The realization of what the priorities should be is growing, yet funds to meet them are drying up. Perhaps the old saying that a hungry man thinks very clearly is beginning to inject a sobering element into our thinking and consequent decisions.

In the case of IRRI and the 12 other centers that were established, it was fortuitous that a small group of farsighted agricultural leaders recognized the problems and set out to do something about them. The situation at the time had all the ingredients of disaster: hunger, political unrest, and untold human misery of hundreds of millions, particularly in Asia and Africa.

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 to continue and expand the great endeavor started by the Ford and Rockefeller Foundations. The CGIAR not only has made international research on food crops and farming systems a keystone for agricultural development in the Third World but also, and equally important, made a commitment to sustain such research. The creation of IRRI and the other centers was a positive and, perhaps, unique innovation that was simple in logic, clear in objectives, humane in underlying principles, and practical in plain economics where the rate of return is a major consideration.

Looking back with the luxury of hindsight, we see the equally (if not more) important fact that international agricultural research, sponsored by a consortium of donors, was the first new dimension in cooperative research.

Before the establishment of the CGIAR, I know of no major, formal system of collective pooling of scientific and financial resources in pursuit of the creation of a better life and a more peaceful world. Implicit to this innovation was the increasing interaction between the programs and capacities of centers and national agricultural research systems, and the building of national expertise where it did not exist. Donors who supported the CGIAR demonstrated a dedication to national institution-building through the establishment of the International Agricultural Development Service and, later, of the International Service for National Agricultural Research. The mandate of both organizations is to strengthen national agricultural research capabilities so that they can better transfer and apply scientific and technical results, not only from the centers but also from other scientific organizations.

A third element of cooperative research was the emphasis that the CGIAR and its Technical Advisory Committee placed on increasing collaboration among centers to make them components of a world system rather than individual entities. We have seen, particularly in the last 5 or 6 yr, a salutary trend of center cooperation. Centers now make use of each other's facilities, share experiences, and help each another forge closer links with national programs.

It is not possible this morning to describe each center's programs. Nevertheless, I wish to acknowledge in passing, but with appreciation, the important work being done by all centers. I have chosen to emphasize the programs of IRRI and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. I am in a better position to deal with IRRI and ICRISAT programs in detail because USDP provided substantial funding for the establishment of some of their more successful endeavors.

The International Rice Testing Program (IRTP) was established in 1975 at the initiative of Dr. Nyle C. Brady, then IRRI director general. The IRTP provides a mechanism through which scientists in different countries can exchange elite rices for evaluation and utilization in their respective environments. IRTP is an intercountry cooperative effort for the genetic improvement of rice and its targeting to the many environments in which rice grows. Access to a wide range of genetic materials through the IRTP purchases time — an important dividend for network scientists in their efforts to develop improved varieties.

The main objectives of IRTP are to:

- make the world's elite germplasm available to rice scientists everywhere, either for release as farm varieties or as parents for use in national breeding programs;
- provide rice scientists an opportunity to assess the performance of their own advanced breeding lines over a wide range of climatic, cultural, soil, and pest conditions;
- identify varieties with a broad spectrum of resistance to major diseases, insects, and other stresses;
- monitor and evaluate the genetic variation of pathogens and insects;
- serve as a center for information on the interaction of varietal characteristics with diverse rice-growing environments; and
- promote interaction among the world's rice scientists.

The IRTP network involves more than 800 rice scientists in 75 countries of Asia, Africa, Latin America, North America, Europe, and Oceania. Representative scientists from participating countries serve on an advisory committee to assist in the planning and implementation of IRTP programs. About 75% of the nurseries are tested in Asia and 10% each in Latin America and Africa. In Latin America, IRTP nurseries are distributed and tested in collaboration with the International Center of Tropical Agriculture (CIAT), and in Africa in collaboration with the International Institute of Tropical Agriculture (IITA) and the West Africa Rice Development Association (WARDA).

More than 30 types of nurseries for the identification of superior varieties for specific rice environments and of genetic donors for individual biological, physical, and chemical stresses are composed and distributed yearly. Elite rices from national programs comprise about 70% of the IRTP entries; the others are from IRRI's Genetic Evaluation and Utilization program.

Entries are also evaluated for suitability for rice-based cropping systems under irrigated and rainfed culture. The relationships of crop performance with major environmental factors are studied through the network in collaboration with the World Meteorological Organization.

Scientists from national programs and IRRI participate in periodic IRTP-sponsored international monitoring tours to review the performance of entries in IRTP nurseries in other countries. The monitoring tours provide a forum for interaction among rice scientists and for planning breeding strategies.

Results from the multilocation nursery trials and monitoring tour observations and recommendations are published and distributed yearly.

The IRTP has become a prime example of technical cooperation between developing countries (TCDC). When this cooperative research program was initiated 10 yr ago, we could only speculate on the results we wished to obtain from it. Today, Dr. Brady and Dr. M.S. Swaminathan, IRRI director general, will agree that the IRTP has become one of the most important elements in IRRI's core program and gives true meaning to IRRI's mandate to improve rice varieties and production. Indeed, the unique mechanism of IRTP — its vitality, versatility, and flexibility — is an important element in bringing scientific results to national programs and important test results back to IRRI for adoption, storage, and expanding knowledge.

In 1974, UNDP encouraged ICKISAT to initiate work on its African cooperative program for the improvement ofsorghum and millets. At first, the proposal met mixed feelings from other CGIAR donors who feared that the very young ICRISAT, preoccupied as it was with getting its Hyderabad operation off the ground, could not simultaneously cope with another program. Our argument was that the two programs augmented and mutually reinforced each other, and would ultimately prove their value. The point was proved. Today, ICRISAT is expanding its work in Africa with the full support of African countries and of donors — another example of harmonious cooperative research working of centers, national programs, and other international and bilateral research efforts in Africa.

Last, but not the least, other centers — the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), the IITA, the Centro Internacional de Agricultura Tropical, the International Livestock Center for Africa, the International Food Policy Research Institute, and the International Service for National Agricultural Research among them — are cooperating in various ways and forms in critically food-deficient parts of the world.

I cite results already achieved through these examples as guideposts for future action.

Cooperative research has yielded great accomplishments in the fight against world hunger. Such successful achievements can and must be expanded. What I have in mind is the wider dimension of research and its applications. There are many other research areas in which the IARCs, other research institutions in agriculture, medicine, and related disciplines are engaged that require the establishment of much closer links if the totality of their ongoing work is to make a broad impact on humanity.

In nutrition, I am pleased to say that we have moved from the discussion stage to actual cooperative programs. I will cite one example in which UNDP played an important role in collaborative research. This involved experiments on rice flour in connection with oral rehydration and nutritional elements on diarrhea of the International Centre for Diarrhoeal Diseases Research, Bangladesh, in collaboration with the Bangladesh Rice Research Institute (BRRI) and IRRI.

Similarly, efforts must be accelerated in the improvement of crops to permit children, particularly those under 4 yr old, to absorb more proteins from maize, sorghum, and other crops. Such initiatives have been undertaken by CIMMYT, ICRISAT, and possibly other centers, but the need to widen this critical research area is urgent. Fortunately, the centers have shown themselves willing to cooperate, but it seems to me that donors should further such collaboration.

In the area of drinking water and sanitation, we have urged the World Health Organization, the World Bank, and other agencies to initiate collaborative research activities in yet another way. Most of the rice in Asia is grown in paddies, which are often breeding grounds for schistosomiasis, mosquitoes, and other vectors. Although some attempts have been made to initiate joint research among biomedical and agricultural scientists to develop scientific means to control such water-borne problems, there is still reluctance to come to grips with the situation.

Indeed, it is becoming clearer with every passing day that what we understood by cooperative research 10 yr ago has changed — and has assumed different and greater dimensions.

I would suggest that there is a growing need to look at cooperative research in environmental terms involving water, soils, agroforestry, and pollution and its effect on plant, animal, and human life. Unless we do so, we may well win battles but lose the war on poverty. We must encourage the centers to look ahead in these terms, because they are uniquely positioned to anticipate, in scientific and technical terms, the projected needs and demands of an every-changing world. Being outside of politics, the centers have the tremendous advantage of being able to call attention to issues of environmental concern that need addressing by political decision-makers, and to make them aware of their responsibilities in ensuring that scientific opportunities are properly exercised to fully benefit their constituents. This is as relevant in developed countries as in the developing countries, for it should by now be clear to all that we and future generations will pay dearly for the neglect of yesterday and today. It is not too late to make major changes in attitudes, in practices, and in research. But to do so requires that many institutions, at all levels, must play their individual roles in cooperation with each other. Those are the real dimensions that we must address.

In closing, may I pay a special tribute to IRRI and the other centers. We in the CGIAR have, until now, been too concerned with matters relating to housekeeping, when we should have addressed the issues, the problems . . . the substance of the system we sustain. The centers have shown tremendous foresight. They were the initiators of special programs outside their core budgets to meet research requirements both in their own interests and in those of the national programs. They have sometimes been criticized for such foresight. The centers have initiated interdisciplinary research and have done it well, because whatever cooperative research exists — and there is a great deal of it - was born of vision worthy of that of the men who created the centers. Dr. Johnson once said that where there is no hope there can be no endeavor. Hope continues to be high in our centers. Let us take advantage of it by encouraging them to go on to greater and better things for the benefit of all mankind.

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WOMEN AND AGRICULTURAL PROGRESS

I wish to thank Dr. M.S. Swaminathan and the other members of the International Rice Research Institute for having invited me to participate in the deliberations of the 25th anniversary symposium and share my thoughts with this body on the concluding plenary session. I am happy to do so and I consider this gesture a privilege and honor to me and my country.

We in India, as most other developing countries, are engaged in the gigantic task of improving the standard of living of our people. Because the bulk of our population derives its sustenance from agriculture and its allied operations, and because self-sufficiency in food has been our prime aim, we have assigned top priority to agricultural development programs, intensive agricultural package programs, and agricultural area programs, some of the measures taken to achieve optimum results in food production, which were necessary to meet the serious food shortages faced by our country in the past years.

Modernization of agriculture through improved irrigation methods, improved knowledge of agricultural operations, and modern agricultural equipment based on latest technology has helped us to combat the situation effectively. Further, development of infrastructure, administrative measures to encourage people's participation in development and introduction of modern credit systems to meet the credit requirements of farmers, and launching of specific rural development programs have proved to be successful in attaining the goal. High-yielding varieties of seeds and improved scientific methods of agricultural operations and other technological developments have helped us usher in an era of revolution in agricultural development, leading to increased food production which not only has made us self-sufficient, but also enabled us to produce enough surplus for export.

In our country, the food habits of people differ from state to state mainly because of the availability of particular food grains in the respective areas. People in the southern states of Andhra Pradesh, Tamil Nadu, Kerala, and Karnataka are primarily rice eaters and these states are the main producers of rice in our country. Rice is also produced in some coastal districts of Maharashtra, Orissa, West Bengal, Assam, large parts of eastern U.P., eastern Madhya Pradesh, and Punjab. The regional concentration of women's agricultural labor varies with the extent of rice cultivation as compared to other food grains. Women are, thus, predominant agricultural laborers in the southern states of India although their number is not negligible in other rice-growing areas.

We can say that no crop, including rice, is produced in our country without the sweat and toil of women. No farm work can be carried out without the labor of women. Although plowing is primarily a man's job, women also work side by side with the men to clean and prepare the soil for sowing. Transplanting in flooded fields is almost entirely the job of women. In addition to their household chores, women do the weeding, watering, harvesting, husking, and storing of rice. Very often they are also required to market and sell their surplus.

The word farmer has no specific feminine gender equivalent in many languages. Even the hard and backbreaking work that she puts in on the field and the farm is not fully taken note of in national statistics or accounting systems. Her contribution to work in the agricultural field is seldom taken into consideration in computing national income figures. This invisibility of women in the statistical work profile in the agricultural sector is part of the general failure of our national data collection systems to measure adequately rural women's work participation in general.

We are thus faced with a situation where female members in a rural family are classified as dependents of the male producer, although they contribute to each stage of agricultural work. This is the general view held by all sections of society and the very planning of our policies is based on this conception.

The first challenge that lies before us is, therefore, the recognition of the true role a woman plays in agriculture and building up a policy framework in tune with this new concept to enable the fulfilment of a woman's production potential.

Women earn a living for themselves by contributing to agricultural operations at different stages of cultivation. Some of the developmental programs undertaken based on scientific and technological innovations, meant for increased productivity, it is feared, may threaten their survival. The slow, painstaking manual work done by women is likely to be managed by machine. Increased productivity, no doubt, is essential for nation's progress and for self-reliance in food production, but this should not be at the cost of women. If mechanization based on modern development must be introduced in rice cultivation, then those engaged in this job, including the women, must be trained to use, service, and maintain the improved tools and machinery that tend to supplant them in their traditional role.

In the traditional methods, women often use few or no modern tools or implements. The crop production processes based on modern methods or tools, such as machinery and artificial fertilizers, tend to involve higher rates of male participation. New methods and machinery have been made available mainly to men. Often they apply only to male jobs such as plowing. In addition, it has been observed that if mechanization is introduced for jobs usually handled by women, the advantage is exploited by men, as has happened, after the introduction of mechanized milling for high-yielding rice varieties in Indonesia and Bangladesh. It has been reported from many parts of our country that the advent of tractors has rendered many women jobless, and they are slowly drifting toward urban areas looking for employment in some other sphere. Extension training that might help their rehabilitation very often tends to exclude them, even in areas where their role has been predominant.

A related area where an equally important challenge lies is the improvement of women's working conditions in agriculture and reduction of health hazards. This is especially true in rice cultivation. Certain operations such as transplanting involve long hours of bending down, with feet planted up to knee level in marshy soil. This type of labor not only brings various forms of diseases, but also leads to miscarriages in early pregnancy because of the posture which the women must take. The International Rice Research Institute has developed a model of a mechanical transplanter, which, on the face of it, would reduce the drudgery involved in the transplanting operations to a considerable extent. However, the model postulates that the seedlings be picked up from special cultivation mats and not from the soil. Therefore, it meant that before we could think of using the transplanter, the technology or the technique of mat cultivation has to be propagated first. In India, we felt that the large mass of cultivators would not be able to make use of this technique straight away and this would, therefore, immediately benefit only the rich cultivators.

The Department of Science and Technology in India has devoted considerable attention to this matter. We are now designing an improved model which can be used by women without bending, but can still be used in the context of the traditional farming method of seedling preparation. This is an example of how we are trying to improve the tools and equipment to reduce drudgery and health hazards of workers, without the attendant danger of displacing workers, especially those belonging to the weaker sectors, such as women. The desirable objective of these efforts is improved productivity and earnings. The philosophical underpinnings of such attempts relate to the premise that, since agriculture is the largest field of employment of the labor force in developing countries like India, technology should be used to improve and support wages and ensure rewards for the toil of the large mass in rural areas.

There has been very little research on critical operations performed by women. Methods and techniques of weeding and transplanting, for example, have not been subject to studies, although these tasks can greatly affect production. Paddy transplanting is a very slow and laborious job. As I mentioned earlier, it requires standing in the water and marshy land for hours which is why women often become prey to certain disabilities.

Any new technological innovation that is dependent on sophisticated processes and involves changes in traditional practices is generally not a welcome proposition initially.

In the rice husking industry of West Bengal, one of our principal rice producing states in the east, household husking is managed almost entirely by women, although the proportion of women is much less in the total agricultural work force. Hand-pounding of rice by women is of great importance to the economy of West Bengal for several reasons.

1. It caters to the subsistence needs of rural households who process and consume their own food crops.
2. Those who have to buy cereals can purchase home-processed food grains that are clean and inexpensive compared to market rates.

With the advent of high milling industry, which should be termed as *technological pluralism,* in the last few decades, there has been growing aversion to hand-pounding which is a drudgery and time-consuming. This has, therefore, led to the loss of a traditional profession for many women. It is estimated that every big rice mill dispenses with the services of about 500 workers and a small huller displaces at least 40 workers. The impact is all the more serious because they offer only limited scope for employment of female labor.

This shows that the introduction of modern technology in agriculture based on traditional economies often has a differential impact and amounts to invidious treatment between sexes. This is especially so if the new methods of production impinge upon an area which for centuries has been the domain of women. Employment prospects of women have a better scope if superior technology offers adequate avenues for alternative employment to displaced workers.

My purpose in highlighting these problems is not to discourage or in any way hamper scientific research or technological development in rice cultivation. Far from it, I am greatly interested in such innovations which would improve productivity and will ensure, at the same time, proper care of the health of workers. On the basis of our experience, I only want to sound a word of caution and to draw your attention to the serious problems which are likely to arise and to which you must find an answer.

The task ahead — the task of raising the standard of living of millions of our countrymen — is really a challenging one. The solution to this vexing problem is not easy. The path to progress is difficult, arduous, and demands the wholehearted cooperation of all, men and women. To put it in the words of our late Prime Minister, Shrimati Indira Gandhi, “The crisis which faces the world, and the nature of the problems posed, demands answers not from men or women but from human beings. It demands maturity, wisdom, energy, and perspective understanding which is neither the sole preserve of man or woman."

I have read, with great interest, some of the papers presented in the Workshop on *Women in vice farming systems* conducted by IRRI. I am extremely glad that IRRI has proposed a research network on the subject. The focus of the proposed network appears to me to be very relevant to the issues I touched today — issues such as increase of women's productivity; adaption of emerging technologies for women; sensitization of policy makers, scientists, and development administrators; training; etc. I look forward to our country's participation in the proposed network. The network will, I hope, bring together the men and women from the scientific community as well as social workers, administrators, trainers, and extension workers who will address themselves to the challenges posed by the juxtaposition of the new technologies on the one hand, and the policy commitment of national governments on the other, to better the economic and social condition of the less advantaged sections of their population. Agriculture holds the key to national, regional, and international prosperity. Let us steadfastly work toward the achievement of our goal.

I have no doubt that all of us will have to strive together to free our people from the bondage of poverty and ignorance, so that they can see the light of day. Modern scientists and technologists, both men and women, are the torch bearers in this direction. I am sure that by their unflinching devotion and dedication to the tasks assigned to them, they will show us the path to progress and prosperity.

FORWARD EDGE

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THE POTENTIAL FOR YIELDS PER CROP PER DAY

In these days of simulation, many models have been published for estimating potential yield per crop based on our current physiological understanding of the major crop plants. Such models are useful in various kinds of forecasting, as syntheses of what we know and for highlighting what we do not know or need to understand more thoroughly. Unlike many physical models, however, those for crop yields are not based on absolute physical relations and, therefore, involve many elements of judgment, e.g., of the limits to grain growth duration. Where these are conservative, the estimates of yield potential may soon be surpassed, to the chagrin of plant physiologists and to the delight of plant breeders. Where they are unconstrained, on the other hand, they run the danger of creating false hopes and expectations.

In estimates of potential rice yields in the tropics I made for an IRRI symposium 14 yr ago, I tried to steer a middle course between these extremes (7). Although the estimated yields have not been surpassed, they may be less responsive to irradiance during grain filling than I previously assumed (9, 13), whereas earlier irradiance may be more important.

Rather than update such estimates of the potential yield of rice in the tropics, I shall examine the nature of past increases in the yield potential of cereals like rice to assess how much headroom is left if we continue along the same path, and what is the likelihood of striking out in a different direction.

INCREASES IN YIELD AND YIELD POTENTIAL

Where environmental conditions are favorable and socioeconomic policies are encouraging, crop yields continue to increase rapidly, as in the case of wheat in the United Kingdom, maize in the USA, and rice in Korea. Apparent plateaus in yield are usually associated with less favorable environmental conditions (in the case of upland rice in the Philippines), non-encouraging price and other policies (for rice in Japan in the 1920s and in recent years), or the pursuit of conflicting objectives (as with sugar beet in the UK and cotton in the USA). In the absence of such constraints, however, there is no evidence that we have reached the limit to yield in any of our major crops.

Past increases in yield have come partly from better agronomy and partly from plant breeding for greater yield potential. In fact, breeding and agronomy interact so strongly, advances in each opening up opportunities for the other, that any attempt to partition the increases in crop yield between them is bound to be arbitrary.

Genetic progress can be assessed from the results of standardized variety trials over the years, provided the successive standard varieties overlap sufficiently, but without the old standard variety beginning to succumb to new strains of insects and diseases before the new standard takes over. Such trials have the advantage that cultivars are compared under the agronomic conditions for which they were bred, and results with several temperate cereals have been analyzed (8, 12, 14). With British winter wheats, for example, the genetic yield potential appears to have increased about 60% over the last 40 yr, with no evidence yet of an approaching plateau. No comparable analyses have yet been made for rice in the tropics.

Alternatively, one can compare ancient and modern varieties directly, so long as care is taken to protect the tall old varieties from lodging and from new strains of insects and diseases which were not important when the old varieties were bred. Otherwise, the yield potential of the old varieties is underestimated, leading to an overestimate ofgenetic progress. With British winter wheats, such an experiment indicated about 60% progress over the last 40 yr, at both high and low fertilizer levels (1), agreeing closely with the results of the standard yield trials, and again there was no evidence of an approaching plateau.

Comparable data with other temperate cereals, including maize in the USA (5), indicate that about half to two-thirds of the increases in yield over the last 40 yr can be ascribed to improved genetic yield potential, but no comparable analyses have been made for rice in the tropics.

THE PHYSIOLOGICAL BASIS OF INCREASED YIELD POTENTIAL

There are many misconceptions about high-yielding varieties. One of the most common is that they have superior growth rate and photosynthetic efficiency. There is not a sliver of evidence that this is so. We have compared the relative growth rates of wild relatives, old varieties, and new varieties in both wheat and rice, and have found no increase. Neither has any been found in maize, millet, cowpea, or tomato. Field experiments at IRRI with a wide array of Philippine rice varieties over the last 60 yr showed no increase in crop growth rate either, when compared at comparable leaf area index (11).

Given all the talk about the inefficiency of photosynthesis, those who do not share my profound respect for what natural selection can achieve might expect to find higher maximum rates of photosynthesis in varieties with higher yield potential. However, this was not found in our comparisons of both Asian and African species of rice (4), nor in comparisons of Philippine rice varieties of differing vintage (11). Nor has it been found in work with many other crops such as wheat, maize, sorghum, pearl and barnyard millet, cotton, and cowpea.

In fact, the maximum rates of photosynthesis in wheat have tended to decrease with crop improvement, as leaf area has increased (10). Similarly, in our evolutionary study with rice, all species and varieties fell on a curve relating leaf area and specific leaf weight (SLW), which was in turn closely related to photosynthetic rate. The genotypes ranged from high leaf area/low SLW and photosynthetic rate (a strategy which is advantageous in some environments and also early in the crop's life cycle where bare ground should be covered quickly to intercept more sunlight) to small leaf area/high SLW and photosynthetic rate (a strategy more suited to other environments and to dense canopies in the later stages of the life cycle). The highest yielding varieties sat in the middle of the curve, which is presumably the best compromise unless varieties could be bred to begin life at the one extreme and then develop toward the other. We found no evidence that modern varieties changed more than older ones in that respect.

These results with rice explain why direct selection for high photosynthetic rate has not succeeded in raising yield potential so far, because such selection has been accompanied by smaller leaves and reduced growth in peas, alfalfa, and maize. Only by breaking the negative relation between leaf area and maximum photosynthetic rate will such selection succeed.

Moreover, although photosynthetic rate has not been raised by selection, it can be raised by improved nutrition, especially with nitrogen, as in rice (3) and wheat (6). This is because photosynthetic capacity is often limited by the key enzyme rubisco, which constitutes a quarter or more of the protein in leaves, making it the most abundant enzyme in the world. If a more efficient rubisco could be designed by genetic engineering, it could have an enormous impact on crop yields and fertilizer use. My guess is that it will be extremely difficult to improve on what prolonged natural selection has already accomplished, but the potential impact of such attempts is so colossal that I hope the Rockefeller program for genetic engineering of rice will encompass such work.

Where has the increased yield potential come from if not from faster growth or photosynthesis? The answer is that modern varieties invest a higher proportion of their biomass in the harvested grain, i.e., they have a higher harvest index than older varieties. Over the last 50 yr or so, the harvest index of wheat varieties has risen about 60%, from 0.3 to 0.5, and a comparable change has occurred in Philippine rice varieties over the same period (11).

Several factors have contributed to the rise in harvest index. For example, with fertilizers, weed control, and irrigation, the crop can get away to a faster start and a greater proportion of its life cycle can be devoted to the stage of grain growth. But the most important factor has been the improved agronomic support for the crop. This has a direct effect on crop yield, e.g., because of faster growth when irrigation and herbicides reduce water and weed stress, or because of faster photosynthesis with higher leaf nitrogen levels as a result of fertilizer use. But it also has an indirect effect which is crucial to breeding for greater harvest index and yield potential. With irrigation and fertilizers, a smaller proportion of the plant's resources are invested in the root system (3), allowing the breeder to select plants which invest the savings in the grain. Research at IRRI, for example, has shown that the proportion of biomass in the root system is twice as high in upland as in lowland varieties.

Similarly, with better weed control it is possible to select for shorter, lighter stems, again freeing resources which, after selection, can be reinvested in the grain. Winter wheat varieties offer a clear example of such redistribution (1). Likewise, with better control of insects, diseases, and other stresses, a high level of reserves to promote recovery is no longer needed, and selection for greater investment of these in the grain can be carried our.

Thus, selection for higher yield potential from these sources is possible only with higher input agriculture which frees resources in the plant for greater investment in grain growth. This is the most important point I want to get across, because it has many consequences. One is that in less favorable environments where intensification of inputs is not economic, e.g., for most upland rice, progress in breeding for greater yield potential must remain slow. It is not neglect but the nature of greater yield potential that dictates this.

Another consequence is that under very low input conditions the improved variety may suffer more than the traditional variety because its more limited root system may be disadvantaged under water or nutrient stress, its short stems disadvantaged under weed competition, and its smaller reserves disadvantaged during recovery after stress. Whether or not there is a crossover in the relative performance of varieties at low inputs is a hotly debated topic, which I cannot go into now, but it is clear that at least some sources of greater yield potential, perhaps the major ones, are almost certainly disadvantageous under poor conditions. If it proves possible to select for faster photosynthesis and growth or for slower respiration, on the other hand, gains under low input conditions might be made, but for the time being it is dangerous to expect marked gains in yield potential from breeding alone without greater agronomic support.

Given adequate support and continuing agronomic innovation, how much further can we expect harvest index to be increased? There is no absolute limit, but it seems likely that after a further 25% increase, i.e., to a harvest index of about 0.63, it will be extremely difficult to make further progress because, however good the agronomy, some root, leaf, and inflorescence stem tissue is still required. Thereafter, progress will hinge on selection for faster growth and photosynthesis, i.e., on trying to improve on natural selection, and that will be difficult. Up to now, by improving the harvest index we have not really been competing with natural selection because the improvement has depended on levels of agronomic support not available in nature.

CROP DURATIONS

As temperature rises, the duration of grain growth in cereals is reduced more than can be compensated by any increase in the rate of grain growth (2, 15), thereby limiting the maximum yield per crop in the tropics to levels well below those attainable in temperate regions. Consequently, increase in the number of crops per year, and in grain yield per day, becomes more important in the tropics. Progress along this route at IRRI has been at least as great as that in yield potential and has not yet reached its limit.

Our comparison of 50 rice varieties grown in the Philippines over the last 60 yr indicated that crop duration has been halved by selection without any reduction in yield potential, the rate of grain production per square meter per day of crop time having doubled (11). We had to have rather sparse field crops in this work so as not to disadvantage the older varieties in the wet season. Consequently, the yield level was not high, but the rise in the yield of grain per day in modern varieties was striking. Unpublished data from the plant breeding program at IRRI indicate that grain yield per day can increase pro rata as crop duration is reduced to at least 92 days (with line IR10179-2-3-l), but how much further than that remains to be seen.

In this direction also, agronomic improvement has been essential to plant breeding progress. The long life cycles of older varieties were needed under low fertility conditions, given the slow accumulation of nitrogen and other nutrients, but with fertilizers, assured water supply and better pest and weed control, plant breeders have been able to drastically shorten the vegetative stage of the crop without loss of yield potential.

Such shortening is of value only if the new varieties are relatively insensitive to day length and can therefore be planted all year round, as is possible in the tropics with irrigation. Many of the old varieties in our comparison of Philippine rices could not flower in long days although they could flower relatively quickly in short days. Modern varieties are much less inhibited by long days but the first varieties released by IRRI, like IR8, had a long juvenile stage. Now, with higher levels of fertilizer use, it has been possible to select for a greatly reduced juvenile stage as well as for insensitivity to day length, and this trend can presumably continue still further.

CONCLUSIONS

Past increases in yield potential have come from a rise in harvest index, and further increases of about 25% should be possible from this source. Thereafter they will depend on the development of ability to select for faster photosynthesis without reduction in leaf area, and therefore for faster growth. Unlike the rise in harvest index, that will require improving on prolonged natural selection, and is likely to be difficult.

Unless photosynthetic efficiency can be improved by genetic engineering, further progress by plant breeders in raising yield potential, both per crop and per day, will remain dependent on agronomic improvement and innovation. Plant breeding and agronomy are truly synergistic and it is important for international centers like IRRI to maintain a balance between the plant breeding and the agronomic domains, using both of these terms in their widest sense.

I would like to thank IRRI's successive directors general and staff for the imagination, enthusiasm, and dedication which have attracted and involved so many scientists from developed countries in the problems of the poorer countries. I count myself lucky to be among these alumni of IRRI.

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EXPANDING THE ENVIRONMENTAL COVERAGE OF HIGH YIELD TECHNOLOGY

Cultivated rice evolved from wild rices found growing along river estuaries. According to T. T. Chang, "rice grains were initially gathered and consumed by prehistoric people of the humid tropics who lived near the river estuaries along the wooded foothills where rice grew wild on poorly drained sites."

As a taste for cereal developed, cultivation began and migration of the early cultivators accelerated the evolution of cultivated forms adapted to different environments.

Today most rice is cultivated under controlled irrigation. In several developing countries it is also grown in a variety of difficult environments where drought, soil fertility, insects, diseases, and mineral toxicity are important constraints.

Most international research efforts have been concentrated on irrigated rice. But recently, more attention began to be paid to problems in the more difficult environments.

Here we report some aspects of the Brazilian experience on upland rice, which indicates that technology can increase yields and reduce instability, and that under difficult environments, upland rice can be a stable and profitable source of food.

Brazil produces about 9 million tonnes of rice yearly; 70% from upland and the rest from irrigated land. Total cultivated area varies from 5 to 6 million hectares.

Size of most farmers' fields varies from 40 to 60 ha but some are more than 2,000 ha.

In general, upland rice in Brazil has three main constraints: drought, disease (mainly blast), and weeds. These constraints are closely interrelated and responsible for the high instability observed in upland rice production.

DROUGHT

Drought is considered the main problem in Brazil. It is caused primarily by the occurrence of dry spells (*veranico*) during rainy season. In some areas of the country, veranico can cause great yield decrease, especially if it occurs at the reproductive stage of the crop, due to the following factors:

1. high evapotranspiration demand,
2. low to medium water-holding capacity of the soils, and
3. shallow root system.

Low natural soil fertility and soil compaction in areas of continuous cultivation seem to cause shallow root development.

A study made by Steinmetz et al (4) indicates that the number and distribution of favorable rainfall periods vary greatly depending on the region. Using the ratio ETr/ETm (real evapotranspiration:maximum evapotranspiration) as criteria to evaluate the climatic risk on distinct regions, they showed that the amount of water extracted by the root system is the main factor influencing the agroclimatic classification of the crop for a given location. Using 30 mm as a hypothetical value of the amount of water extracted by the root system, a large part of the country would be considered as *unfavorable* (high risk). On the other hand, if 90 mm is used, the larger area of the country is considered as *favorable* (low risk) or *highly favorable* (very low risk). Results clearly indicate that, at least in some regions where upland rice is grown, plant and soil management to promote a deeper root system are essential to decrease the risk of drought stress.

Influence of soil management on increase drought effect

Soils from most Brazilian upland rice regions are Oxisols, that are very intemperized showing good physical but poor chemical and biological characteristics. Natural fertility is found only in the 0-10 cm layer and results from the accumulation and decomposition of organic matter. This natural fertility is rapidly destroyed, making the soil unsuitable for cropping after 2 or 3 yr of cultivation as a result of the farmers' land preparation methods erosion, and the burning of crop residues. The land is easily mechanized, and farmers have adopted heavy implements responsible for very hard compaction below 10-12 cm depth.

The soil's low fertility and the compaction of the subsurface layer prevent roots from growing deeper, making the crop unproductive and very susceptible to dry spells.

Based on the previous discussions, one realizes that soil management to reduce water stress can be done in two ways: 1) by increasing soil fertility, especially that of the subsoil; and 2) by removing soil compaction.

According to Steinmetz et al (4), deeper root growth can be obtained either by eliminating the aluminum toxicity and other toxic elements or by increasing subsoil fertility. These can be achieved either by applying lime and fertilizers by deep plowing, or by increasing the movement of calcium, magnesium, and other nutrients to the deeper layers of the soil. Calcium moves faster when applied as $CaCl_2$ or $CaCO_4$ than when used as $CaCo_3$.

Experiments at CNPAF by Seguy et al (3) show that upland rice yields in Brazil can be increased more than three times if the land is well prepared before planting. With the traditional method of soil preparation (heavy harrowing), yields were about 1.1 t/ha, whereas with an improved method — preincorporating straw and weeds by a light harrowing and then deep plowing (25-35 cm) — yield increased to 3.1 t/ha. In the second year, the new method improved the yields more (5.7 t/ha).

The increase in yields was explained by the researchers based on the following observations:

1. The initial harrowing provides a fine cutting of the residual materials and weeds allowing a homogeneous incorporation along the soil profile. Consequently, there is an improvement of physical, chemical, and biological characteristics of a deeper profile.
2. Superficial hydric erosion was reduced because the rainfall could infiltrate the soil more easily and become available to the roots.
3. The roots could elongate much more, exploiting nutrients and water deeper than 1 m. Usually, with the traditional method of soil preparation, roots can explore only the superficial layer (0-1 5 cm) of the soil.

Another interesting observation made was the possibility of changing the time of planting. In most regions of Brazil, upland rice is sown in October at the beginning of rainy season. With the new method of soil preparation it is possible to plant rice at the middle of rainy season, during the second or third week of January, and still obtain yields of 3 t/ha.

Breeding for drought resistance

Breeding for drought resistance is difficult. Adding to the complexity of the trait, there is lack of adequate methodology to screen in segregating generations.

Visual screening during reproductive stage, based on spikelet sterility and leaf rolling, has been useful in detecting potential progenitors from introduced and native genotypes at CNPAF. Crosses between national and African genotypes provided several promising lines in advanced generations or in regional trials.

The methodology prevents degeneration of the moderate level of resistance observed in adapted genotypes. However, researchers believe that the strategy for increasing drought resistance is to selectively incorporate certain characteristics of the adapted genotypes. Only in this way can loss of time in crossing and selecting without a good basis of variability be avoided.

However, such a program has to rely on the solid knowledge of the parameters of drought resistance to be transferred. There is general consensus on the importance of root thickness and depth on stress avoidance. But upland rice, and especially Brazilian genotypes, have an adequate root system. The problem is probably lack of expression of the characteristics under upland condition and soil management.

Leaf area has been a concern in the CNPAF program. National genotypes have a great plasticity in leaf growth. With adequate fertility and water availability, leaf area indexes as high as 7 can be attained, which promotes lodging. CNPAF data indicate a relationship between yield losses due to drought in the reproductive stage and leaf area indexes higher than 3. Fortunately, such leaf area does not prevent attaining the target yield for upland rice. On the other hand, effect of reduced leaf area on root development and carbohydrate accumulation during vegetative stage is not known. There is indication that translocation of reserves plays an important role in grain filling under water stress.

Other investigations concern the role of stomatal closure, leaf rolling, and leaf death, in the balance between stress avoidance, growth, and ultimately, yield.

Studies on rice water relations, especially on panicles and spikelets, are few. Studies available on leaves do not fully exploit possible genetic variation. Nevertheless, rice was found to have the ability to adjust osmotically.

The mechanisms or processes by which low water/turgor potentials are transduced into spikelet sterility are still not known. CNPAF researchers are currently developing studies on the subject. The possible relationship between loss of turgor in leaves, abscissic acid export to the spikelets, and damage to the reproductive structure in certain species, complicates this studies.

The role of stress-induced accumulation of metabolic substances is still controversial. Do they represent a stress adaptation linked to specific genetic information or are they passive results of changes in growth? There is a recent evidence of active accumulation of betaines, in certain species, related to synthesis of specific enzymes, under stress conditions. Such stress-mediated metabolism eventually contributes to osmotic adjustment.

RICE BLAST

Rice blast is the principal disease problem of upland rice. It continues to cause significant yield losses in central Brazil where most upland rice is grown. The losses are of varying dimension depending on the cultural practices adopted and the soil and environmental conditions. Widespread planting of blast-susceptible cultivars increases disease incidence in Brazil. Average yield losses have been estimated to be 36% in IAC 47 and 17% in IAC 25, when blast was partially controlled under experimental conditions. In farmers' fields, losses from blast up to 100% have been registered. Despite efforts to breed for resistant varieties, the problem will continue because of need to grow upland rice in extensive areas where conditions favor disease incidence and development. Besides, the pathogen is highly variable and readily adapts to different agroclimatic conditions. The danger is enhanced if cultivars are released without regard for their susceptibility to the pathogen. The solution, according to Prabhu (2), lies inlearning to live with the disease and reduce its impact by proper disease management practices. All practices such as planting date, seed quality, seeding rate, cultivar, fertilization rates, and tillage, influence blast. It is, however, incorrect to adopt the same practices in different upland production systems. For example, in subsistence and shifting agriculture systems where rice is intercropped with maize, cassava, and beans, blast is of little economic importance. The system is confined to north and northeastern parts of Brazil. Farm size is small and production is totally dependent on family labor. In general, unimproved local varieties are planted. Such a system requires only the introduction of a cultivar with moderate blast resistance.

Efforts of CNPAF to reduce rice blast to tolerable levels are concentrated on a highly mechanized extensive monocropping system where the disease constitutes a limiting factor.

High blast incidence in upland rice

Blast incidence is higher in upland rice than in irrigated rice because of 1) prolonged dew duration periods due to wide differences in day and night temperatures, 2) predisposition of rice plant to blast under soil moisture stress, and 3) altered changes in nutritional status in plant tissue under drought conditions. The soil factors and their influence on uptake of nutrients under water-deficit conditions have been overlooked in the past. Available information has shown that accumulation of soluble sugars and nitrogen in different parts of the panicle under moisture stress conditions is associated with high panicle blast severity. Thus, all practices that reduce soil moisture stress suppress panicle blast to tolerable levels.

Disease management

Efforts that involve several measures are likely to yield more profitable results than adopting only one measure (1). In many cases, varietal resistance is insufficient for adequate disease suppression and should be accompanied by other disease management techniques. Considering the environmental and edaphic conditions in Brazil, several disease management practices have been evolved that reduce blast to tolerable levels. Early planting in October is one of the disease escape measures. Planting short-duration (100-110 days) cultivars in the early season reduces the risk from drought in February, and the uniform distribution of rain during grain formation reduces panicle blast incidence.

Planting rice against the wind prevents dissemination of inoculum from early planting to the later ones on the same farm. Avoiding excessive use of nitrogen fertilizer at planting reduces leaf blast. Balanced fertilizer rates promote plant growth and vigor resulting in reduced percentage of leaf area affected. Practices to reduce soil moisture stress during plant growth such as deep plowing, deep fertilizer placement, and low plant population reduce leaf blast to low levels. Using healthy or disinfected seed delays establishment of primary inoculum. One application of systemic fungicide at heading reduces panicle blast and increases grain yield under conditions favorable for disease development.

These measures involve little or no additional expenditure. Disease-resistant varieties are an important component of blast disease management. Brazilian upland rice varieties are drought tolerant; well adapted to acid, low-fertility soil; and possess consumer-preferred grain quality. The challenge lies in improving local upland rice cultivars for stable blast resistance. The recent breeding efforts at CNPAF yielded several blast-resistant promising lines. Crosses made with local cultivar IAC 47 utilizing resistant sources from Korea (SR 2041-50-1) and Nigeria (TOS 2578/7-4-2-3-B_2) resulted in two resistant cultivars, CNA 108 and CNA 104. The improved blast-resistant lines outyielded the local check IAC 47 (Table 1).

Grain yield of the blast-resistant cultivars was stable in both low- and high-input tests. Our experience has shown that there is potential in developing blast-resistant upland rice germplasm and in sequential release of resistant intermediate-height, early-maturing cultivars. With improved blast-resistant cultivars and recommended disease management practices, an average yield of 3 t/ha under unfavorable upland conditions is attainable.

WEEDS

Weeds are considered one of the primary constraints in upland rice production in Brazil.

In newly open areas, weed populations are low and weed control is not a problem. However, during the second year onward, weed population increases causing yield losses of 50% or more, depending on rainfall distribution. This is one of the reasons farmers shift to crops such as soybean or pasture, that offer less risks and good profits. Weeds not only affect rice yields by competing for water, nutrients, and light, but also hamper harvesting.

To avoid or minimize decreases in rice productivity, efficient weed control during the first 40-45 days is necessary. Experiments at CNPAF have shown that depending on the size of the crop field and labor availability, handweeding, use of mechanical cultivators, or use of herbicides can satisfactorily control weeds.

To assure effective and economical weed control in upland rice, a combination of methods is most convenient. Good soil preparation must be combined with adequate plant spacing and densities and use of fast-growing cultivars with high competitive ability.

Table 1. Yields (t/ha) of three promising blast-resistant lines in unfavorable upland, Goiås, Brazil, 1983-84.[a]

Line/variety	Grain yield (t/ha)	Blast reaction
CNA 108-B-28-13-1B	3.0	Resistant
CNA 104-B-2-43-2 [b]	2.6	Moderately resistant
CNA 104-6-34-2-1	2.5	Moderately resistant
IAC 47 (local check)	2.4	Susceptible

[a] Averages based on 16 multinational yield trials. [b] Released as Cuiabana in the Mato Grosso state.

Chemical weed control in upland rice cannot be overlooked, because herbicides are efficient weed control tools in extensive farming systems where there is a labor shortage.

CONCLUSION

The Brazilian examples are found in other Asian, African, and Latin American countries. They are upland and other *difficult environments* for rice. The examples show that high yield technology can be developed and extended to rice grown in these environments.

The international centers, mainly IRRI, can be very important in coordinating the definition and organization of research priorities for the different environments and regions and in promoting cooperation among national and international rice research agencies.

IRRI has a comparative advantage in carrying out some basic research directly or in cooperation with laboratories from developed countries and in rendering scientific services through its germplasm bank, genetic evaluation and utilization, and training programs.

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INCREASING INCOME AND EMPLOYMENT IN RICE FARMING AREAS — ROLE OF WHOLE PLANT UTILIZATION AND MINI RICE REFINERIES

By enabling drastically increased yields through new varieties and other inputs such as fertilizers, the green revolution opened up a new type of human behavior for the farmer who could generate enough capital to use external inputs in agriculture. Thus, in a few years, some farmers in developing countries were able to implement what it had taken European and American farmers decades to achieve. The inputs from the industry in agriculture and food manufacturing are now so great in the industrial countries that our food to a large extent is now made from oil, at least from an energy point of view. We are producing a lot of cereal and food per hectare but with a wasteful and unbalanced use of nonrenewable resources. We have, at our laboratory, made a study for the EEC (European Economic Community) Commission in Brussels (6) and forecast a surplus of at least 50 million tonnes of cereals in the year 2000 in the EEC — a surplus which will greatly disturb the agricultural economy of the EEC and its individual farmers. Of course, you realize what a nightmare it would imply to farmers in developing countries if this EEC surplus was dumped at the market place in these countries. We have pointed out in our EEC report that expensive agricultural machinery badly adapted to European weather conditions is utilized only a few hundred hours per year — a wasteful overmechanization.

If the agricultural machinery in Denmark could be used for a longer time — about 2000 h/yr by introducing machine stations and new types of multifunctional tool carriers, a sum equal to the present subventions from the

EEC to Danish agriculture could be spared. The present depression in cereal prices in the U.S. and Europe caused by the overproduction makes it urgent to study if the total crop, including straw, can be used for purposes other than for food and feed, e.g., for the manufacturing industry. Such an endeavor would also bring about a much wanted increase in employment — both locally in agriculture as well as in industry. At the same time, we will have to be more cost-benefit sensible in our future agriculture. To open up for new product applications in the interface between industry and agriculture, new harvesting and treatment centers are necessary. We have called these centers *agricultural refineries* because they will be able to collect, treat, and produce a wide range of raw materials and products as well as fractionate different whole crops into intermediate products of defined quality tailored to be used as raw materials in the industry.

Summing up, we do not think it would be wise for us in the industrial world to brag too much about our high yields and superior efficiency.

In 1971, I visited IRRI. Coming back to IRRI in January 1985, I was very positively surprised by your awareness of how to administrate the impetus of the green revolution on a realistic cost-benefit basis (4). You have substituted insecticide sprays with insect-resistant rice strains and you have been able to drastically reduce fertilizer losses by your deep-placement fertilizer applicators. You have introduced simple machinery which has alleviated the farmer family from drudgery, such as the IRRI rice harvester and thresher. You have improved rice quality and nutritive value by creating an innovative rice warehouse dryer which could be fired by rice hull charcoals and built from rice hull burnt bricks. In fact, you have advanced much further on the road of resource conservation than we have in Europe, a road which we all sooner or later must enter. On the other hand, all of us could learn much more from Europe's industrialization history when industry based on the agricultural platform took off with millions of new working places produced. We do not want to copy it directly with all of its drawbacks but to learn about the basic mechanism of innovations in human behavior.

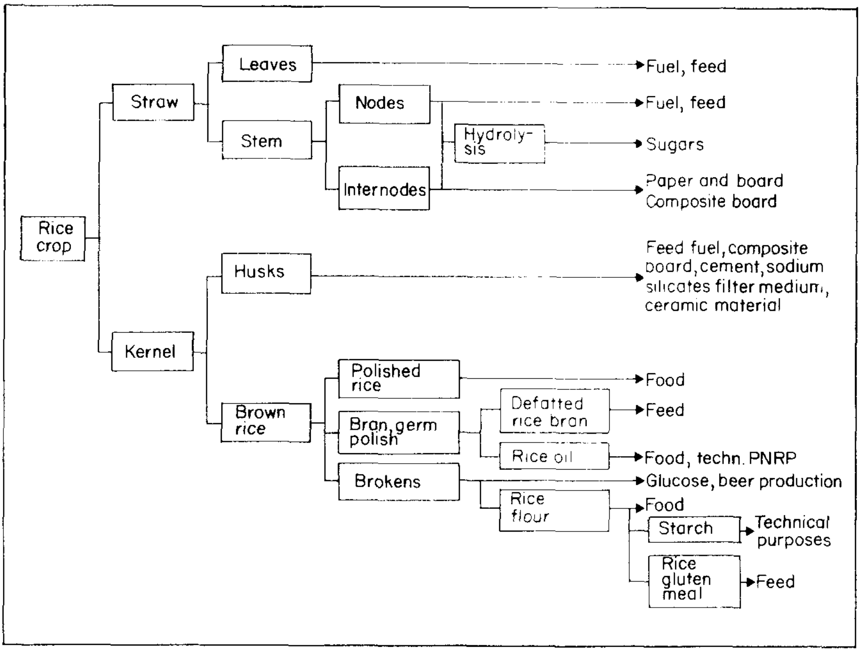
Obviously a boost in rice production for a farmer will be advantageous for his family and add to the surplus — that is, to the common heap of rice accessible against payment or through exchange of goods. No payment, no rice, is the hard, unavoidable fact of life. We could anticipate that if we could use another agricultural resource, for example, straw, to make attractive products such as feed, fuel, building boards and paper, the surplus from the common heap of straw would give working places and cash that will make the common heap of rice accessible to women and landless laborers who lost some of their jobs — although heavy and unproductive — through the introduction of the IRRI planter, harvester, and thresher. Fifty years ago in Europe, we used much more agricultural raw material in industry, which were later pushed back by oil substitutes (6). The increase in oil prices and a cost benefit rationalization of agriculture will make agricultural raw materials much more competitive not only in Europe but especially in the developing countries that lack hard currency. There are enough agricultural raw materials (Table 1). From rice, world basis, we produce about 600 million tonnes of straw, 80 million tonnes of husk, and 40 million tonnes of bran, as well as 85 million tonnes of broken rice, part of which could be used for starch manufacture. The world's forests are in a bad shape due to overcutting and damage both in developing and industrialized countries. The rice straw would give a significant contribution both as a raw material for fiber board and as a source for cellulose. We have, together with IRRI scientists, preliminarily studied how to dry and treat rice straw both outdoors and in a modified IRRI warehouse dryer. In contrast to barley and wheat it seems necessary to thresh the whole rice crop before drying to avoid shattering. There are still problems to be solved if rice should be dried properly in the wet tropics during rainy season. IRRI is extremely well suited to solve these problems.

Let us now first look at the possible uses of the whole rice crop in a rice refinery (Fig. 1). The refinery collects and separates the botanical components of the rice plant, e.g. to divide straw into internodes (stem), nodes, and leaves to be distributed to industries as semimanufactures for particle boards, paper, and chemicals. The refinery process could also include pelleting equipment for making alkali feed pellets or fuel pellets which could be sold back to the farmers. In Figure 1, the various fractions of rough rice and their potential uses are demonstrated. To make high-quality particle building boards, a fractionation of the straw into leafmeal and chips (internodes) is made by processing in a disc mill combined with a simple sifter (Fig. 2). The leafmeal is high in protein and hemicellulose but low in cellulose, making it a good feed pellet for ruminants if sprayed with 1.2% NaOH just before pelleting. It can also be used directly as a fuel source before or after pelleting without NaOH. The straw chips containing more cellulose than the leaves make an excellent fiber board pressed with a ureaformaldehyde glue modified with isocyanate (Fig. 3). This product can be made superior to most particle boards of wood chips with a very attractive structure. The high level of silicium in rice material seems to give reduced swelling and absorption of water which is favorable. Figure 4 shows the different steps in making rice-chip fiberboard including chopping, deflakening, drying, sifting, glueing, forming, and pressing. The question is, will such a

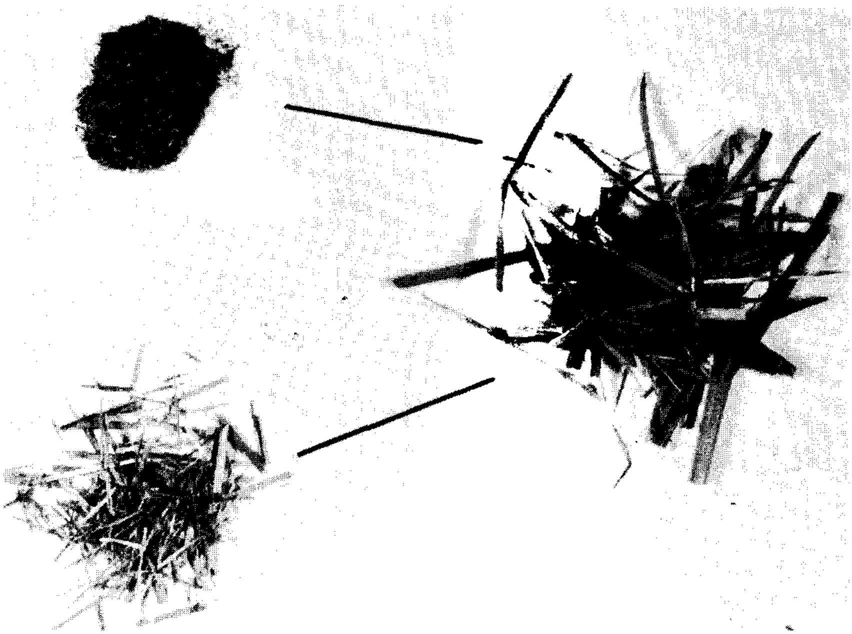
Table 1. World production of rice and rice by-products (1).

Product	Production (million t)	Products	Production (million t)
Straw	600	Husks	80
Rough rice	390	Bran	40
White rice	168	Brokens	85

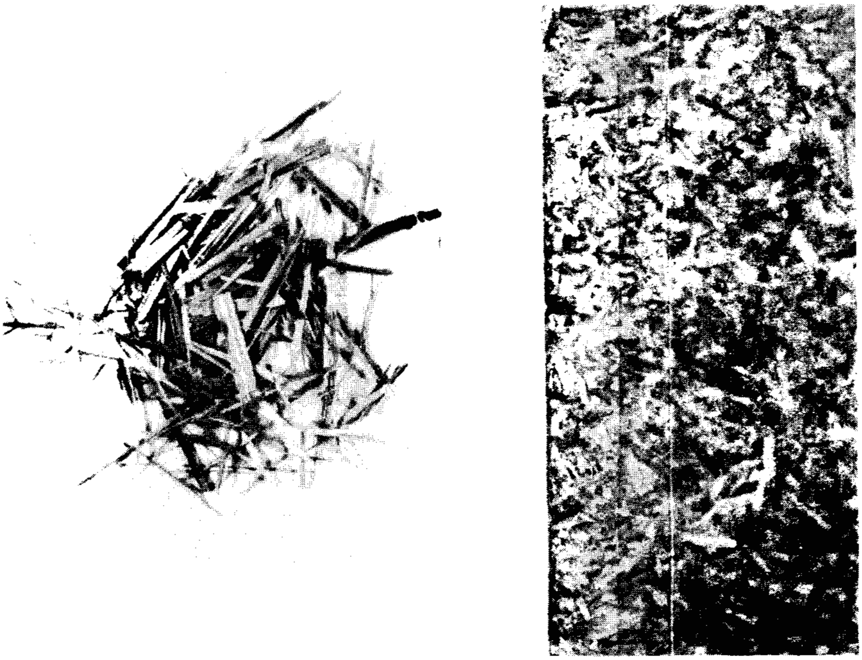
Potentials
Straw and husks: fuel value equivalent to 170 million t of fuel oil, feed value (chemical treated) equivalent to 340 million t of cereal grain.
Bran: 5 million t of food protein and 6 million t of edible oil.
Brokens: 50 million t of starch.



1. Rice: total crop utilization.



2. Fractionation of straw into leafmeal and chips for manufacture of high-quality particle board.

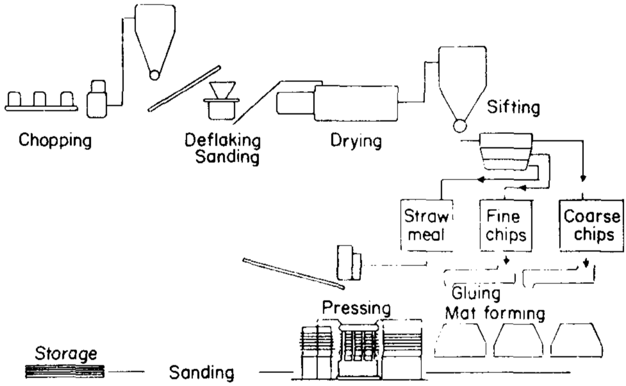


3. Particle board made of straw chips.

particle board be economically competitive and how much can the process pay for the straw which has to be collected and separated?

If we consider the two biologically produced polymers of major importance — starch and cellulose — available in approximate equal quantities in a cereal field, their world market price is astonishing enough — about US$0.20/kg for starch and about US$0.30/kg for cellulose. Cellulose is now becoming more expensive than starch. The raw material price which could be paid for straw to make fiber board and paper in competition with wood is as high as US$0.04-0.07/kg. It would thus be more rewarding for the developing countries which still have some forests left to keep these for the future and for keeping up the water balance in the environments, and instead make fuel, particle boards, and cellulose from their agriculturally produced straw, for their own need and for export to major industrial countries, instead of from the trees now cut down.

The major problem is that of entropy, how to effectively collect the dispersed straw to feed the comparatively large factories needed. However, this should not be impossible if an incentive in the form of a reasonable price for straw could be realized. Today in the Philippines, the price of feed is so high that about 150 kilos of straw per day collected free and delivered to an alkali pellet factory would be enough to feed a family. This again brings in the organizational aspect and thus the concept of refineries as the necessary intermediate between agriculture and industry.



4. Steps in making rice-chip fiberboard.

We were very pleased to hear that the farmers in Indonesia are now organizing themselves into farming groups consisting of up to 100 farmers covering an area of up to 100 ha. Such a group would be ideal for a mini rice refinery consisting of a harvesting, drying, and threshing station plus a straw and food processing center producing straw chips for export out of the farm area, feed pellets, fuel pellets, and rice and baby food for own consumption. Keeping in mind that in Kerala, India, it is possible to keep fairly large dairies running on the base of very small deliveries, the idea of several mini refineries as intermediates between the farmers and the particle board and paper industry should be workable. As you can see from Table 2, several harvesting centers/mini refineries could deliver straw chips to fiber board factories, factories for packaging material, for production of rice oil from bran, as well as to straw pulp factories which represent the full-industrial scale of operation.

A few people might argue that bringing straw from the field would extract important minerals and an important carbon and nitrogen source from the paddy fields, thus decreasing fertility and the long-range cropping endurance of the area. I do feel that this problem is manageable and would not constitute a serious problem if the straw exploitation was performed with a variety of uses. Thus, if the leaf fraction was used for cattle and the resulting manure was brought back to the field after composting, this would compensate for some of the losses. One should critically monitor the fate of all organic materials in a farm village and utilize even such sources as human manure to feed back to the fields after a proper composting regime to kill parasites. If this is done, one would easily be able to extract the internode fraction of straw to be used out of the farm in industry.

Table 2. The concept of harvesting centers/mini refineries.

Farmers (no.)	Harvesting centers (no.)	1st degree refinery	2d degree refinery	3d degree refinery
110	11	Food preparation center		
110	11	Straw processing center		
110	11	1 straw processing center	Paper container plant	
660	66	6 straw processing centers	Particle board plant	
2750	275	25 food processing centers		Oil extraction plant
4400	440	40 straw processing centers		Pulp mill

Another argument which invariably is put forward regarding nonfood uses of, for example, cereals for modified starch such as glues is that it is considered immoral to use food for industry in a starving world. For instance, our EEC report (6) was characterized in the major Danish newspapers as "now they are going to make plastic out of food." To illustrate the irrelevance of such a superficial argument, I would discuss the possibility of using rice starch for encapsulation of fertilizer to improve efficiency of its use. I feel that the IRRI deep-placement fertilizer applicator (4, p. 102) is one of the main innovations from your institute. It is remarkable but understandable that the fertilizer industry has not been able to make such a discovery. Now the next step to improve fertilizer administration would be to make a glue locally, for example, based on rice starch from broken rice plus a phenol additive which could be made from petrol or even from an extract of high-tannin sorghum (6, p. 94). It will take some time to develop this idea, but I really feel that there is a fair chance that it would work also locally, bringing in new possibilities for more rewarding work especially for women. We can thus anticipate different encapsulated fertilizer granules which will release nitrogen in different rates and which can be put out in the field by the IRRI applicator. Biotechnological investigations of nucleic acid regulation have proved that it is possible to turn on genes for protein synthesis a few weeks earlier by applying fertilizer at the right time. Thus, not only are losses to surface water of fertilizer minimized, it also would be possible to exactly manipulate the growth rate and production of rice according to environmental conditions. The encapsulated fertilizer could also be used for direct application in hard soil under upland conditions where the IRRI applicator is not used.

Thus, an investment of, say, less than 0.1% of the harvest yield of rice seed into encapsulation of fertilizer might save fertilizer to a level of less than 50% of the present application and still increase yield above the investment of rice material and labor, at the same time bringing about qualified local working places.

Still, our most dedicated critic will maintain that it is immoral to use rice meant for food as a glue! Of course, arguing and keeping the conversation going is one of man’s main activities. The situation reminds me about Charles Darwin’s observation (2, p. 239). “It is an important principle that in the process of selection man almost invariably wishes to go to an extreme point.“ This is valid both in conversation as well as in experimental behavior. By processing one significant item at a time, this strategy is successful. We plant breeders use it every day. We select, for example, low plants and high plants, and find out what type yields more. It works because plant stature is a limiting factor for yield under high fertilizer conditions. However, when the situation is more complex, as in the case of viewing an integrated plant environment/ human behavior system, we get entirely wrong when we ruthlessly try the methods of purification of the extremes regarding individual attributes. Here we must utilize a new scientific approach to stratify the factors according to their limitation and then act through trial and error accordingly but with an open mind for surprises. Otherwise we will go on arguing forever.

Why should it be that the best always seems to be the evil of the good? Local-central, rural-urban, cooperative and private are all the strings we need in our instrument to make an acceptable tune.

We should now consider the point where our different subsystems are coming together which I have called the meeting of the waters. Here we envisage a rather unusual situation in physical life where three main rivers meet in one point and divide into a delta. In the reality of human mind this happens often. Here IRRI‘s knowledge about plant husbandry in rice-growing countries is combined with outside inputs of mechanical and chemical processing and with local innovations in human behavior and unified in a demonstration center serving as a source of inspiration and transfer of technology before it breaks up into a delta of local projects combining concepts from all three rivers of resource. This idea builds on Dr. M. S. Swaminathan’s original cafeteria approach to obtain a local diversification of job opportunities connected to agriculture and which you have seen demonstrated at IRRI. It must be rewarding to trace innovative local people in the rice-growing countries, farmers, women, landless laborers, businessmen, and small-scale industrialists, and support them in local developmental projects. A small task force should identify major local innovations in human behavior which have given considerable impetus for the quality of life of the inventors.

Both agriculturally (rural) and industrially (urban) based ideas should be considered. A major problem, especially in Africa, is that the urban population largely is not eating foods produced from local raw materials such as sorghum and rice but from wheat which is imported and difficult to produce in those countries (3, 5). We should here remember the development in Europe. If, for example, ryebread baking in Denmark had not been industrialized, no Danes, would, today, eat ryebread. It takes about 5 h to make ryebread. Very few people would, today, make that effort at home. By analogy, we must in the urban areas industrialize the manufacture of, for example, Ugali in Tanzania and Ogi in Nigeria based on local raw materials, thus indirectly increasing the incentives of the farmers to sell their local food products to the cities.

I have worked with this concept for the last 8 yr in Africa with very little result. There is a lot of interest but no incentive for implementation of the idea. We must now discuss how we could get local small- and medium-scale business ideas in agriculture implemented and multiplied with the help of the international agricultural institutes. I am suggesting that the World Bank and the Asian Development Bank should support innovations in the utilization of agricultural raw materials in rice-producing countries, and forward local incentives and stimulate those incentives with technical demonstration centers where additional technologies could be selected and tried carefully by the local people themselves. The successful local development projects could then be funded and later multiplied in large scale with regular bank loans. We have heard how IRRI is developing from regular rice breeding to conveying semimanufactured rice lines made by the new biotechnologies which could be utilized by the now quite advanced national breeding programs. At the same time, IRRI, in cooperation with the international agricultural institutes and others, could take the responsibility to favor the incentives of local people in developing countries to support them in the fragile implementation phase regarding the efficient utilization of the whole rice crop. Thus, the benefits of the green revolution could be more evenly utilized and appreciated by different groups of people with the intention to create an evolution in human employment. The plant breeder is by his profession a master of selection of alternatives and should, by proper support in the aspects of technical processing, economy, and social affairs, be able to breed plant and human society together.

Social and economical support without production incentives are, at their best, able to comfort people but provide very little advance in living standard.

Technology without social innovation results in frustration and unequality.

The full combination bred according to the needs of individual countries is the only realistic solution. In this second step of the green revolution — the evolution of human employment based on agriculture — *the quality of the product is going to be the decisive incentive* just as yield triggered the first step in the green revolution. IRRI, as we have seen, has already moved into the second step of the green revolution — a real diversification achievement. I suggest this process which is so typical for IRRI be called IRRI - gation.

I wish you good luck in your work during the next 25 yr.

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PRIORITIES FOR RESEARCHAND TRAINING: THE VIEWPOINT OF THE TECHNICAL ADVISORY COMMITTEE TO THE CGIAR

I am very pleased to address you on this happy occasion. It gives me the opportunity to join, on a personal basis and on behalf of my colleagues from the Technical Advisory Committee of the CGIAR, in congratulating IRRI for its outstanding achievements in the last 25 yr. The task was enormous, despite the existing knowledge base, and 25 yr is a fairly short time.

Looking at what has already been achieved, IRRI deserves our highest commendations. But we should not forger it is the national systems, their governments, scientists, and farmers who have made it happen. We, in the CG System, consider your success as our reward and we look forward, above and beyond the present case of rice production, to the continuing expansion to other commodities and with other centers of the CG System of a partnership which has proven to be so fruitful for rice, the most important staple food in the world.

Asia, very rightly in the early 1960s, was the major concern of the founders of IRRI who were also the pioneers of the CG System. While the spectrum of hunger and famine was then almost omnipresent globally, the food situation has now dramatically improved. To limit myself to rice production since it is the purpose of this meeting, I would like to just quote a couple of figures which eloquently demonstrate the progress made. These figures, extracted from IRRI's publication *25 years of partnership,* concern the 12 leading Asian producers.

While the acreage devoted to rice increased by only 13% between 1965 and 1982, rice production rose by 66%, outrunning a net population change of 45%. Spectacular success in wheat production was also attained.

In Asia, obviously, and thanks to efforts deployed both at national and international levels, and to the machinery now in place, highly efficient in some countries, improving in others, we all have bought some time in our endless fight against hunger and malnutrition, This does not mean, of course, that all the problems have been solved, that all the challenges are being fully met, but at least the political will and the necessary tools are there.

Unfortunately, other parts of the world are in a much less favorable situation. The problems of Africa, where food production per capita, not only rice, is steadily decreasing, have been compounded in large parts of the continent by repeated devastating droughts over the last decade. To improve the situation, a series of problems must be solved. Among them, and probably soon within our reach, technologies specially designed to fit particularly harsh environmental conditions are urgently needed. The African continent is to receive from the CG System the particular attention it deserves within the framework of a hopefully increased and more coordinated approach from the donor community. We see Africa as the greatest challenge for today.

Research and technology generation goes through, but for very few exceptions, a considerable strengthening of the national research systems. It also goes through an increased cooperation between them and the international centers, which, on their side, as I can assure you, are prepared to adapt themselves to changing needs and to tackle increasingly difficult problems.

I would like to briefly share with you where we stand on a fairly complex exercise — a review of the evolution of the CGIAR's present activities and strategies for the short, medium, and long term.

Our work is still in progress. Our recommendations will be presented to donors in October 1985 and, in the meantime, we shall benefit from the Group's reactions, next week in Tokyo, to the broad overview I intend to present. The present draft of our paper shall be examined again, as a practically final step, by the Committee two weeks from now when we return to IRRI for our 37th meeting. This shall give us one more opportunity to discuss our views in joint session with the center directors. Some few, although important, decisions remain to be taken, particularly regarding priorities among commodities. I am not going to specifically address any given commodity. Rather, I would like to share with you what has been our approach and philosophy.

When the CGIAR was established in 1971 the necessity of an advisory body was immediately felt, the first task of which was to help develop the system in its early stages. Later, as the complexity increased — you are all aware that there are now 13 centers in 1985 — the role of TAC has gradually evolved toward the integration and balance of the various activities conducted by those 13 centers.

Several mechanisms are presently utilized to ensure the necessary coordination. Two are conducted at regular intervals. One consists in the yearly examination of the program and budget of each center and this has been particularly important since 1982 when the financial crisis began to have severe implications for the system as a whole, not to speak of the personnel and technical issues facing the centers. The second concerns the external 5-yr program reviews, which are also conducted centerwise. Although both allow a thorough examination of the system's individual components, they do not permit following the evolution of a given activity across the system. Hence, the last mechanism set up whenever needed — a review of priorities across the System. This is the third time since the Group's creation that the Committee has undertaken such a task.

TAC and all those who have collaborated with us —center directors, board chairpersons, leaders of national research systems, donors, and resource persons — have invested considerable time and effort in this priority study, which was decided upon in late 1982, under the pressure of the funding situation.

However, scope and context of our study have evolved considerably over time. What was to be a narrow priority-setting exercise — an update of the 1979 priorities paper — with a focus on short-term priorities among ongoing activities, has broadened. In full accordance with guidance from the Group, it has developed into what now is a "TAC Review of CGIAR Priorities and Future Strategies."

I would like to comment on some aspects of our study. First, I want to outline the product of this exercise, while highlighting some of its salient features. Second, I want to present to you the conceptual framework developed by TAC for this review. This will allow me to tell you how we now define the system's long-term goal and how we went about conceptualizing its program structure, linked to that goal.

Before presenting some of the key features of our study, let me enumerate TAC's objectives. These are to identify the changes needed to make the system more effective and responsive to meeting present and future demands of the developing world, and, at the same time, to place in a broader framework the problem of adjusting the annual programs and budgets of centers to the resources made available by the CGIAR. The central issue is to define an appropriate path for the development of the system to keep it lively, efficient, and effective in an evolving environment.

Priority assessment in the CG System is an increasingly complex exercise due to the expanding breadth of the system's activities, the heterogeneity of center mandates, and the system's position as one member of a global research effort, working in collaboration with increasingly diverse national research systems as well as specialized institutions and development agencies in both developing and developed countries.

To adequately address this higher level of complexity both in the CGIAR and in the context in which it operates, TAC has expanded the scope and depth of the priority assessment process for this review far beyond that of earlier exercises. The salient features of our study are:

- *The context of the approach.* It views the CG System as one component of an emerging global research system. As such, the system can perform most effectively if it works in concert with the other components and concentrates on a limited number of research problems for which it has a comparative advantage.

- *The breadth of the approach.* It presents a comprehensive review of priorities both among current activities/commodities in the system and among activities/commodities not presently included.
- *The conceptual framework for the approach.* It develops an innovative framework to systematically compare the heterogeneous research and research-related activities of the CG System. By linking activities to the central goal of the system, it provides an effective means for establishing priorities and making resource allocation recommendations.
- *The analytical approach.* It uses a more formal approach to priority assessment and resource allocation decisions, based on indicators which are used to systematically guide TAC's collective scientific judgment. The indicators selected address a broad range of concerns relevant to priority selection in the CG System context.
- *The time horizon.* We have been working with a dual time horizon regarding both the short (5-10 yr) and the long term (25 yr). Our wish to keep realistic has prevented us from looking further ahead, in view of the fairly unpredictable evolution of some of the factors concerned. Such a time horizon introduces a long-term perspective regarding the evolution of the CG System and uses this as a basis for rational decision-making regarding short-term priorities, in particular concerning the evolution of priority setting among commodities. This union of long-term perspectives with short-term decision-making is particularly important in the case of research with its extended time-lags and gestation periods.
- *The financial context.* TAC's objective is to use the priorities established to generate broad resource allocation recommendations among program activities/commodities. The financial context in which TAC made the resource allocation recommendations involved two scenarios. The first scenario is conservative: TAC used the System's present resource situation and assumed no real increase in funding. In the second, TAC assumed that funding would expand to meet the needs presented by the immense challenges to international agricultural research in the future.

The first scenario was used to force a critical analysis and evaluation of the current program structure. It thus ensures that a complacent perpetuation of the status quo would be avoided. TAC used the established priorities to confront hard decisions on resource allocation among the many diverse activities competing for funds in the system. The no growth funding assumption means that any recommendations for additional funding of high priority activities would entail internal shifts away from current activities. To achieve effective utilization of available funds, TAC considers that a certain amount of consolidation is required. It intends to recommend for funding only those programs for which a minimum critical mass can be assured. This policy avoids spreading the system's resources too thinly and favors the concentration of efforts on a number of viable programs with true impact potential.

On the other hand, the future challenges for international agriculture are of such proportions that greater efficiency of resource use will not be sufficient to free adequate funds to support the required efforts to meet them; expanded financial commitment will be a necessity. However, some high priority research areas not presently within the system also deserve to be brought to the attention of the donor community. At present, we have identified three of these. Therefore, TAC also employed an optimistic scenario for resource allocation recommendations which assumed a 25% increase in funding. This scenario draws attention to the additional high priority needs which cannot be funded solely through internal consolidation within the system. I would like to underline, at this stage, that the notion of funding, as we use it, is not restricted to core funds, as usually understood. On the contrary, it comprises all the funds utilized by the centers, including special projects, with the expectation that the donor community will see fit to increase and reorient some of the extra core funds to meet approved high priority needs.

Two essential steps are required for priority assessment, particularly in a system as complex as the CGIAR. The first is to define the central goal of the system in operational terms. The second step is to link in a clear and structured manner the activities being reviewed to the operational goal. To assist the CG system to establish priorities among its diverse research and research-related activities, TAC has developed an analytical framework that relates all these activities to the central goal.

The definition of the system's long-term goal has evolved over time and gained clarity and specificity. There has been a convergence of originally differing ideas and perceptions. Accordingly, TAC has adopted the following goal statement:

> Through international agricultural research and research-related activities, to contribute to increasing sustainable food production in developing countries in such a way that the nutritional levels and general economic well-being of low income people is improved.

This goal statement specifies and thereby focuses on

- research and research-related activities, not development or technical assistance activities;
- international, not national research;
- food and feed, not industrial commodities;
- developing, not developed countries;
- technologies for long-term sustainable production, not technologies that sacrifice ecological stability for short-term gains in productivity; and
- improved nutrition and economic well-being of low-income people not solely through increased food production, but also through improved quality of food, more stable supplies, and increased income.

As a framework for systematically analyzing the program strategy of the CG System, the central goal has been disaggregated into a set of eight interrelated objectives or program approaches which reflect important constraints to increased food production and utilization in the developing world. In collaboration with other members of the global system, especially for national research systems, the CG System strives to develop the means for

1. managing and conserving the natural resource base in developing countries (e.g. soil, water, and genetic resources) for a stable and productive agriculture in the long term;
2. increasing the productivity of essential food crops with a view to integrating them into improved sustainable production system;
3. improving the productivity and ecological stability of livestock production systems;
4. achieving more complete utilization of agricultural products in rural and urban areas through improvements in postharvest commodity conversion, storage, and utilization;
5. promoting better human health and economic well-being, through improved nutritional quality of foods, enhanced equity in access to foods, expanded economic opportunities, and better management of overall family resources;
6. improving the policy environment to ensure the formulation of rational agricultural and food policies which favor increases in food production and productivity through the adoption of enhanced technologies;
7. strengthening national agricultural research capacities in developing countries to accelerate the indigenous generation, adaptation, and effective utilization of enhanced technologies; and
8. integrating efforts within and among centers of the CG system and, equally important, integrating the CG Systems's objectives and activities with those of its various partners in the global system.

This order of presentation does not imply any order of priority and all eight program approaches we present as the petals of a circular flower are integral to the central goal. Hence, progress toward achieving them contributes to that goal.

We have then proceeded, and it is the first time that this has been possible, thanks to the disaggregation process I just described, to assess priorities among the different program approaches. In this priority assessment, we have used two levels of analysis.

The first is on the aggregate level and considers globally the various program approaches. We systematically examined, in this case, the potential contribution of the approach to the goal, the evolving priority ranking of each approach in light of changing circumstances in the future, the adequacy of the current resource allocation, and the need for change. It should be pointed out, however, that the relative priority assigned to an approach does not necessarily entail an allocation of CGIAR resources in proportional terms. For example, in the postharvest area, which addresses an important constraint particularly to root crop development in the tropics, the involvement of other institutions and development agencies has allowed the CG System allocation to continue at relatively modest levels. The time frame for analysis at the global level is essentially medium to long term.

The second level of priority assessment concerns a detailed and disaggregated examination of commodity improvement programs, the primary vehicles for research in the CG System. Priorities are established among commodity research programs in terms of relevance to the central goal, research opportunities, and efficiency considerations. For this, we have used as analytic tools, a complex set of indicators to help structure our judgment. I would like to underline here that these indicators have been used at both the global and regional levels. The time frame for this second level of analysis is short to medium term.

We are reaching the end of a long process, but we are convinced that the system has reached a point where it has really to reflect on itself and go, carefully but decidedly, beyond marginal adjustments on a yearly basis.

As I tried to show to you, our approach and the resulting framework in which we have circumscribed our study is hopefully wide enough, that the donor community can examine in October our recommendations in the light of a broad-based analysis. We in TAC feel confident that the decisions taken then shall make the CG System able to meet the challenges of the future as it has met those of the 1970s.

CLOSING SESSION

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CLOSING ADDRESS

When the first international centers were created 20–25 yr ago, the concept was that the centers would do research, until national institutions could stand on their own. This implied that the centers were temporary institutions that would remain for, maybe, only 20–25 yr. Things have changed since those early days, for which the centers themselves have been largely responsible. Partly due to the extensive training programs that have always been a prominent feature of the centers' activities, and perhaps more as a result of the ways in which the centers have sought to involve the national programs in joint research programs, it is now increasingly recognized that the centers are here to stay and that their primary functions are to service, support, and strengthen national programs and not to be a substitute for them. The centers are doing this by concentrating their efforts on those programs and activities where international institutions have a comparative advantage over national institutions. One of these advantages has been, and probably will be for some time to come, the collection, evaluation, and distribution of germplasm and the rather specialized research associated with such a function. Another is the ability to create and sustain research networks that involve scientists from many different countries regardless of current political differences. Training is another function where the international centers can play a vital role that few, if any, national institutions can do so extensively.

What we now see is a system evolving in which the centers are not so much the direct doers of research, as they are facilitators of a mechanism by which work is done by a series of institutions (both national and international) working together on problems of common interest, each contributing its special resources and skills. In this way, far greater resources and skills can be mobilized to generate new agricultural technology than the CGIAR alone can provide.

It is also apparent that the national research institutions are becoming an extremely important component of the system. They are not just modifiers of technology developed by the centers, they are also important contributors to the development and adaptation of that technology. But not only are they contributors, they also are major beneficiaries, not least because by joining in research networks catalyzed by the centers, they obtain access to each others' skills and knowledge. These are exciting developments with wide implications, and are a tribute to the boards and managements of the centers that have encouraged such developments.

What I find impressive is the speed with which the process of participation has evolved. And it is evidenced in many different ways. For instance, about 55 nationalities are represented among the 200 or so trustees on the various centers' boards, and there are more than 60 nationalities among the 750 to 800 senior scientists and administrators in the system. And, I am glad to say, the developing countries are well represented in both capacities. Also, most encouragingly, developing countries are joining the system as full donor members of the Group. Five such countries are among the existing 39 donor members and several other developing countries will, we hope, join in the relatively near future. This, too, is a development the founding fathers of the first centers to be established probably did not anticipate. In point of fact, from being essentially and exercise in overseas aid, the system is now evolving into one where both developed and developing countries are donors and both are beneficiaries.

May I now touch very briefly on three key issues of particular importance to us in the CGIAR.

The first is the precise role of the centers in the bigger world of national research institutions. I have mentioned how this role is evolving. It is something we must constantly keep under consideration, to make certain our limited resources are well used. Also, within that role, what should be our priorities? The technical advisory committee of the Group is looking at these issues in depth.

The second is the impact of the CGIAR. What has the system achieved, and where? We have an ongoing major study which I am sure will produce very interesting data and conclusions.

The third is Africa, the problem continent as far as agricultural development is concerned. What more can the CGIAR do to help — where can it best deploy its resources? This issue is of major concern and we are actively addressing it.

I do not want to elaborate on these three issues, but I mention them to illustrate that the CGIAR has the permanent habit of questioning its roles and responsibilities and thereby, I believe, retains its sense of purpose and its ability to innovate. This is a source of its dynamic and forward looking approach to agricultural development.

Gentlemen, I believe, and I hope you share my conviction, that in the CGIAR system, we have an unusually effective instrument to encourage cooperation and participation among countries in agricultural research throughout the world. I think it has also been proved beyond all doubt, particularly by institutions such as IRRI, that effective research is a first class national investment, a most powerful tool to generate economic development. I believe that we should do our utmost to increase support for the CGIAR and all it stands for. There are no better investments and very few causes that are more worthwhile.

May I ask you to do two things. First, please bring your considerable influence to bear on your own government to join the CGIAR as a full donor member, or, if your country is already a donor member, to steadily increase its annual contribution. Second, whenever you get the chance, please be a strong advocate of the CGIAR system when you discuss your agricultural development plans with colleagues in the wealthier countries of the world. Urge such people, most of whose governments are already members of our group, to increase their contributions to the system. Your voices are not without influence and you will be listened to carefully. In doing these two things, I am sure you will be making a significant contribution to the welfare of your people.

R. F. CHANDLER, JR.
Charter Member, Founder Trustee,
and
First Director General,IRRI

LOOKING BACK AND FORWARD

I consider a privilege and an honor to participate in this 25th anniversary celebration of the International Rice Research Institute. For me, the quarter-century mark is particularly significant because at the time we were establishing IRRI, in 1960, the Ford and Rockefeller Foundations made it clear that they could not assure us of financial support beyond 25 yr. Consequently, aware from the start that significant advances could not be left to evolve in a comfortably indefinite and distance future, we focused our research program on achieving an early impact on rice yields, especially in Asia where 90% of the world's rice was grown and consumed. Furthermore, we tailored our physical plant and the size of our professional staff to a lifetime of 25 yr. My colleagues and I in the early days fully expected that by 1985 IRRI would have phased out its research and training program and turned over its buildings and equipment to the College of Agriculture of the University of the Philippines.

For the first 7 or 8 yr IRRI's only major financial supporters were the two private foundations, and there was no assurance that other donors could be found to join them in funding the enterprise.

As it happened, IRRI got off to such a good start that both foundations grew increasingly enthusiastic about using the same approach to the problems of underproduction of other major food crops. Accordingly, by 1969, the Rockefeller Foundation's successful Mexican Agricultural Program had been converted into CIMMYT, and its Colombian Program had been reorganized to form CIAT. In addition, feeling that Africa needed special attention, the foundations established IITA. These were costly projects requiring millions of dollars for buildings and equipment. By 1969 the Ford and Rockefeller Foundations together were contributing up to $1.5 million annually toward the operating costs of each of the four centers.

With expenditures at such a level, it became evident that the foundations could not support the 4 existing centers for even 25 yr, Moreover, influenced primarily by the successes of IRRI and CIMMYT, agricultural development authorities were suggesting that more centers were needed to conduct research on additional crops and on animals. Obviously, it was necessary to induce other foreign assistance agencies to join the two foundations in financing the international agricultural research centers (IARCs).

In conversations among principal officers of the Ford and Rockefeller Foundations on ways of interesting other donors in supporting the IARCs, Sterling Wortman, director for Agricultural Sciences of the Rockefeller Foundation and formerly the first associate director of IRRI, came up with an idea. He suggested that the major foreign assistance agencies be invited to attend a meeting at the Rockefeller Foundation's Conference Center in Bellagio, Italy, at which the role and importance of the IARCs would be presented by officers of the two foundations. This proposal was thoroughly endorsed by both foundations and the meeting was held in April 1969. Involved in organizing and conducting the conference were J. George Harrar, Will M. Myers, and Sterling Wortman of the Rockefeller Foundation; and Forrest F. Hill, David E. Bell, and Lowell S. Harin of the Ford Foundation. I was privileged to present to the group the story of IRRI as an example of what an international agricultural research institute could do in increasing the yield potential of an ancient and vital food crop. The conference, to which 15 national and international donor agencies had sent representatives, was an unqualified success. The meeting became known as Bellagio I, the start of a series of Bellagio conferences which by 1971 resulted in the formation of the Consultative Group on International Agricultural Research (CGIAR), a consortium of donors who have been the main supports of the IARCs since that year.

These details, although mainly of historical value, I feel are of particular significance at IRRI's 25th anniversary. If the CGIAR had not been formed, it is unlikely that the institute would be what it is today or even that it would still exist. Furthermore, such centers as CIP, ICRISAT, ILRAD, ILCA, IFPRI, and ICARDA (acronyms with which I am sure most of you are familiar) might never have been established, or at least would have had an uncertain future. The CGIAR now has about 40 members, contributing more than $180 million annually toward the support of 13 international organizations. With such backing, it seems certain today that IRRI has a long, bright future.

Before citing some of IRRI's notable achievements, I have a point to make about the chronological order of IARC founding. In a 1982 article (1) Plucknett and Smith stated that CIMMYT, having been set up in 1943, was the first of the IARCs. Although the Rockefeller Foundation did indeed start its Mexican Agricultural Program at that time, it was by agreement solely between the foundation and the Government of Mexico. The undertaking was exclusively a country program, not an international one. It had no board of trustees, and the entire senior professional staff consisted of Americans hired by the Rockefeller Foundation. The Program was closed in 1962 and all responsibility for its projects was transferred to Mexico's own institutions and scientists. However, a group of Rockefeller Foundation scientists remained in Mexico and continued to work informally with Mexican scientists at national experiment stations. Among them were such internationally known agriculturists as E. J. Wellhausen, Norman E. Borlaug, and John S. Niederhauser. Seeking a way to use these experts and some of their Mexican counterparts internationally, the Rockefeller Foundation and the Government of Mexico signed an agreement, on 25 October 1963, establishing the International Maize and Wheat Improvement Center (CIMMYT, from its Spanish name). Facilities were inadequate and financial support came entirely from the Rockefeller Foundation and the Mexican Government.

When Sterling Wortman became Director for Agricultural Sciences of the Rockefeller Foundation he reported to its trustees that with such limited financial resources CIMMYT could not be effective internationally and recommended that it be reorganized as a private corporation in Mexico, with a structure similar to IRRI's, to attract broader financial support. The reconstituted CIMMYT was founded on 12 April 1966. The Ford Foundation joined in its early support, and after 1971 funding came through the CGIAR. Without question, the rapid progress made by CIMMYT in the 1960s can be credited to its experienced staff and to the basic work done in the previous two decades under the Rockefeller Foundation's country program in Mexico. However, because IRRI — in contrast to the precursor of CIMMYT — had an international Board of Trustees, a multinational staff, and worldwide responsibility for the improvement of the selected crop, I maintain that chronologically it was the first of the IARCs.

PAST ACHIEVEMENT

Some of you may recall that at IRRI's 10th anniversary celebration (which was 12 yr after its actual founding), I gave a talk entitled *IRRI — The first decade.* Today, borrowing a phrase used by the late William T. Myers of Cornell in similar circumstances, I shall "rearrange my prejudices" and shall present again some of the thoughts I had 13 yr ago.

IRRI's first major achievement, in my opinion, was its founders' decision as to the Institute's principal objective. That would be to develop a practical, problem-oriented research program designed to create, through plant breeding, rice varieties with a much higher yield potential, accompanied by investigations to develop the technology to enable the new varieties to express their true yield capacity when grown by farmers.

IRRI has conducted basic research from the outset, but never at the exclusion of identifying and seeking solutions to the constraints to high yields 'on farmers' fields.

On the subject of early decisions concerning IRRI's future activities, it is interesting to note that the key programs IRRI carries on today were mentioned in the Memorandum of Understanding, signed in New York on 9 December 1959, between the Ford and Rockefeller Foundations and the Government of the Republic of the Philippines. Activities spelled out in the memorandum included basic and applied research, publication and dissemination of research findings, distribution of improved plant materials to other research centers, a training program for promising young scientists, establishment of a library and documentation center for the world's literature on rice, and the organization of conferences, workshops, and symposia on current problems in rice research and development.

This list of activities was prepared some 4 mo before the first meeting of the Board of Trustees and is a tribute — mentioned with special appropriateness at this 25th anniversary — to the knowledge and foresight of J. George Harrar of the Rockefeller Foundation and Forrest F. Hill of the Ford Foundation who first defined the nature and objectives of IRRI.

The first major achievement of IRRI's research, which got under way in 1962, was the breeding, selection, and distribution of rice varieties that were stiff strawed, short statured, lodging resistant, and fertilizer responsive. The most outstanding early product of that program was the variety IR8, which was widely tested in many countries in 1965 and 1966 and finally named by IRRI in November 1966. Although lacking resistance to attack by several principal insects and diseases and possessing poor grain quality, IR8 nevertheless had an ideal plant type — one which has not been surpassed to this day. Its stiff straw, upright leaves, high grain-straw ratio, and heavy tillering capacity gave it a high yield potential. Under ideal management and if kept free of insects and diseases, IR8 still yields as well as any other tropical variety. Although now long obsolete, IR8's wide distribution from 1965 (when it was known as IR8-288-3) through 1967 was an important event in the history of rice improvement. It opened new vistas for rice yields in the tropics and subtropics and gave fresh hope to rice breeders in many countries where harvests had stagnated at pitifully low levels. Before 1960 most of Asia had rice yields averaging between 1.2 and 2 t/ha, and even under ideal conditions it was almost impossible to obtain more than 4 t/ha. On the other hand, with proper management, especially in the dry season when there was adequate solar radiation, IR8 would often produce between 8 and 10 t/ha. Thus, the yield potential of the rice plant had been doubled.

The creation of IR8 and IR5, IRRI's first-named varieties, was a milestone in the Institute's history, yet the cultivars to emerge from IRRI's breeding program during the next two decades would be far more important. These later varieties possessed earliness, along with high levels of resistance to insects and diseases. In addition, most of them surpassed IR8 and IR5 in eating and cooking quality and in market appearance of milled grain.

IR36, for example, was the most widely planted variety in the tropics in 1982, covering more than 10 million hectares. Its popularity was due largely to its earliness, insect and disease resistance, and high yield capacity. IR60 and IR62 not only are early maturing, they also possess resistance to all known biotypes of the brown planthopper. IR64, released by the Philippine Seedboard in late May 1985, has essentially all the advantages of IR60 and IR62 and, in addition, has excellent cooking and eating quality because its starch has a medium amylose content and an intermediate gelatinization temperature. While it is true that IRRI stopped naming varieties in 1975, those developed at the Institute and approved by the Philippine Seed Board still carry the IRRI designation, and when they are successful in other countries IRRI receives credit for their performance. More important, of course, is the fact that more than 100 varieties that originated from genetic materials distributed by IRRI to other countries have been named and released by national programs. Many of the selections were originally included in IRRI's far-flung international Rice Testing Program (IRTP).

The formation of the Genetic Evaluation and Utilization program (GEU), introduced at IRRI by Nyle Brady in 1973, was a major advance. In it teams of IRRI scientists from various disciplines worked together in developing and testing varieties for wide adaptability. Thus, the soil chemist was involved in selecting varieties with tolerance for adverse soils, the agronomist tested the fertilizer responsiveness of the modern varieties, the chemist was concerned with cooking and eating qualities and nutritional value, the plant pathologist and entomologist were evaluating new selections for disease and insect resistance, and the plant physiologist was part of a team identifying tolerance for such factors as high and low temperatures, deep water, and drought. The GEU program continues today and occupies about 40% of the research effort of the Institute. The only other activity approaching it in size is the Cropping Systems program, which receives 20% of the total emphasis on research. IRRI's current plant breeding undertaking of making about 4,000 crosses annually and evaluating some 12,500 progenies a year is surely the world's largest rice improvement effort and will continue to furnish abundant superior germplasm to rice breeders everywhere.

Obviously, in a 20-minute talk it is impossible to cite IRRI's many achievements nor to commend individually those responsible for such successes. There is no senior scientist who, along with the indispensable research associates, has not made significant contributions to the Institute's outstanding research program. Congratulations and praise are due them all, whether they served at headquarters or in an outreach program.

Since there is not time to describe fully the scope of IRRI's comprehensive, worldwide program, I hope that a rundown of its principal features will suffice on this occasion to indicate its breadth and influence:

1. Since 1963 more than 3,700 young scientists have participated in one or another of IRRI's training courses, about half of them completing the formal, research-oriented type.
2. IRRI's five principal networks have involved about 1,000 cooperating scientists from 118 countries.

3. During the 20-yr period of 1962 to 1982, IRRI sponsored and conducted approximately 15 symposia, 50 workshops, and 40 international conferences.
4. IRRI's Communication and Publications Department has published more than 100 books and prepared more than 60 audiovisual training modules. It distributes about 70,000 publications annually, 80% of them going to Third World countries. Twenty-five editions of *A farmer's primer on growing rice* have been copublished with national programs in 22 languages. The 1983 edition of *Field problems of tropical* rice has been published in 8 languages, and another 21 language editions are in press. These two publications are probably the most widely translated agricultural texts in existence.
5. IRRI's Library and Documentation Center has about 70,600 holdings and issues annual bibliographies for both rice and cropping systems that make available to the world's scientists citations of all important writings on those subjects.
6. IRRI maintains the world's largest germplasm collection, numbering over 78,000 accessions, samples of which are made available on request to rice breeders everywhere.
7. During recent years the agronomists have made significant advances in methods of detecting losses of nitrogen from soils and have developed superior methods of soil management to reduce losses of fertilizer nitrogen from flooded rice soils.
8. IRRI's programs in cropping systems and in studies of constraints to high yields of rice have produced much valuable knowledge but more importantly have developed excellent methodology handbooks that will be equally valuable in future research.
9. To its great credit IRRI has developed an intense program of cooperation with the People's Republic of China, the world's most populous nation and largest producer of rice.
10. That today more than 40% of the rice land of South and Southeast Asia is planted to modern varieties with a high yield potential is a fact IRRI can be justly proud of, for a goodly share of these varieties either were developed by IRRI or originated from genetic materials that it distributed.

Over the years, IRRI has received prestigious recognition for its achievements. Among the most notable are the 1969 Ramon Magsaysay Award for International Understanding, the UNESCO Science Award in 1970 (shared with CIMMYT), the King Baudoin International Research award in 1982, and the $100,000 Third World Prize, awarded in late 1982 and presented to IRRI's director general in Beijing in April 1983. In addition, IRRI's professional staff have been honored individually by international organizations and by their own countries with countless awards, prizes, medals, and honorary degrees. The most recent of these was the $25,000 LDC Innovation

Award to Amir U. Khan for his contributions to the mechanization of agriculture in the less developed countries.

CONTINUING CHALLENGES

Probably IRRI faces no greater challenge than to develop varieties with a higher yield potential for upland conditions and to devise improved methods of management for those varieties. Rice is a naturally semiaquatic plant, and to breed varieties with drought resistance similar to that of many upland crops is a challenge of the highest order. Furthermore, there are serious management problems in upland rice, chief among which are weed control and the prevalence of the rice blast disease.

During IRRI's early days, I recall, I was speaking to a group of visiting scientists from Africa and was asked to name a few of the best upland rice varieties. I replied, "Maize, sorghum, millet, cowpea, and soybean would be my choice." Although this naturally was said in a humorous vein, there was something in it of the old adage, "Many a truth is spoken in jest." I so often had seen upland rice fields suffering serious damage in a wet season in which there happened to be no rain for 10 d. I knew also that even back then, 70% of the rice produced in Southeast Asia came from the 30% of the land that was irrigated. Consequently, it seemed to me more logical to grow drought-tolerant crops, rather than rice, in the uplands.

I am still of the opinion that we should not expect miracles in breeding high-yielding, drought-resistant upland rices. Nevertheless, there remain vast areas of land that cannot be irrigated economically, areas where topography and soil type are unsuitable for growing rice under rainfed, wetland management (that is, bunded paddies that can store water). Estimates indicate that the area of upland rice in the world is about 19 million hectares, with average yields ranging generally between 1 and 1.5 t/ha. A reasonable goal would seem to he to double those figures through a program of plant breeding and the development of improved management techniques.

In addition to the strictly upland areas, about 15 million hectares of shallow lowland, rainfed, bunded rice land are subject either to periods of drought or to occasional intervals of excess flooding or to both. Such environments require varieties that are both tolerant to drought and able to stand submergence for 10-d periods. Ideal varieties for such conditions are yet to be created.

It was gratifying to read in the September 1984 issue of "IITA Research Briefs" that representatives of IRRI, IITA, and WARDA had signed a memorandum of understanding designed to make the International Rice Testing Program (IRTP), coordinated by IRRI, better serve the rice improvement needs of Africa.

We all have our special interests and prejudices. My own conviction is that a more intensive rice improvement and cropping systems research program should be carried out in the humid forest zone of West Africa. I feel it imperative in the long run that systems of permanent agriculture be developed to replace the wasteful method of shifting cultivation (slash and burn). This is no easy task and can challenge the best talent of IRRI, IITA, WARDA, and ICRAF (the International Council for Research in Agroforestry).

In a region of Africa stretching westward from Ivory Coast through Liberia, Sierra Leone, Guinea, and Guinea Bissau, rice is the staple food of the population, with per capita annual consumption between 65 and 120 kg. Yields are deplorably low, having remained at about 1.1 t/ha for the past several decades. Because of high demand and low yields, the 5-country region spends scarce foreign exchange to purchase about 350,000 t of milled rice annually. Yearly rainfall ranges between 1,800 and 2,800 mm during a 5- to 6-mo period.

This seems to be a somewhat neglected region of Africa, perhaps because precipitation is abundant and crops seldom suffer from drought during wet season. There is no scarcity of fuelwood, a problem in more arid regions, and population pressures are not yet severe. Offsetting these advantages, however, the soils — developed from granite — are sandy, easily eroded, with low capacity for holding water and nutrients. Rice diseases are rampant, especially blast, *Helminthosporium,* and glume discoloration. Moreover, the region lacks the wide river valleys and floodplains that are so abundant in Asia. Thus, much of the rice is grown under upland conditions without bunding. The small swamps scattered throughout the region are often so poorly drained that iron toxicity problems limit yields even on lowland rainfed rice.

Although IITA, in its farming systems research program, is doing some valuable research on mulching, minimum tillage, and agroforestry techniques such as alley cropping between rows of leguminous trees, more work is needed in the regions of higher rainfall and more that is geared to the needs of the small farmer.

I believe there is a significant opportunity here for IRRI to make a valuable contribution, through its GEU and cropping systems programs, by working out a cooperative agreement with IITA, WARDA, and ICRAF to launch a long-term research project. The ultimate objective of the effort would be to develop a permanent system of rice-based land management that would relieve the poverty and improve the nutrition of the rural people of the humid forest zone of West Africa who now barely eke out a living from shifting cultivation.

There obviously are numerous other problems that will continue to face IRRI scientists during the years ahead. Among them are those I shall now list:

1. Rice varieties are needed that are photoperiod sensitive and have a satisfactory plant type for rainfed lowland areas that remain flooded late in the growing season.
2. More must be learned about the nature of varietal resistance to many important rice diseases and insects.
3. Donor rice varieties with high resistance to stem borers, leaf rollers, whorl maggot, caseworm, and rice bug are yet to be found.

4. The economic feasibility of hybrid rice in South and Southeast Asia has still to be determined.
5. The level of tolerance of currently available modern rice varieties to drought, alkalinity, salinity, and hot and cold temperatures is too low for them to be grown on many naturally occurring sites.
6. The technology for developing integrated pest management technology across disciplines requires improvement.
7. Strains of azolla that require less phosphorus and are tolerant of temperatures above 30°C are needed.
8. The adoption of IRRI-recommended rice-based cropping systems by farmers in South and Southeast Asia is low, largely because the crops grown after rice are plagued by extremely poor yields, lack of seed sources, and uncertain markets for the produce. Although these constraints may not be the direct responsibility of IRRI, I feel that the Institute should use its influence to help remove them.
9. The potential for increasing the biological fixation of atmospheric nitrogen presents a real challenge for the future.
10. In addition to the rather practical problem-oriented research that is still needed, one can only speculate at this stage as to what IRRI scientists may achieve in the future. As genetic engineering techniques are perfected, the Institute may create revolutionary rice varieties which have yet unheard of resistance to insects and diseases and drought, and which can accommodate nitrogen-fixing organisms in a symbiotic relationship like that of leguminous plants.

In closing, may I express Sunny's and my appreciation for having been invited back to IRRI on this unforgettable occasion. We spent 12 busy, exciting, and rewarding years here. We have watched IRRI grow and prosper and have felt pride and satisfaction in its achievements. Our thoughts and best wishes go with the Institute, and with its staff, as it enters the second quarter-century of its productive life.

REFERENCE CITED

1. Plucknett, DL., and N.J.H. Smith. 1982. Agricultural research and Third World food production. Science 217:215-219.