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INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

AS ADMINISTRATOR AND EXECUTING AGENCY FOR A SPECIAL ACCOUNT FOR REVIEW OF CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH NETWORK

REPORT AND STATEMENT

DECEMBER 31, 1975

Price Waterhouse & Co.

INTERNATIONAL BANK FOR RECONSTRUCTION
AND DEVELOPMENT
AS ADMINISTRATOR AND EXECUTING AGENCY
FOR A SPECIAL ACCOUNT FOR
REVIEW OF CONSULTATIVE GROUP ON
INTERNATIONAL AGRICULTURAL
RESEARCH NETWORK
REPORT AND STATEMENT
DECEMBER 31, 1975

Price Waterhouse & Co.

Price Waterhouse & Co.

1801 K STREET, N. W.
WASHINGTON, D. C. 20006
202-296-0800

April 15, 1976

To International Bank for Reconstruction
and Development

In our opinion, the accompanying statement presents fairly the cash balance at December 31, 1975 and the cash receipts and disbursements for the period November 21, 1975 (first transaction date) to December 31, 1975 of the Special Account for Review of Consultative Group on International Agricultural Research (CGIAR) Network which is administered by the International Bank for Reconstruction and Development in accordance with the provisions of the proposal for formation of the CGIAR Network. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Price Waterhouse & Co.

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
AS ADMINISTRATOR AND EXECUTING AGENCY FOR A SPECIAL ACCOUNT FOR REVIEW OF CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH (CGIAR) NETWORK
STATEMENT OF CASH RECEIPTS, CASH DISBURSEMENTS AND CASH BALANCE
NOVEMBER 21, 1975 (FIRST TRANSACTION DATE) TO DECEMBER 31, 1975

(Expressed in United States dollars)

Receipts (contributions) - see Note	
Federal Republic of Germany	$38,300
United Nations Development Programme	15,000
Total receipts	$53,300
Cash balance, December 31, 1975	$53,300

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

AS ADMINISTRATOR AND EXECUTING AGENCY FOR A SPECIAL ACCOUNT FOR REVIEW OF CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH (CGIAR) NETWORK

NOTE TO FINANCIAL STATEMENT (DECEMBER 31, 1975)

The Review of Consultative Group on International Agricultural Research (CGIAR) Network was established to review the future growth, direction and administration of the network of international agricultural research centers and programs supported by the Consultative Group on International Agricultural Research. In accordance with the terms set forth in the proposal for formation of the CGIAR Network, the International Bank for Reconstruction and Development (the Bank) agreed to serve as Administrator and Executing Agency for a Special Account to finance the work.

As Administrator and Executing Agency for the Special Account, the Bank is responsible for overseeing the collection of contributions from various countries and international organizations and the disbursement of such funds for expenses of the project.

Contributions received by the Bank in currency other than U.S. dollars are converted to U.S. dollars upon receipt and are recorded in the Special Account at the U.S. dollar amounts received.

As of December 31, 1975, no disbursements had been made from the Special Account for the project.

ATTACHMENT 2

REGIONAL DEEP WATER RICE PROJECT

6. DEVELOPMENT PLAN

6.1 Varietal Improvement

6.2 Agronomy Trials

6.3 Germ Plasm Evaluation

6.4 Improvement of Cultural Practices

6.5 Pest Management

6.6 Basic Research

6.7 Training

6.8 Annual Seminar-Workshops

6.9 Visit Among Scientists

7. BUDGET

8. APPENDIX

8.1 Deep Water Areas - Appendix I

8.2 Present Situation in Deep Water Work - Appendix II

PROPOSAL FOR A
REGIONAL DEEP WATER RICE PROJECT

1. INTRODUCTION

1.1 Background

Farmers grow improved rice varieties extensively in the world's "shallow water" regions, where water depths range from 5 to about 50 centimeters. Although the extent of these areas is not known with certainty, they probably represent from 25 to 30 percent of the total rice land.

But the new rice technology has bypassed other areas, including the vast regions where water is not controlled and may become too deep during the monsoon season for the semidwarf varieties. Estimates of such areas range from 25 to 40 percent of the world's rice land. These involve areas where water normally reaches from 200 to 600 centimeters and farmers grow special "floating" rice varieties. Over centuries these varieties, which are broadcast in dry soil and subject to drought at the early stages of growth, are subjected to deep water at later stages of growth. They have developed a mechanism which enable them to grow normally in deep water and to escape flood submergence - their stems elongate as water rise. These floating varieties are harvested when the water has receded. About 10 percent of the rice land in Asia and Africa is planted in floating rices.

The greater area of deep water rice is planted to tall non-floating varieties adapted to medium-deep water (50 to 200 centimeters). Initial work at IRRI and Thailand has shown that the ability to elongate can be incorporated into the semidwarfs so that varieties under normal conditions retain their efficient, short-to-intermediate plant types but can escape submergence, if necessary, by elongating like a floating rice. In these marginal flood areas, such improved varieties could have a tremendous impact in improving grain yields.

IRRI hopes to improve these areas which, mostly because of poor water control, have not yet been touched by the green revolution.

1.2 Deep Water Rice Areas

As a rule, places where the modern semi-dwarf varieties cannot be grown for fear of drowning is classified as deep water.

Several countries have deep water rice areas (see Appendix I) but the large expanses are found in the major river deltas of the Mekong (Vietnam and Cambodia) Chao Phya (Thailand), Irrawaddy (Burma), Brahmaputra (Bangladesh) and Ganges (India).

In Indonesia, about 250,000 ha of tidal swamp land are planted to a single crop of rice and additional areas are being developed. Malaysia has about 3.5 million ha of tidal swamp land; most has not been brought into production because of relatively deep water.

Several African countries also have deep water rice areas, Mali having the biggest hectarage, consisting of about 70 percent of its total rice area.

1.3 The Problem

The deep water regions are among the most heavily populated on earth, increasing rice production in these areas is particularly important. Often, floating rice is the only food crop that farmers can grow in these areas. Their yields have remained stagnant for decades or longer at 1 or 2 tons per hectare.

The biggest obstacle in the improvement of grain yield potential of deep water rice has been the lack of facilities in the deep water areas, lack of trained personnel and lack of coordination among the very few workers.

2. OBJECTIVE OF THE PROJECT

The main objective of the Deep Water Rice Project is to increase and stabilize the grain yields of the deep water rice areas. To do so, plant breeding, agronomic, physiological and pest management work have to be accelerated. The outreach program and the coordination of research efforts plus the training of the personnel have to be undertaken.

3. PLAN OF ACTION

To obtain the objectives of this project, the following activities will be undertaken:

3.1 Varietal Improvement

Improvement in yielding potential, that is, in more tillers, heavier panicles, good plant type, etc. Greater adaptability of the variety will be obtained by increasing its conditional ability for stem elongation, resistance to submergence, resistance to drought at seedling stage, etc.

3.2 Agronomy Trials

With the advent of new plant types in floating rice, these improved lines will have to be field tested. Agronomic characters will be evaluated. Trials on farmers' field will be conducted. In the deep water rice areas, growth duration is very critical so that site testing is needed. Simulation of field conditions are extremely difficult in the case of deep water rice.

3.3 Germ Plasm Evaluation

There will be an accelerated program on the evaluation of the germ plasm collection at IRRI for the superior characters needed in improving floating rice i.e. elongation ability, resistance to submergence and drought, tiller angle and number, rooting ability, photoperiod sensitivity.

3.4 Improvement of Cultural Practices

Land preparation, sowing, fertilizer application and particularly weed control will be given special attention. Hardly any research have been conducted along these lines.

3.5 Pest Management

Diseases and pests of floating rice have not been studied in a systematic manner. A survey of the diseases and pests and of the resistance present in the deep water rice varieties will be helpful in the breeding objectives.

Control and management of the more serious pests, such as ufra, stem borers, etc. will be undertaken.

3.6 Basic Research

Understanding the elongation mechanism, the growth pattern, the limiting factors for growth and yield of floating rices is essential in the process of improving its grain yield and stability. Such physiological work, including the development of better screening techniques will be undertaken.

3.7 Training

Very few of the past IRRI trainees have gone to work in deep water rice. Special training will be needed in breeding techniques and agronomy.

Young scientists from the deep water rice area will be sent to IRRI and/or Thailand for training in various aspects of deep water rice research and production. This training will involve at least 6 months and in some cases it may be a degree course.

Training is needed in order to make expansion of the work possible.

3.8 Annual Seminar-Workshops

Yearly meetings of the deep water rice workers, around 20, are essential in order to insure that everybody is aware of the developments. The meetings will be held, if possible, at the various countries involved.

3.9 Visit Among Scientists

Individual workers should be able to visit the floating rice areas at opportune moments to observe cooperative tests, to improve their insight in the adaptation of their own material elsewhere, and to measure their own progress and problems against those of their colleagues.

4. PRESENT SITUATION IN DEEP WATER RESEARCH

Improvement of the deep water and floating rices in the past was generally limited to identification of the better local strains. Hardly any work was conducted on cultural practices and pest management.

The findings at IRRI and Thailand that semidwarf and intermediate-statured rices can be developed which can adjust their heights to water depth have led to many crosses involving floating and semidwarf rices (see Appendix II). Progenies are being tested, to a limited extent, at experiment stations.

Because the research can best be done in an area where deep water is common, IRRI and the Thai Department of Agriculture have started a cooperative research effort. Center for the program is at the Huntra Deep Water Rice Research Station.

The present project will expand and accelerate the activities on deep water rice of the Asian countries and possibly those of the West African countries.

5. ORGANIZATION

5.1 Responsibilities

IRRI will be responsible for the organization and execution of the project.

IRRI will:

a) Undertake research leading to increase production in deep water rice;

b) Coordinate the research efforts of the different countries;

c) Train personnel for work in deep water rice;

d) Plan the annual seminar-workshops and travel of the rice workers concerned with this project;

e) Be responsible directly to the UNDP for all material and equipment furnished to the project by the UNDP;

f) And consult with the "Deep Water Rice Technical Working Group" on policies and program of work, particularly as to emphasis to be given to research, training and field testing activities during the life of this contract. It is emphasized that this committee shall advise on policy and planning activities as requested by the IRRI. It shall not involve itself in operational or supervisory aspects of the project.

5.2 Set-up

The project leader and project coordinator will be stationed in Thailand where the greater bulk of breeding work and agronomic field experiments will be conducted. The central location of Thailand makes it an ideal starting place for travel and visits.

Several senior IRRI personnel stationed in the Philippines will be involved on a part time basis in research and cooperative work on floating rice. Their salaries will be under IRRI core budget but travels to other countries involving deep water rice will be under this project. Salaries of their additional assistants and laborers who are working full time on deep water rice will also be under this project.

5.3 Personnel

5.3.1 At the Regional Center - Thailand

Iten.	Source of fund	Number needed					Percent of time on the project
		1976	1977	1978	1979	1980	
Project leader/Plant breeder[1]	Core[2]	1	1	1	1	1	30
Plant breeder	Core	1	1	1	1	1	100
Agronomist/Network coordinator	Regional[3]	1	1	1	1	1	100
Entomologist	Regional	1	1	1	1	1	100
Research assistants	Regional	1	2	2	2	2	100
Laborers	Core	6	6	7	8	8	100
	Regional	4	5	7	7	7	100
5.3.2 At IRRI - Philippines							
Plant physiologist	Core	1	1	1	1	1	60
Agronomist	Core	1	1	1	1	1	25
Plant breeder	Core	1	1	1	1	1	30
Senior research assistant	Regional	1	1	1	1	1	100
Research assistant	Core	1	1	1	1	1	100
	Regional	1	1	1	1	1	100
Laborers	Core	3	3	4	4	4	100
	Regional	2	3	4	4	4	100

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[1] Assigned by Rockefeller Foundation
[2] From the Core Budget of IRRI
[3] From the proposed Regional Project

6. DEVELOPMENT PLAN FOR THE FIRST FIVE YEARS - 1976-1980

6.1 Varietal Improvement

This phase has already been started in many countries. Selection of promising lines will be needed for regional field trials. This will be a continuing process.

6.2 Agronomy Trials

Field testing of the improved lines can start in 1976. However, the locations will be limited since trained personnel are insufficient at present.

6.3 Germ Plasm Evaluation

This has been started at IRRI as early as 1973. Majority of the IRRI collection has already been screened. However, field collection of the existing floating varieties is still going on and these varieties will be evaluated.

After two years the amount of work will shift mainly in the evaluation of breeding lines.

6.4 Improvement of Cultural Practices

Preliminary work in Thailand on herbicide and fertilizer application will start in 1975 and field activity in different countries will start in 1976 and 1977.

6.5 Pest Management

The field survey of pests and diseases will start in 1976 and continue for 3 years. Preliminary work on the important pests will start in 1976.

6.6 Basic Research

IRRI and Thailand are conducting and will continue to conduct basic research in order to understand the factors limiting the grain yield of floating rice.

The work will be accelerated in 1977 or 1978 when the station facilities have been developed and trained personnel are available.

6.7 Training

The long term training will start in 1976, involving students for an MS or Ph.D. degree in order to make expansion of work possible.

Specialized training on deep water rice, on a short term basis, can be developed at later date (1977-1978). However, training on a specific aspect of deep water rice i.e. screening technique, will start in 1976 at IRRI and Thailand.

6.8 Annual Seminar-Workshops

Annual meetings to discuss the latest research findings, the recent crosses made, the lines available for testing, the results of agronomic trials, etc. started in 1975 at IRRI.

The next meeting is being planned in late November in Thailand.

6.9 Visit Among Scientists

To a limited extent this has been started at IRRI. However, funds are not available for the country scientists to visit each other. A group of 4 or 5 scientists visiting two or three countries at opportune moments will be started in 1976.

7. ADDITIONAL BUDGET REQUIRED

Budget required for the expanded program on Deep Water and Flood Tolerance Rice Project

	1976	1977	1978	1979	1980	TOTAL
Salaries & Benefits						
Agronomist/Network coordinator	$56,600	$42,800	$47,000	$51,700	$60,950	$259,050
Pest management scientist	56,600	42,800	47,000	51,700	60,950	259,050
Research assistants (5)	6,600(3)	13,300(5)	15,900(5)	19,000(5)	22,800(5)	77,600
Secretaries (2)	3,000	4,000	5,000	6,000	8,000	26,000
Laborers (13)	9,000	14,000(11)	17,000(13)	20,000(13)	24,000(13)	84,000
	$131,800	$116,900	$131,900	$148,400	$176,700	$ 705,700
Equipment	$ 12,700	$ 8,000	$ 1,500	$ 4,000	$ 15,400	$ 41,600
Supplies	$ 10,000	$ 12,000	$ 14,000	$ 15,000	$ 16,000	$ 67,000
Travel						
IRRI Staff	$10,500	$11,400	$ 9,800	$12,600	$14,600	$ 58,900
Cooperating Scientist (5)	7,700	9,300	11,200	13,500	16,200	57,900
Local Travel	1,000	3,000	3,500	4,000	4,500	16,000
	$19,200	$23,700	$24,500	$30,100	$35,300	$ 132,800
Training (2 research scholars and 20 trainees)						
Travel	$ 3,600	$ 8,700	$10,500	$12,600	$ 7,600	$ 43,000
Stipend	20,000	24,000	30,000	36,000	43,000	153,000
	$23,600	$32,700	$40,500	$48,600	$50,600	$ 196,000
Annual Seminar-Workshop (20 scientists)						
Travel	$12,000	$14,400	$17,300	$20,800	$25,000	$ 89,500
Stipend	2,000	2,400	3,000	3,600	4,300	15,300
	$14,000	$16,800	$20,300	$24,400	$29,300	$ 104,800
Central Services	$21,100	$21,000	$23,300	$27,000	$32,300	$ 124,700
TOTAL	$232,400	$231,100	$256,000	$297,500	$355,600	$1,372,600

ATTACHMENT 3

THE GENETIC CONSERVATION PROGRAM OF IRRI

An in-depth report on the
Genetic Conservation Program and the
Genetic Evaluation and Utilization (GEU) Program

and

plans for extending the
conservation operations into
the next decade

THE INTERNATIONAL RICE RESEARCH INSTITUTE
Los Baños, Laguna
Philippines

December, 1974

CONTENTS

***

1. Introduction

While the Institute was being built and staffed, the establishment of a rice germ plasm collection was conceived as one of the unique services that IRRI could perform for the rice-growing countries of the world (Chandler, 1961). With many national and international institutions extending full cooperation, a large varietal collection of 9,000 accessions was assembled within a few years and the Institute soon played a vigorous role in the exchange of rice germ plasm. While the Institute is the principal beneficiary of its seed bank, seeds drawn from its germ plasm bank lend great impetus to varietal improvement programs in many countries. The willingness of nearly every rice research institution of the world to deposit its varietal collection with IRRI reflects not only confidence in IRRI's capacity to preserve gene-pools but also satisfaction with IRRI's services in the distribution and exchange of genetic materials.

Although IRRI has become widely known as a world-wide genetic resources center for the rice crop, its physical facilities and technical personnel do not adequately meet the needs of the vastly expanded activities of the seed bank. It is time to re-examine IRRI's genetic conservation and evaluation programs, with the ultimate aim of further increasing its effectiveness in serving the diverse needs of many production areas. This report will provide the foundation for designing improvements on a decade-long basis.

2. Progress of the Genetic Conservation Program

a. Scope of germ plasm in the IRRI seed bank prior to 1972

Prior to 1972, IRRI acquired seed stocks mostly from national and state research institutions and only occasionally from plant explorers or farmers. By the end of 1971, IRRI had 19,374 cultivars of *O. sativa*, 263 strains of *O. glaberrima*, 316 genetic testers, and 1,037 strains of wild taxa. In its geographic coverage, the IRRI collection of rice cultivars represented fairly adequately the national collections of Japan, Malaysia, Philippines, Taiwan, South Vietnam, and the U.S.A. but was rather deficient in the cultivars of Bangladesh, Burma, mainland China, India, Indonesia, Laos, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam. In terms of varietal diversity, the IRRI collection shared the same weakness of most national collections: it had adequate coverage of the major commercial cultivars and improved varieties but poor coverage of the minor varieties, primitive (unimproved) forms, and special types (Chang, 1972a). It was also deficient in the African rices and the wild taxa.

b. Progress in field collection during 1972-1974

The field collection programs received full cooperation from the national governments concerned and financial support from The Rockefeller Foundation, the Ford Foundation, USAID, and the ODA. Assisted by IRRI's out-reach projects, IRRI and the collaborating national centers acquired 12,837 seed samples from farmers' fields in 12 countries during the period from 1971 to the end of December 1974 (Table A). Moreover, about 1,220 seed stocks were gathered from widely scattered rice experiment stations in Bangladesh, Burma, and Khmer and deposited in the national center. The IRRI staff participated in the field collection programs in the remote areas of Bangladesh, Burma, Indonesia, Khmer, and Sri Lanka. It gave technical assistance to the collection operations in Laos, Malaysia, Nepal, Pakistan, Philippines, South Vietnam, and Thailand. Forty-six samples of wild taxa were also collected (Table B). FAO/UNDP rice experts in Liberia collaborated with IRRI on the collection of the African rices.

During the same period IRRI intensified its efforts in canvassing the existing collections of many strategically located rice experiment stations and succeeded in channelling the remnant collections into the IRRI seed bank. About 4,550 accessions were added to the Institute bank by correspondence.

In the field collection program, emphasis was given to special areas where one or more ecological factors limit rice production. The collection teams obtained more than 3,900 samples known to have resistance or tolerance to salinity problem soils, cool temperatures, drought, deep water, or prolonged submergence (Table B). The true quality of such special types needs to be verified, however.

By the end of 1974 IRRI's germ plasm bank had 35,000 cultivars and a second collection of 3,000 entries, consisting of African rices, genetic testers, and wild taxa.

c. Assistance to other facets of different national conservation programs

The 32-page Manual for Field Collectors of Rice (Chang et al., 1972) was widely used in the national field collection programs. A comprehensive manual on genetic conservation, evaluation, and utilization is being prepared for the use of workers in national programs. A decimal code system for the growth stages of cereals (Zadoks, Chang and Konzak, 1973) has been published and widely reprinted in several field crop newsletters.

National rice catalogs in India and Malaysia adopted the format of the IRRI variety catalog (IRRI, 1970).

IRRI has trained genetic stock officers for Bangladesh, Malaysia, Pakistan, and Thailand and will continue the resident training program at Los Baños.

IRRI assisted Burma and Indonesia in acquiring refrigerated seed storage facilities. Its staff has also advised several national centers on the procedures and physical facilities required for genetic conservation programs.

IRRI's assistance in these areas is designed to improve the capability of the national research centers in continuing their genetic conservation efforts.

3. Progress of the Genetic Evaluation and Utilization (GEU) Program

a. Promising sources of resistance or tolerance identified at IRRI

Systematic screening for resistance to an important pest began with the screening for resistance to the blast pathogen in 1962 at IRRI. This was soon followed by testing for resistance to the stem borers, the bacterial blight, the tungro virus, and the leafhoppers. From the early 1970's, several research departments began the systematic screening for tolerance to the yield-limiting, ecologic, and edaphic factors. The present GEU program includes 32 problem traits under systematic evaluation.

Table C shows the progress in different facets of the GEU program. The magnitude of screening each problem trait, the status of the evaluation program, and the sources of resistance or tolerance that were identified are given in the Appendices.

Table C does not show the magnitude of the screening tests of the breeding lines, however. About 30,000 to 35,000 lines are annually tested under many facets of the GEU program, especially for their reactions to the diseases and insects and for quality evaluation.

The largest numbers of accessions have been screened for reaction to bacterial blight when the cultivars were grown in the seed increase and characterization plots each season. Nearly one-half of the total collection have been screened for protein and lysine contents, resistance to blast, and resistance to the striped stem borer. The tests for virus resistance, drought resistance and tolerance, hopper resistance, and tolerance to adverse problem soils can be greatly expanded when additional space and facilities are made available to IRRI. Reactions to certain diseases and insects, tolerance to adverse edaphic factors, floating ability, and tolerance to cool temperatures — factors not present at Los Baños — can be more effectively evaluated outside IRRI under the network of coordinated international variety testing programs. The newly built phytotron will add new dimensions to IRRI's search for useful genes in coping with climatic factors and their interactions with biotic or edaphic factors.

Many outstanding sources of resistance to a specific disease or insect have been found. Although the resistant varieties often are many, genetic studies indicate that non-allelic genes for resistance are rather few. For instance, only three loci are known for the resistance to the green leafhopper (Nephotettix virescens), two for the brown planthopper (Nilaparvata lugens), and two for bacterial leaf blight. In the case of the grassy stunt virus, a dominant gene for resistance in O. nivara is the only known source among 5,000 cultivars and more than 100 wild taxa included in the testing program. The recessive semidwarfing gene from Dee-geo-woo-gen of Taiwan is the only one being extensively used in rice breeding programs of many nations because more than 10 semidwarf varieties or mutants originating in India, Burma, and China share the same locus. It is therefore urgent that more diverse sources of useful genes be identified and this can be done only by expanding the collection and evaluation operations.

b. Contribution of IRRI's seed bank services and GEU findings to national rice research programs.

Although IRRI is the immediate beneficiary of its seed bank and GEU operations,many national rice research programs have also benefited from IRRI's services and findings. Table D shows the volume of seed packages being requested and sent abroad. From seeds supplied by IRRI, Taichung Native 1 and Tainan 3 spearheaded the acceptance of the new plant type in India. Two U.S. selections were tested and named varieties in the Dominican Republic. Kaohsiung 21 of Taiwan became a recommended variety in southern Brazil. Seeds drawn from the IRRI germ plasm bank have restored thousands of varieties to the national collections of Indonesia, Malaysia, Sri Lanka, South Vietnam, and Tanzania (Chang, 1972b).

The outstanding resistance of blast found in several tropical varieties and the grassy stunt resistance in a wild relative would not be available to rice breeders if these strains had not been preserved by foreign institutions.

To an even greater extent, IRRI-identified sources of disease or insect resistance were extensively utilized in several national breeding programs. The finding of outstanding sources of resistance or tolerance has prompted several national rice research centers to undertake similar evaluation activities. Such efforts, along with IRRI's, are being coordinated and systematized under the network of coordinated trials.

c. Proposed measures to improve the efficiency of GEU operations and to facilitate information retrieval

While IRRI's GEU activities have yielded many useful sources of resistance or tolerance for individual traits, several measures should be adopted to increase the effectiveness of the GEU program. Along with the accumulation of information about the geographic distribution of resistance or tolerance, newly received samples can be sorted out by place of origin and associated ecological conditions. Such information could be channelled into a specific evaluation program. This approach will reduce the number of accessions to be tested in any one program and will also lead to more speedy findings. Such a measure is being implemented for special types which are known to be tolerant to an ecologic factor (stress) or edaphic problem. It should be extended to cover a specific disease or insect whenever applicable.

Every IRRI accession that has been identified as having resistance (or tolerance) to one trait or another should be completely tested and listed for its reaction to other pests and problems so that findings from different testing programs can be collated. Although such an effort has been done for the morpho-agronomic traits, the blast, and bacterial blight reactions, and the stem borer resistance of 8,628 accessions in the first IRRI variety catalog (IRRI, 1970), a computer program should be established to cope with the multiplicity of resistances and tolerances being covered in the GEU program. Such an information recording and retrieval system would also help in reducing the number of accessions to be tested for any particular trait and in disseminating the findings to rice researchers in foreign lands. The tables in the Appendixes are preliminary steps leading to the multiple listing of reactions.

Attention shall be given to developing an efficient way of identifying and eliminating the most likely duplicate samples -- a situation arising from the collection of indigenous germ plasm by many extension workers in adjacent areas within a country or an island. IRRI will explore biochemical techniques that will facilitate the identification of duplicate accessions, possibly in cooperation with a university or universities in the U.K.

We also need to collaborate with other gene banks and data banks in improving the biological and biometrical aspects of genetic conservation. IRRI will seek the assistance of FAO/IBPGR and the cooperation of other international organizations in sharing the work load of seed rejuvenation and storage. The USDA researchers have agreed in principle to rejuvenate and maintain the temperate zone varieties in the U.S. collection. Regional rice research centers, such as IITA, CIAT, and an agency in Japan will be approached to assist IRRI on the seed increase of stocks which are not adapted to Los Baños conditions. In addition to the U.S. National Seed Storage Laboratory at which 18,780 duplicate seed samples have been deposited, other gene banks will be asked to assist in the storage of duplicate seed samples.

IRRI is willing to serve national centers in tropical Asia by storing their duplicate seed samples. Similar services may be extended to other cereals or grain legumes maintained by regional genetic resources centers in Southeast Asia.

4. Anticipated Needs for Additional Germ Plasm

By the end of 1974 various rice production areas in tropical and subtropical Asia will be systematically canvassed, except for the following:

1) Bangladesh - transplanted aman and floating varieties with special features; wild species.

2) Burma - hilly areas of the Chins, the Shans, the Kayahs, the Kashins, and the Mons for hill rices; wild species.

3) China - areas little collected in the past.

4) India - remote areas in the sub-Himalayan region (Kashmir, Jammu, H.P., W.Bengal), central India (Ranchi of Bihar, Rewa of M.P., west Orissa, north and west Andhra), Dangs and Konkan, for minor varieties tolerant to adverse ecologic or edaphic factors; wild species.

5) Indonesia - upland varieties of west Java, central Java, east Java; upland types on Kalimantan, Sulawesi, Nuga Tenggara (islands east of Bali) and West Irian; tungro-resistant lowland varieties; wild species.

6) Khmer - areas controlled by the Khmer Rouge; floating varieties planted along the shores of the Tonle Sap lake; wild species.

7) Laos - hilly areas controlled by the Pathet Lao for hill rices; wild species.

8) Nepal, Sikkim and Bhutan - high-elevation areas or special types.

9) Pakistan - Swat Valley for cold-tolerant types; Sind district for salinity--and alkalinity-tolerant types, or heat-tolerant types.

10) Thailand - hilly areas in the north and northeast for hill rices; floating varieties with special features; Khorat area for saline- and alkaline-resistant types; wild species.

11) Malaysia - mainly in the hills of Sarawak for hill rices; northern part of West Malaysia for tungro-resistant varieties.

12) North Vietnam - areas not covered in the past.

13) South Vietnam - remote areas for varieties tolerant to acid-sulfate soil, salinity, or deep water; wild species.

14) Sri Lanka - Yala season varieties; cultivars that are tolerant to iron toxicity, drought, or salinity.

15) West Africa - _O. glaberrima_ races; _O. sativa_ cultivars of special ecological merit or tolerant to iron toxicity and phosphorus deficiency.

Aside from the above geographic areas, much remains to be sought from special ecologic niches in various areas for the following traits or types:

1) Tolerance to salinity;

2) Tolerance to extremely acid soils, either under flooded or mesic conditions;

3) Tolerance to soil alkalinity;

4) Tolerance to submergence;

5) Floating ability;

6) Tolerance to cool temperatures;

7) Drought resistance and tolerance;

8) Resistance to the leafhoppers and planthoppers;

9) Resistance to the virus diseases especially grassy stunt and yellow dwarf;

10) Resistance to presently minor fungus diseases, such as the brown leaf spots, stem and sheath rots, and false and kernel smuts which may gain importance in the future;

11) Resistance to presently minor insect pests, namely, several species of leafhoppers and planthoppers, rice hispa, thrips and root aphid;

12) Tolerance to iron deficiency or zinc deficiency;

13) Tolerance to pollutants;

14) Wild relatives of O. sativa and O. glaberrima.

While geographic regions and areas with specific ecologic restraints such as soil salinity and cool temperatures are largely known and can be canvassed comprehensively, sources of resistance to most of the minor pests or to some of the insect pests are not necessarily present in areas where the disease or insect is endemic. Thus both endemic and non-endemic areas shall be covered in future collections.

IRRI and the countries concerned will re-collect special types in certain area where preliminary evaluation has yielded promising sources of desired traits. Potentially promising areas are Bangladesh, Burma, India, Indonesia, Malaysia, and Vietnam.

The above plan for future collection is aimed at broadening the geographic coverage of conserved materials as well as at expanding the genetic base of the varietal collection. A wider genetic base is essential in coping with genetic changes within a pest or with shifts in the prevalence among different pests.

Moreover, the completion of the IRRI phytotron allows refined studies on cold tolerance, heat tolerance, thermoperiodicity, and interaction among physical environmental factors related to water economy.

For countries with ample technical manpower such as China and India, field collection can be executed by national research centers with IRRI collaborating at the planning phase. For most of the other countries, IRRI's direct participation will be a continuing necessity to sustain the impetus generated.

A tentative plan for IRRI's further efforts in field collection is summarized in Table E. Both the geographic areas and projected targets are expected to increase as IRRI researchers continue to identify promising materials from the collected samples.

We expect the size of IRRI's germ plasm bank to grow to a total between 60,000 and 80,000 accessions within the next decade.

5. Projected Needs for Seed Processing and Storage Facilities and for Technical Personnel

IRRI's field collection activities have outgrown its existing facilities and manpower for genetic conservation. During 1973-74 it did not have sufficient field space to plant all the collected samples. Thousands of collected samples are being temporarily stored. The medium-term cold storage room (36 sq m) -- good for 15 to 20 years of seed longevity -- is completely filled with seed samples of 22,000 accessions (250 g./accession) and 77 large cans of 4,000 breeding lines each. The short-term seed laboratory (216 sq m) -- good for 3 to 5 years of seed longevity -- is becoming so crowded that the storage of bulk samples has been shortened from 3 years to 2 years. Moreover, seeds of about 6,780 accessions in the medium-term storage room are more than 10 years old -- estimated to be 5 years away from the point of rapid deterioration in seed viability (Roberts, 1960). Seed viability is definitely deteriorating among the temperate-zone varieties (Table F). Seed rejuvenation needs to be carried out within the next few years. Fresh seed should be sealed in metal cans under vacuum and stored under sub-zero temperature (-5°C, 30-40% RH), as suggested by the FAO (1974) for base collections. Such storage conditions could preserve seed viability up to 300 years (Ito and Kumagai, 1969). Meanwhile, the 250-g seeds stocks in the medium-term storage unit will continue to serve the needs of rice researchers until the stock runs out.

The present staff of one research assistant, one research aide, two laboratory helpers, one field assistant, and three laborers (including one emergency laborer) is not large enough to cope with the overall needs of the seed bank. Additional personnel is also needed to fulfill the expanded seed requirements of the GEU program. The records system for the seed bank needs to be improved and updated. A second volume of the IRRI variety catalog of morpho-agronomic characteristics needs to be assembled and published. A recording and information retrieval system for the GEU program should be set up and integrated with the morpho-agronomic data taken on the accessions.

To meet the impending needs, the following expansions in physical facility and technical personnel are envisaged. The seed processing and storage facilities shall also include the immediate requirements of the expanded plant breeding program.

(1) A seed processing and storage building at a new site -- conveniently located with assurance of security; away from potential fire hazards; allowing an efficient flow of seeds for processing, evaluation, storage and distribution; but serviceable by the emergency generators -- be built to house the 13 essential components.

A. Seed storage rooms (continuously refrigerated)

   1. Short-term seed storage -- 440 sq m; 4-m high ceiling; 21-22°C, 40-60% RH; includes area for seed drier and seed canning machinery (about 20 sq m); one exhaust fan.

   2. Medium-term seed storage -- 120 sq m; 3-m high ceiling; 2-3°C; 25-40% RH; insulated door; temperature and humidity recording devices.

   3. Long-term seed storage -- 40 sq m; 3-m high ceiling; -5°C; 30-40% RH; insulated door; dehumidified air circulation; temperature and humidity recording devices.

   4. Buffer area (in front of the doors to 2. and 3.) -- at least 2-m clearance to the doors of 2. and 3.; wide sliding door to permit a lab cart to pass through; can be served by the dehumidifying unit when the door of 2. or 3. is open.

B. Seed processing area (air-conditioning during working hours) -- 3-m.high ceiling; 240 sq m area; with one air-exhaust.

C. Quality evaluation labs (air-conditioning during working hours).

   1. Milling lab -- 3-m high ceiling; 80 sq m area; with one air-exhaust.

   2. Quality lab -- 3-m high ceiling; 80 sq m area; one air-exhaust; accessible to water heater.

D. Office-lab (air-conditioning during working hours) -- 3-m high ceiling; 120 sq m area; includes data-storing space.

E. Service areas (air-conditioning during working hours)

   1. Storeroom for supplies -- about 30 sq m

   2. Men's toilet and lockers -- about 24 sq m

   3. Women's toilet and lockers-- about 16 sq m

F. Room for the refrigerating units, dehumidifying device, and water heater -- about 80 sq m

G. Storage area for glass jars and tin cans in the attic, includes staircase.

Figure A shows the existing Plant Breeding facilities in the Service Building. The proposed seed lab is sketched in Fig. B.

Fig. A. Existing Seed Lab, Seed Storage Area, Milling Lab and Quality Lab of Plant Breeding Department, IRRI.

PB-1	112 m^2	Work area
1-a	36 m^2	Office of res. assistants
1-b	32 m^2	Storage of tools & supplies
PB-2	66 m^2	Quality Lab
2-a	72 m^2	Milling Lab
PB-3	216 m^2	Short-term seed storage
PB-4	72 m^2	Seed Processing
4-a	36 m^2	Medium-term seed storage

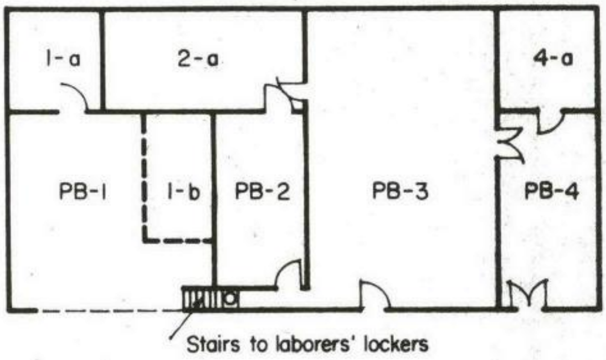
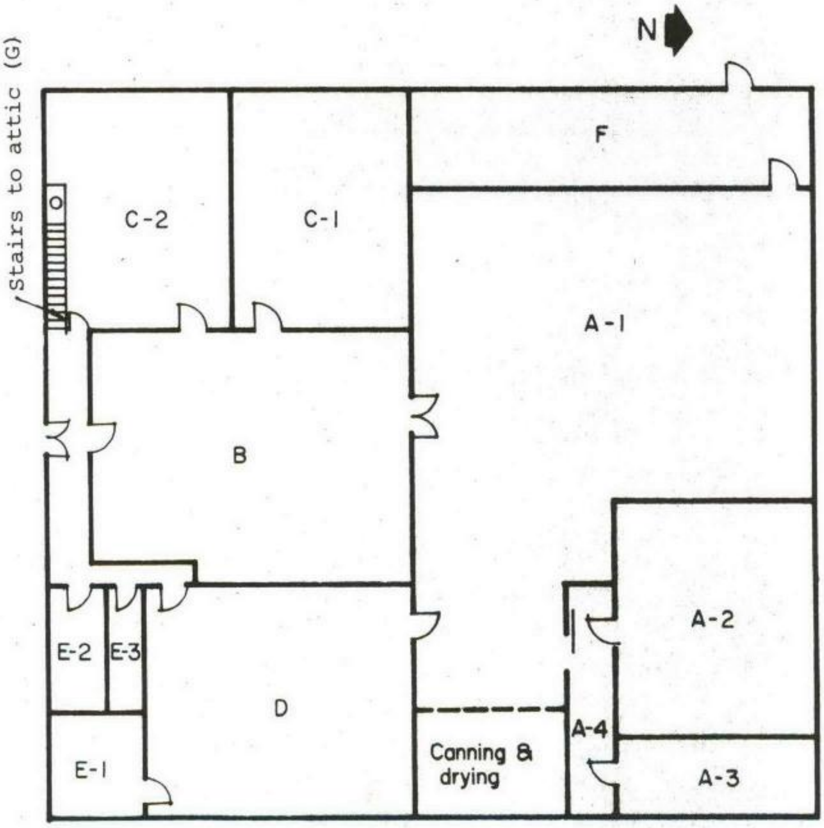


Fig. B. Proposed GEU Seed Lab

A-1	440 m^2	Short-term seed storage
A-2	120 m^2	Medium-term seed storage
A-3	40 m^2	Long-term seed storage
A-4	c20 m^2	Buffer area
B	240 m^2	Seed processing
C-1	80 m^2	Milling Lab
C-2	80 m^2	Quality Lab
D	120 m^2	Office-Lab
E-1	c30 m^2	Storeroom
E-2	c24 m^2	Men's toilet & lockers
E-3	c16 m^2	Women's toilet & lockers
F	c80 m^2	Refrigerating & dehumifying machineries
G		Storage area in attic

Total floor space: c1070 m^2



(Sketches not drawn to scale)

(2) The personnel requirements are enumerated as follows:

Position (rank)	Responsibility	Number	Old or new position
Geneticist	Overall planning and supervision	1	Old
Senior Assistant Scientist	Coordination and supervision of routine operations, also serving as field advisor on field collection to agencies outside the Philippines	1	To partly replace the temporary Field Advisor (1972-74)
Assistant Scientist or Senior Research Assistant	(1) To take morpho-agronomic notes in field and to increase seed stocks of cultivars	2	1 old
	(2) To supervise the flow of seeds into seed bank and into GEU operations		1 new
Research Assistant or Research Aide	(1) To record and multiply (if necessary) incoming seed samples from abroad and to look after African rices, mutants, and wild species	2	1 old
	(2) To implement seed increases for GEU use and to rejuvenate old seedstocks		1 new
Clerk	Record keeping	1	new
Laboratory Assistants	Lab measurements, transfer of records, preparation of seed samples for storage or distribution	3	2 old, 1 new
Field Assistant	To supervise laborers	1	old
Laborers	(a) Field operations - 6 (b) Lab operations - 1	7	3 old, 4 new

(3) Special project on the conservation of the African cultivated rices (O. glaberrima) and its weed relative (O. barthii) — These races are also facing the threat of extinction. IRRI has encouraged rice researchers in West Africa to conserve the African rices. About 940 strains are being maintained at Los Baños, of which 324 samples were recently collected in Liberia. While IRRI is perfectly willing to assume the major responsibility of conserving the African segment of rice germ plasm, inputs from IITA and WARDA are needed. Because the African rices are highly susceptible to the insects and diseases prevalent at Los Baños, it appears necessary to increase seeds at an appropriate location in West Africa which is free from such pest ravages. Perhaps the International Board for Plant Genetic Resources (IBPGR) of the Consultative Group could assist IRRI in obtaining such collaboration from an institution in Africa.

6. Budgetary requirements (to be added following consultation with architects and engineers)

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December 1974

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Table A. Progress in field collection in twelve collaborating Asian countries with IRRI's direct or indirect participation, September 1971 to December 1974.

Year	Country	Samples collected Directly	 Indirectly
1971	Nepal		907
1972	Sri Lanka	412	
	Indonesia	1363	1130
	Pakistan		567
	Philippines		128
	Vietnam, S.		226
	Laos		351
1973	Khmer	280	
	Bangladesh	122	1813
	Burma	115	
	Indonesia	1526	517
	Malaysia, E.		87
	Philippines		127
	Vietnam, S.		104
	Laos		4
	Pakistan		182
	Thailand		127
1974	Bangladesh	234	548
	Burma	110	
	Indonesia	927	583
	Malaysia, E.		288
	Philippines		59
	Total	5089	7748

Table B. Special types of rice varieties and wild taxa acquired from July 1972 to December 1974.

Reported feature	Samples (No.)
Tolerance to salinity	124
Tolerance to acid soils (flooded)	150
Tolerance to alkaline soils	11
Upland types	2425
Floating types	518
High-elevation types	600
Resistance to nematodes	5
Escape from rodent damage	9
Aromatic types	89
(Total for special types)	(3931)
Wild taxa	46

Table C. Progress of systematic evaluation operations in IRRI's GEU program, 1962-74.

Problem trait and index no. in Appendix	Accessions screened to date	Projected number of accessions to be screened					Special types collected	Promising sources identified		
		1974	1975	1976	1977	1978		Accessions (no.)	Countries of origin	Non-allelic sources
/Deep water/										
1) Floating ability	248 cv.	120	400	400	400	400	404	41	Thailand, India, Italy, Bangladesh, China, Vietnam, Portugal	--
2) Submergence tolerance	1,126 cv.	1200	2000	2000	2000	2000	41	26	Sri Lanka, Thailand, Indonesia, Surinam	-
/Diseases/										
3) Bacterial blight	22,100 cv.	3500	3000	3000+	3000+	3000+	-	259	India, Indonesia, Japan, U.S.A.	2+
4) Bacterial leaf streak	2,200 cv.	3000	3000	3000	3000	3000	-	c. 1000 need confirmation	Bangladesh, India, China, Japan, U.S.A.	-
5) Blast	10,251 cv.	3000	6000	6000	3000+	3000+	-	115	Widely distributed	Probably many
6) Sheath blight	433 cv.	2000	4000	4000	4000	4000	-	None with high level of resistance	-	
7) Tungro	3,559 cv.	(16,000 total annual capacity in greenhouse; volume can be increased by field tests)					-	9 HR 21 R-MR	India, Bangladesh, China, Indonesia, Thailand	

Table C../2

Problem trait and index no. in Appendix	Accessions screened to date	Projected number of accessions to be screened					Special types collected	Promising sources identified		
		1974	1975	1976	1977	1978		Accessions (no.)	Countries of origin	Non-allelic sources
8) Grassy stunt	5,000 cv. 100 wild	(5,000 total annual capacity in greenhouse; volume can be increased by field tests)						0 1	*O. nivara* of India	-
/Insect pests/										
9a) Green leafhopper (*N. nigropictus*)	232 cv.	1000	2000	2000	2000	2000	-	4	India, Bangladesh	-
9b) Green leafhopper (*N. virescens*)	5,810 cv.	3000	3000	3000	3000	3000	-	123	India, Bangladesh, Ghana, Indonesia, Sri Lanka, Malaysia, Sierra Leone, Laos	3
9c) Brown planthopper (*N. lugens*)	9,311 cv.	4000	4000	4000	4000	4000	-	103	India, Sri Lanka, Burma, China, Indonesia, Vietnam	2
9d) White-back planthopper (*S. furcifera*)	2,684 cv.	3000	3000	3000	3000	3000	-	45	India, Indonesia, Vietnam, China, Sudan, Malaysia, Pakistan	-
9e) Zigzag leafhopper (*R. dorsalis*)	1,500 cv.	1000	2000	2000	2000	2000	-	5	India, Pakistan, Sri Lanka	-

Table C../3

Problem trait and index no. in Appendix	Accessions screened to date	Projected number of accessions to be screened					Special types collected	Promising sources identified		
		1974	1975	1976	1977	1978		Accessions (no.)	Countries of origin	Non-allelic sources
10a) Striped borer (*C. suppressalis*)	10,375	600	1000	1000	1000	1000	- -	26 26	China, U.S.A., Burma, India, Philippines	- -
10b) Yellow borer (*T. incertulas*)	741 cv.	950	1000	1000	1000	1000	-	12	Indonesia, Africa, India, Thailand, China	-
11) Whorl maggot (*H. philippina*)	5,000 cv.	2000	4000	4000	4000	4000		131	India, China, Japan, Laos, Sri Lanka, Egypt, Italy, Brazil, Hungary, Philippines, Spain	
12) Leaf folder (*C. medinalis*)	687 cv.	(No firm schedule)						6	India, Laos, E. Africa, Bangladesh	
/Nitrogen utilization/										
13a) Atmospheric N	102 cv.	102	400	800	800	800				
13b) Soil N	99 cv.	99	400	800	800	800				
/Nutritive quality/										
14) Protein	12,500 cv. 17 wild	0	(No firm schedule)				None			

Table C../4

Problem trait and index no. in Appendix	Accessions screened to date	Projected number of accessions to be screened					Special types collected	Promising sources identified		
		1974	1975	1976	1977	1978		Accessions (no.)	Countries of origin	Non-allelic sources
14) Lysine	12,500 cv. 17 wild	0	0	0	0	0	None			
[Drought]										
15a) Field resistance	2,118 cv.	2655	3000	5000	5000	5000	2401	114	Laos, W. Africa, Bangladesh, Philippines, Malaysia, Thailand, Colombia, Vietnam	
	112 *O. glab.* strains	112	200	300	300	500	939	none		
15b) Drought resistance	20 cv.	200	200	400	600	800		7	Africa, Philippines, Bangladesh	
15b) Root system in upland soil	78 cv.	120	200	400	600	800		7	Africa, Philippines, Bangladesh	
15c) Drought tolerance GH	102 cv.	226	1500	1500	1500	1500		3 cv. 12 lines	Africa, Philippines	
Field	20 cv.	1500	1500	1500	1500	1500				
[Cold tolerance]										
16) Cool air	1,000 cv.	500	(No firm schedule)				572	10+	Widely distributed	
16) Cold water	1,000 cv.	500	(No firm schedule)					6+	Widely distributed	
[Pesticide tolerance]										
Pesticide tolerance	52 cv.	52	(No firm schedule)							

Table C../5

Problem trait and index no. in Appendix	Accessions screened to date	Projected number of accessions to be screened					Special types collected	Promising sources identified		
		1974	1975	1976	1977	1978		Accessions (no.)	Countries of origin	Non-allelic sources
/Problem soils7										
17) Alkali resistance	61 cv.	150	2000	(No firm schedule)			11	1	India	
17) Aluminum and manganese toxicity	32 cv.	50	50	("	"	")		1	Philippines	
17) Iron deficiency	61 cv.	50	50	("	"	")	4	1	Philippines	
17) Iron toxicity	100 cv.	200	1000	("	"	")	148	1	India	
17) Phosphorus deficiency	65 cv.	250	100	("	"	")	3	1	Sri Lanka	
17) Salt resistance	65 cv.	50	2000	("	"	")	121	1	India	
17) Zinc deficiency	18 cv.	50	1000	("	"	")	1	2	India, Sri Lanka	

Table D. Number of seed packages sent to foreign requesting agencies and researchers from the IRRI seed bank, 1962-1974.

Year	Cultivars		Genetic testers and wild taxa	
	Packages	Requests	Packages	Requests
1962-63	400	17	111	10
1964	2,355	67	228	16
1965	1,608	56	122	6
1966	1,052	41	461	12
1967	1,764	121	789	7
1968	5,286	147	241	18
1969	5,800	101	287	19
1970	5,660	106	91	8
1971	2,300	132	325	10
1972	2,501	83	610	15
1973	9,777	96	422	22
1974	2,602	141	167	11
Total	41,105	1,108	3,854	154

Table E. Schedule of IRRI's direct role in field collection activities during the next decade (excluding indirect participation in collecting programs of China, India, Pakistan and North Vietnam).

Year and Period		Country and area	Types to be collected	Estimated collection size [a]
1975	1st half	South Vietnam	Floating rices, double-transplanted[b]; acid sulfate tolerant types; saline tolerant types; wild species	300 - 500
	2nd half	West Africa	Discussion with national centers concerned	-
		Bangladesh[b]	Floating rices (broadcast aman); transplanted aman; wild species	800 - 1000
1976	1st half	Bangladesh[b]	Aman types	
		Indonesia (Java)	Upland rices of the bulu and cere types	250 - 400
	2nd half	Laos	Hill rices; wild species	500 - 800
		Burma	Hill rices; delta varieties[c]; cool tolerant types quality rices; wild species	400 - 500
1977	1st half	Indonesia (Kalimantan)[d]	Tidal swamps; upland (ladang and gogo types); wild species	250 - 300
	2nd half	Thailand	Floating rices; hill rices; wild species	150 - 200
1978	1st half	Indonesia (Sumatra)[e]	Upland; high elevation; tidal swamp (Jambi) varieties	200 - 400
	2nd half	Khmer[b]	Floating rices; long-duration types with pest resistance; wild species	100 - 150
1979	1st half	Indonesia (small islands)[f]	Upland and lowland varieties (bulu and cere); wild species	200 - 300
	2nd half	Malaysia (Sarawak)	Hill rices; acid-sulfate tolerant types	150 - 300
1980 thru 1984		Re-collect special types in South and Southeast Asia; direct participation in field collection in West Africa		15,000

a Wild species numbering 3,000 not included in the estimated size
b Extending into the early part of the next year
c 50 to 100 cm standing water throughout the growing season
d East, west and central parts
e Aceh, Jambi, Bengkulu provinces
f Nusa Tenggara, Maluku, West Irian

Table F. Changes in the germination percentage of three control varieties stored in the medium-term storage room over an 11-year period.

Variety	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Peta	56	89	96	96	97	93	90	90	95	97	96	97
Siam 29	80	95	97	97	97	97	95	96	97	96	97	98
Chianan 8	74	72	76	80	77	74	74	84	77	63	63	54

Note: (1) Initial seed moisture content before storage was 12 percent; moisture content was reduced and stabilized at 9 percent during storage.

(2) Seed viability is tested twice a year; germination percentages given represent first-of-the-year test.

APPENDIXES

Progress of IRRI's GEU Program in Screening Rice Cultivars and Wild Taxa

The following appendixes summarize the information on magnitude of the problem trait being screened, the status of the testing programs, and promising sources of resistance or tolerance. Traits such as protein content and quality, the outstanding sources of which have yet to be identified, are described briefly.

The appendixes and tables are categorized as follows:

1) Floating ability
2) Tolerance to submergence
3) Bacterial blight
4) Bacterial leaf streak
5) Blast
6) Sheath blight
7) Tungro virus
8) Grassy stunt virus
9) Leafhoppers and planthoppers
10) Stem borers
11) Whorl maggot
12) Leaf folder
13) Nitrogen utilization
14) Nutritive quality
15) Drought resistance and tolerance
16) Tolerance to cold water and cool air
17) Problem soils

1. Floating ability via internode elongation

Deep-water rice is grown in water from 150 to 500 cm deep. Around 10,000,000 hectares or 10 percent of the rice growing area in South and Southeast Asia is planted to floating rice varieties. In Bangladesh, Thailand, India, Burma, Cambodia, Vietnam and certain parts of Africa, floating rice is the only crop that can be planted in the deep water areas so that if the crop fails, the whole planting season fails.

Grain yields in these areas are low and the prospect of improving the grain yields in the near future is not too bright since very little work is being conducted for the improvement of this particular rice culture. The high-yielding rice varieties are not adapted to these areas since the HYVs are unable to elongate and survive the deep water conditions.

The direction for the improvement of grain yield in deep-water areas has not been well defined, as it has been for lowland rice culture. However, the grain yield of floating rices can be stabilized if certain characteristics, such as resistance to drought in the juvenile stage and a greater ability for internode elongation are incorporated into its germ plasm. In areas where the water level rises rapidly, many plants die because they are unable to keep up with the rise in water level. A greater ability to elongate is therefore needed.

IRRI is screening the germ plasm collection to identify varieties with greater ability to elongate. About 100 varieties collected from deep water areas were initially screened. Table 1 lists those varieties showing good elongation ability.

Screening of varieties from other non-floating areas might also identify those varieties which can elongate and in addition have other useful characteristics. Three European varieties included in the screening program showed good internode elongation when submerged in water (Table 1). These three varieties are not planted as floating varieties; they have a more erect tillering angle and greater number of tillers than the typical floating variety. These plant characters may be useful in improving the grain yields of floating rice, i.e., in increasing the tiller number per unit area.

The three European varieties indicate the importance of screening varieties from areas where the water is not deep. If several non-allelic genes are involved in the ability to elongate, it is important to screen and identify diverse sources which have different plant characteristics and have the ability to elongate.

There are about 1,000 floating rice varieties. IRRI has more than 400 floating varieties. Further collections are needed, especially from African countries and the tidal swamp areas.

Table 1. Varieties with rapid rate of internode elongation when submerged in deep water.

Variety	Acc. No.	Origin
Baishbish	5811	Bangladesh
Banor Jhota	26297	Bangladesh
Bhawalia Digha	1246	Bangladesh
Bhoro Digha	1269	Bangladesh
Bhoro Nepa	1160	Bangladesh
Boon Nahk	24220	Thailand
Cheng Chang	1630	China
Choto Digha	1159	Bangladesh
Digha	1033	Bangladesh
DM 53	8735	Pakistan
Dol Kochu	1196	Bangladesh
DW 6255	24132	India
Goda Laki (HBJ Aman II)	5912	Bangladesh
Gourkajol	1277	Bangladesh
Habiganj Deep Water 1	11749	Bangladesh
Habiganj Deep Water 2	11750	Bangladesh
Habiganj Deep Water 8	11751	Bangladesh
Hawn Chahng	24222	Thailand
Hijli Digha	1263	Bangladesh
Jabra	1254	Bangladesh
Jhota	1175	Bangladesh
Kala Digha	1272	Bangladesh
Katia Bagder 13/20	6498	Bangladesh
Kekowa Bao	21324	India
Khao Hawn	24225	Thailand
Leb Mue Nahng	7819	Thailand
Mal Bhog	1034	Bangladesh
Maliabhangar	5810	Bangladesh
Manik Digha	1268	Bangladesh
Nak Neva	24227	Thailand
Nam Sagui 19	11462	Thailand
Nang Dum To*	231	Vietnam
Ponta Rubra**	3187	Portugal
Rajamoral	1279	Bangladesh
Rosa Marchetti**	17017	Italy
Royna	1152	Bangladesh
Saibur	24229	Thailand
Srau Kraham	23258	Khmer
Suna Digha	1169	Bangladesh
TD 72	8297	Thailand
Vialone**	3134	Italy

* Also resistant to submergence or flooding.

** Japonica type with ability to elongate.

2. Tolerance to submergence

The area that is flooded or submerged varies from year to year and is therefore difficult to estimate. However, more than 35,000,000 hectares of rice are annually flooded -- these are the deep-water areas, the tidal land along sea coasts and tidal swamps.

The grain yields lost annually as a result of flooding could be minimized by increasing the resistance of rice plants to submergence.

IRRI has screened more than 600 varieties. Table 2 shows the most resistant varieties identified so far. Most of the resistant varieties came from areas in Sri Lanka where rice is annually submerged for short periods of time.

Two types of tolerance are needed for rice. The first is tolerance to submergence in flood water from one day to a few weeks. The second is tolerance to submergence in flood waters remaining in the field for 2 to 5 months. The first type of tolerance enables the varieties to withstand submergence without elongating so that the plants do not lodge when the water recedes. The second type prompts the varieties to elongate enabling them to grow above the water level.

Screening for resistance to submergence is relatively rapid even without limited facilities. The germ plasm collection will eventually be screened systematically.

Table 2. Varieties tolerant to submergence.

Variety	Acc. No.	Origin
Buruma Thavalu	15335	Sri Lanka
Goda Heenati	15419	Sri Lanka
Jamis Wee	15294	Sri Lanka
Kaharamana	15479	Sri Lanka
Kalu Gires	15330	Sri Lanka
Kalu Kanda	15430	Sri Lanka
Kaluwee	15425	Sri Lanka
Kanni Murunga	15432	Sri Lanka
Kottamalli	15435	Sri Lanka
Kurkaruppan	15449	Sri Lanka
Lumbini	15319	Sri Lanka
Madabaru	15333	Sri Lanka
Madael	15426	Sri Lanka
Nang Dum To	231	Vietnam
Nam Sagui 19	11462	Thailand
Padi Ewang Janggut	24758	Indonesia
Periya Karuppan	15460	Sri Lanka
Pokuru Samba	15337	Sri Lanka
Ratawee	15185	Sri Lanka
SML Temerin	10870	Surinam
Sudu Gires	15331	Sri Lanka
T442-57	13016	Thailand
Thavalu	15314	Sri Lanka
Thavalu	15325	Sri Lanka
Venan Vellai	15464	Sri Lanka
Weli Handiran	15433	Sri Lanka

3. Bacterial blight

In Asia, during the monsoon season, on up to 15 million hectares where intensive cultivation practices are followed bacterial blight is a major disease. Losses in grain yield frequently range from 5 to 10 percent but occasionally reach 50 percent.

Out of approximately 22,000 cultivars screened for bacterial blight resistance, 259 have shown moderate to strong resistance. Genetic studies on approximately 25 cultivars have so far identified two distinct sources: a single dominant gene and a single recessive gene. Several other cultivars have intermediate field resistance.

Field collections for cultivars resistant to bacterial blight should continue in northeast India, Bangladesh and Burma. Cultivars from the People's Republic of China could add new resistant sources.

4. Bacterial leaf streak

Bacterial leaf streak is found only in tropical Asia, primarily in the monsoon season following strong winds. Yield losses are generally much less than for bacterial blight.

Many cultivars have shown resistance to bacterial leaf streak but no genetic studies have been conducted to determine the mode of inheritance or the non-allelic sources. A high proportion of the cultivars so far identified have originated in Bangladesh, northeast India, China, Japan, and U.S.A. Several strains of *O. rufipogon*, *O. sativa* f. *spontanea*, and *O. glaberrima* were also resistant.

No special area of collection is recommended.

Table 3a. Promising sources for resistance to bacterial blight.
- Screened at least 3 times against Philippine isolates.
- December 1974.

Variety	Acc. No.	Origin	Variety	Acc. No.	Origin
ADT 25	5151	India	ARC 7406	20617	India
Andel	17153	Indonesia	ARC 7416	20625	India
ARC 5756	20220	India	ARC 7423	20627	India
ARC 5758	12122	India	ARC 10025	20653	India
ARC 5793	12133	India	ARC 10027	20655	India
ARC 5955	20288	India	ARC 10068	20685	India
ARC 6003	12174	India	ARC 10070	21184	India
ARC 6018	12180	India	ARC 10313	20845	India
ARC 6068	20325	India	ARC 10372	20884	India
ARC 6079	20335	India	ARC 10376	20887	India
ARC 6125	20349	India	ARC 10520	20967	India
ARC 6230	12259	India	ARC 10674	12567	India
ARC 6231	12260	India	ARC 10945	12678	India
ARC 6565	20400	India	ARC 10952	12682	India
ARC 6608	12293	India	ARC 10957	21157	India
ARC 7001	20436	India	ARC 10959	12686	India
ARC 7013	20437	India	ARC 10968	12690	India
ARC 7043	20458	India	ARC 11069	21183	India
ARC 7045	20460	India	ARC 11070	21184	India
ARC 7046	20461	India	ARC 11071	21185	India
ARC 7055	20468	India	ARC 11072	21186	India
ARC 7060	20471	India	ARC 11075	21188	India
ARC 7090	20490	India	ARC 11083	21199	India
ARC 7098	20498	India	ARC 11092	21192	India
ARC 7102	20501	India	ARC 11104	21196	India
ARC 7128	20524	India	ARC 11109	21199	India
ARC 7132	19679	India	ARC 11118	21205	India
ARC 7207	20545	India	ARC 11121	21207	India
ARC 7260	12346	India	ARC 11124	21209	India
ARC 7286	20580	India	ARC 11204	21223	India
ARC 7291	12356	India	ARC 11219	21236	India
ARC 7303	12359	India	ARC 11226	21241	India
ARC 7320	20599	India	ARC 11252	21256	India
ARC 7323	20602	India	ARC 11255	21259	India
ARC 7323	20602	India	ARC 11287	21289	India
ARC 7327	12368	India	ARC 11295	21297	India
ARC 7328	12369	India	ARC 11311	21308	India
ARC 7334	20605	India	ARC 11322	21315	India
ARC 7336	20606	India	ARC 11328	21320	India
ARC 7347	12376	India	ARC 11332	21324	India

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Variety	Acc. No.	Origin	Variety	Acc. No.	Origin
ARC 11351	21340	India	DL-5	8593	Bangladesh
ARC 11558	21476	India	DNJ 142	8426	"
ARC 12162	21952	India	Dudhi	16256	Nepal
ARC 12172	21960	India	Dular (R)	636	India
A-kuk-do	19689	India	DV 29	8816	Bangladesh
Bacon		Vietnam	DV 32	8818	"
Bageri	16193	Nepal	DV 52	8828	"
Bajang	17183	Indonesia	DV 85	8839	"
Bakai	23806	Nepal	DV 86	8840	"
Balacung	19232	Indonesia	DV 139	8870	"
Balik Semah	17201	Indonesia	DZ 78	8555	"
Bandja Ili	17216	Indonesia	DZ 192	8518	India
Bangaluwa	16268	Nepal	Gaja Baru	17586	Indonesia
Bathkiriel	15212	Sri Lanka	Gewal Bangoran	17651	"
Beak Ganggas	17253	Indonesia	Gokhue Saier	16195	Nepal
Belanok Kesambi Barak	17264	Indonesia	Gropak Gede	17687	Indonesia
Bendjah Urang	17639	Indonesia	Halsudu Heenati	15599	Sri Lanka
Benong	13530	Indonesia	Halsuduwee	15723	"
Bilekagga	19927	India	Hashikalmi	3397	Surinam
BJ1	3711	India	Hegar Manah	17733	Indonesia
Boder	17315	Indonesia	Hom Thong	12969	Laos
Bulu Baselijan	17341	Indonesia	Ikogan	19502	Philippines
Bulu Djambu	17343	Indonesia	Indel	17748	Indonesia
Bulu Manggali	17348	Indonesia	Jawa Renges II	17763	"
Bulu Putih	17350	Indonesia	Kalimadu 50	19338	Sierra Leone
Bulu Sampang	17352	Indonesia	Kentjana	922	Indonesia
Buntak Tuwungbatu	17356	"	Ketan Bajong	17830	"
Camor	17366	"	Ketan Bas	17834	"
Chinsurah Boro I	11483	Japan	Ketan Bedug	17837	"
Chinsurah Boro II	11484	Japan	Ketan Bendu	17838	"
Dayaggot qan bunuggon	9134	Philippines	Ketan Gabel	17851	"
DB-3	8361	Bangladesh	Ketan Gadjih	13512	"
DD-48	8620	"	Ketan Gondel	17857	"
DD 100	8649	"	Ketan Gondopuro	17859	"
Devarasi	16173	Nepal	Ketan Gundel	17865	"
DF-1	8365	Bangladesh	Ketan Kunir	17887	"
Djalawara	17471	Indonesia	Ketan Kutuk	17894	"
Djawa Sredek	17517	"	Ketan Laler	17897	"
Djelita	13714	"	Ketan Lumbu	16461	"
Djarabang	17543	"	Ketan Mari Kangen	17910	"

..... more

Table 3a ....

Variety	Acc. No.	Origin	Variety	Acc. No.	Origin
Ketan Pandang	17832	Indonesia	Patchaiperumal	15681	Sri Lanka
Ketan Seponjono	17959	"	Patong 32	13843	Malaysia
Ketan Simbukan	19965	"	Perum Karuppan	15513	Sri Lanka
Ketan Temon	17967	"	Perunel O. 69-18	19581	India
Ketan Tjendani	17970		Peuteuj	18484	Indonesia
Ketan Tjrumik	17973	Indonesia	P.I. 18006-1	3687	India
Ketan Tolo	17975	"	PI 231129	11114	America
Khao Lo	12904	Laos	PI 346824	16820	
Kirikunda	15558	Sri Lanka	Plampeyan	18494	Indonesia
Kolongi Bao	24135	India	Pulo	18519	"
Krawang Hadji	18024	Indonesia	Pulu Banrakaja	20073	Indonesia
Lal Ahu	16121	Nepal	Pusur	8350	Bangladesh
Lalaka Gadur	16255	"	Race	15706	Sri Lanka
Lal Sar	16185	"	Randjani	18596	Indonesia
Latu	18093	Indonesia	Rangun Serta	18600	"
Lenggang Genuk Bulu	18119	Indonesia	Rante	18608	Indonesia
Lua Ngu	16852	Vietnam	Rante	18609	"
Madhukan	14781	India	Rathu Heenati	15609	Sri Lanka
Mahamawee	15213	Sri Lanka	Remadja	679	Indonesia
Malagkit Sungsong	755	Philippines	Remadja Bulu	18620	"
Malalwariyan	15203	Sri Lanka	Rengesi	18628	Indonesia
Maturi	16187	Nepal	Rerm Bilash	16273	Nepal
Matury	16190	"	Rodjolele	9909	Indonesia
M.C.M.-2	19301	India	Sajani	16177	Nepal
Meritam	18267	Indonesia	Sampang Kuning	18678	Indonesia
Mond-Ba	15813	Senegal	Sampang Lempuyang	18679	Indonesia
Mujaer	18296	Indonesia	Sampangan Perak	18677	"
Murunga Balawee	15725	Sri Lanka	Seksrek	18740	"
Murungawee	15498	"	Semora Mangga	4181	"
Nagir	23984	Nepal	Sereh	16566	"
Nagkayat	584	Philippines	Sidjangguk	18826	Indonesia
Nakhi	16254	Nepal	Sidjero Gundil	18829	
Ngane Tia	13010	Laos	Sigadis	4095	"
No. 20	15606	Sri Lanka	Sintawati	18863	"
Olek Bandung	18337	Indonesia	Slendoran	18962	"
Padi Ireng	18373	Indonesia	Soal byeo #2	19868	
Padi Tomat	18408	"	Sogol	18905	Indonesia
Palotan Melati	18426	"	Sokan Dhan	16250	"
Pare Buwun	18456	"	Soponjono	18913	"
Pare Djerah	18458	"	Sri Kuning	14622	"

Table 3a .....

Variety	Acc. No.	Origin	Variety	Acc. No.	Origin
Sudumalawee	15218	Sri Lanka	Walen	16685	Indonesia
Sukonandi	18937	Indonesia	Wanni Dahanala	15721	Sri Lanka
Syntha	10307	"	Wase Aikoku	525	Japan
Tally	16146	Nepal	W 1263	11057	India
Taothabi (M-163)	13146	India	Yakadawee	15293	Sri Lanka
Tjempo Manggi	19034	Indonesia	Zenith	131	America
TKM 6	237	India			
Tolil 14	13836	Malaysia			
UCP 28	8728	Bangladesh			
Vella Peruvazha O. 68-12	19588	India			

Table 3b. Origin of varieties resistant to bacterial blight.

ASIA			
East	-	Japan	3
		Korea	1
Southeast	-	Indonesia	87
		Laos	3
		Malaysia	2
		Philippines	4
		Vietnam	2
South	-	Bangladesh	16
		India	98
		Nepal	17
		Sri Lanka	16
AFRICA		Senegal	1
		Sierra Leone	1
N. AMERICA		U.S.A.	2

5. Blast

Blast is the most widespread disease of rice since it occurs in all countries where rice is grown. Losses are generally most severe in areas at high elevation in the tropics or in lowland areas during the cool season.

Because of the variability of the pathogen, limited work has been done on the inheritance of resistance or on the non-allelic sources. Varieties that have been identified in the International Blast Nurseries are resistant at nearly all test locations, however.

Future collections should concentrate in highland areas of tropical Asia, upland rice areas, and in endemic areas of Africa and Latin America.

Table 5a. Promising sources for blast resistance.
- Screened in IBN: 1964-1973.
- December 1974.

Variety	IRRI Acc. No.	Origin	International Blast Nursery		
			No.[a]	SI[b]	R[c]
Ahmee Puthe	5735	Burma	172	1.48	97.1
Amritsari HR 22	6394	India	203	1.81	92.8
Andi from N. Pokhara	3707	U.S.A.	150	1.98	90.1
Badshabhog	5753	India	173	1.64	94.1
Badshabhog (scented)	4804	India	166	1.77	91.1
Basmati (C-5888)	9035	Pakistan	345	2.09	88.7
Basmati T3	6447	India	208	1.74	93.4
BMT 53R 3540	4132	Thailand	161	1.85	93.0
C46-15	6785	Burma	217	1.51	97.3
C-46-15	6786	Burma	41	1.56	93.1
Ca 435/b/5/1	6350	Indonesia	196	1.56	97.1
Ca 902/b/2/1	6349	Chad, Af.	195	1.54	94.9
Ca 902/b/2/2	6382	India	201	1.60	94.5
Ca 902/b/3/3	6347	Chad, Af.	194	1.60	94.7
Carreon	5993	Phil.	180	1.38	97.4
CI 2011-1	3311	U.S.A.	132	1.61	94.6
CI 6037-4	3667	India	144	2.01	92.2
CI 6914	4098	U.S.A.	160	1.79	90.6
CI 7338-5	3990	Phil.	156	1.84	91.6
CI 7787	11108	U.S.A.	1	1.83	91.7
Ptb 26 (Cheu Kayama)	6301	India	192	2.05	90.9
Chugoku 31		Japan	351	2.14	84.1
Ptb 30 (Chuvannam Modan)	6304	India	193	1.86	91.5
Colombia 1	19293	Colombia	353	2.11	89.5
Colombia 2	19294	Colombia	353	2.20	88.3
Colombia 3	19295	Colombia	355	2.11	90.2
CP 231 x HO 12	6741	U.S.A.	215	1.70	90.9
CP 231 x HO 12	6764	U.S.A.	216	1.65	91.2
Ctg 1516	8704	Bangladesh	312	1.87	92.0
D-25-4	6806	Burma	42	1.73	90.4
D-44-1	6804	Burma	218	2.05	89.1
DB-3	8361	B'desh	255	1.81	92.4
DD-6	8608	B'desh	294	1.99	90.9
DD 48	8620	B'desh	297	1.77	91.6
DD-89	8644	B'desh	301	2.01	90.6

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a/ Number of tests.
b/ Susceptibility index = average disease score over all locations.
c/ % R = Proportion of tests with R reaction.

Variety	IRRI Acc. No.	Origin	International Blast Nursery		
			No.	SI	% R
DD-91	8645	Bangladesh	302	2.05	92.6
Dissi Hatif	7802	Senegal	244	1.51	97.3
DL-2	8591	Bangladesh	287	2.26	90.9
DL-5	8953	Bangladesh	288	1.64	94.1
DL-9	8596	Bangladesh	290	2.02	88.4
DL-10	8597	Bangladesh	291	1.91	91.8
DL-12	8599	Bangladesh	293	1.77	93.3
DM-59	8779	Bangladesh	321	1.97	91.4
DNJ-60	8375	Bangladesh	257	1.93	93.7
DNJ-129	8463	Bangladesh	270	1.77	92.1
DNJ 131	8435	India	269	2.00	87.6
DNJ 142	8426	Bangladesh	266	1.91	89.0
DNJ 146	8425	Bangladesh	265	1.97	89.0
Dondoni Kunluz	7535	Afghanistan	232	1.93	89.0
DZ 193	8517	Bangladesh	278	1.79	94.4
El Gopher	6951	U.S.A.	224	1.68	93.7
H-5	156	Sri Lanka	46	1.71	92.7
Huan-sen-go	4619	China	164	1.35	96.3
J-519	4089	U.S.A.	158	1.88	92.8
Jhung Paddy 7	5796	India	174	1.78	91.8
Slo 16 (Kasipchodi)	6378	India	200	1.86	92.6
Laka	4217	Indonesia	162	1.88	89.2
Leter 08	6062	India	182	1.93	93.0
M-302	154	Sri Lanka	44	1.86	90.3
M-302	154	Sri Lanka	125	1.67	94.9
Macan Tago	5827	Philippines	176	1.79	95.5
Mamoriaka	3441	Malagasy	137	1.48	97.9
Mekeo White	11146	Papua, N. G.	81	1.94	92.8
Milketan 20	4033	Philippines	157	2.05	89.7
N-12	3716	Japan	151	1.80	93.8
N32	3717	India	152	1.89	93.8
Nang chet cuc	199	Vietnam	105	1.64	95.9
No. 79	3390	India	134	1.77	92.0
NP-97	3700	India	148	1.87	94.6
NP-130	3702	India	149	2.08	93.8
Padang Trengganu 22	11139	Malaysia	76	1.93	86.4
Pah Leuad 29-8-11	175	Thailand	126	1.65	95.5
Pah Leuad	24443	Thailand	122	1.57	94.2
Pi 3	6734	Japan	214	1.66	93.6
Pi 4	6733	Japan	213	1.54	94.0

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Table 5a .....

Variety	IRRI Acc. No.	Origin	International Blast Nursery		
			No.	SI	% R
PI 184675-2	7366	Iran	226	1.82	92.5
PI 184675-4	7368	Iran	227	1.76	93.8
Pusur	8350	Bangladesh	254	1.81	93.7
R-67	8350	Senegal	88	1.85	92.4
R-67	9011	Senegal	341	1.64	94.6
Rajbhog N22	6264	India	188	2.01	91.4
Ramgarh	3643	India	143	1.82	92.1
Ram Tulasi	181	India	128	1.41	97.2
Ram Tulasi (sel)	178	India	56	1.70	92.0
Ram Tulasi (sel)	178	India	127	1.42	97.4
S · 1		Japan	352	2.36	86.4
S12 DZK	6827	India	221	1.92	93.0
S12 O.Z.K.	3747	India	155	2.07	90.7
S20 J.K.W.	6822	Pakistan	219	1.63	92.9
S39 J.K.W.	6836	Pakistan	222	1.68	93.9
Samba	8916	Sri Lanka	339	1.68	92.8
Secano do Brazil	3375	El Salvador	133	1.75	94.1
Simpangan Kuning	5472	Malaysia	168	1.74	92.0
Sitasail	3739	India	154	2.29	90.9
Soavina	9012	Gambia, Africa	342	2.22	89.6
Sornavari	8443	French Sudan Africa	138	1.73	92.9
Surjamkuhi	8256	India	247	1.91	92.7
T1	3392	India	135	1.89	93.9
T1	6294	India	191	1.93	93.7
T3	3694	India	147	1.82	93.6
T9	3719	India	153	1.85	92.3
T23	6433	India	207	1.74	94.10
Tadukan	9804	Philippines	12	1.50	94.5
Ta-poo-cho-z	4285	China	121	1.61	91.34
TD 58	8288	Thailand	251	1.82	91.2
TD 68	8294	Thailand	252	1.74	92.6
Tetep	11115	Vietnam	11	1.24	98.0
Ptb 9 (Thava Lakkanan)	6274	India	189	1.52	96.8
Trang Cut L. 11	200	Vietnam	106	1.70	94.3
Unblatuzi Valley Sugar Co.	3440	India	136	1.82	93.7
W.R.C. 4	5801	India	175	1.67	93.2
41 Mushkan	6418	Bangladesh	204	1.85	90.9
268b/Pr/8/1/1	7623	Indonesia	233	1.76	91.5
370 Basmati	6426	Pakistan	205	1.82	92.5
818-3 BR9	5881	India	178	1.78	89.4

Table 5b. Origin of blast resistant entries.

ASIA		No. of resistant varieties	% of Total
East	Japan	5	4.38
	China	2	1.75
Southeast	Burma	5	4.38
	Indonesia	3	2.63
	Malaysia	1	0.87
	Papua New Guinea	1	0.87
	Philippines	5	4.38
	Thailand	5	4.38
	Vietnam	3	2.63
South	Afghanistan	1	0.87
	Bangladesh	20	17.50
	India	32	28.05
	Iran	2	1.75
	Pakistan	4	3.50
	Sri Lanka	4	3.50
AFRICA			
	Chad	2	1.75
	Gambia	1	0.85
	Malagasy	2	1.75
	Senegal	1	0.85
	Sudan	1	0.85
SOUTH & CENTRAL AMERICA			
	Colombia	3	2.63
	El Salvador	1	0.87
NORTH AMERICA			
	U.S.A.	8	7.02

6. Sheath blight

In recent years, the occurrence of sheath blight has increased considerably in Asia as more intensive cultural practices have been adopted. Although studies on yield losses are few, moderately severe losses in the monsoon season have been reported.

No resistant cultivars have been identified, although a few appear to be less susceptible than others.

Systematic screening will continue although highly resistant varieties may not be found.

7. Tungro virus

Tungro virus continues to be the major disease threatening rice production in tropical Asia. Past experience has shown that when epidemics occur, production is cut drastically.

Many cultivars, mostly from India, have been found to be resistant to tungro. Although the inheritance of resistance has not been studied, there is a high level (Gam Pai, Pankhari 203) and an intermediate level (Peta, Sigadis, TKM 6) of resistance, which would indicate at least two distinct sources (Tables 7a and 7b).

Future collections should be concentrated in Indonesia, Malaysia, and the Philippines where the virus has been endemic for many years.

8. Grassy stunt virus

The grassy stunt virus has developed into a major disease in localized areas of the Philippines, Indonesia, South Vietnam and India. It poses a threat to all tropical Asian countries because of the general buildup of the vector, the brown planthopper, under intensive practices of rice cultivation.

The only source of strong resistance has been found in an accession of _Oryza nivara_ and it is controlled by one dominant gene. Field resistance has been observed in several cultivars of _Oryza sativa_ but no inheritance studies have been conducted. Field resistance is suspected to be multigenic.

Future collections should focus on wild species from various continents. More collections of _Oryza sativa_ should be made in south India where most of the cultivars have field resistance.

Table 7a. Varieties highly resistant to tungro virus (seedling screening).

Variety	Acc. No.	Origin
Adday Local Sel.	180	India
Andi	3707	"
ARC 6064	12203	"
Habiganj DW 8	11751	Bangladesh
HR 21	663	India
JW 47	9121	India
Pankhari 203	5999	"
T 412	5894	"
Yi Shih Hsing*	1113	China

* Tested once only.

Table 7b. Varieties moderately resistant to tungro virus (field screening).

Variety	Acc. No.	Origin
ADT 25	5151	India
Ambemohor 159	5896	"
ARC 7010	12313	"
ARC 10531	20976	"
ARC 11254	21258	"
CO 10	6261	India
CO 20	6035, 8883	"
BJ 1	3711	"
Gam Pai 30-12-15	831	Thailand
Hashikalmi	3397	Bangladesh via Surinam
Kamod 253	23317	India
Kataribhog	12765	"
Latisail	8340	Bangladesh
Malagkit Sungsong	599	Philippines
Peta	35	Indonesia
PTB 18	19312 & 11052	India
Ram Tulasi	181	"
Sigadis	5324	Indonesia
TKM 6	237	India
Tjeremas	34	Indonesia
Warangal Culture 1263 (W1263)	11057	India

9. Leafhoppers and planthoppers

Rice green leafhoppers although extremely common in tropical and temperate Asia seldom appear to cause serious direct damage because of their low density. However, because they carry virus diseases, their control is of critical importance. The two leafhoppers, Nephotettix virescens and N. nigropictus, are capable of transmitting the yellow dwarf, tungro, penyakit merah, yellow orange leaf, and leaf-yellowing viruses.

A larger number of accessions have been tested against N. virescens than against N. nigropictus. Although a fairly large number of resistant sources have been identified (Tables 9a and 9b), genetically diverse sources are probably limited to a few because of the common geographic areas involved. Varieties do not always have the same response to both species of Nephotettix. We expect that resistance to both species will have to be considered in breeding for commercial varieties.

Nymphs and adults of the brown planthopper (Nilaparvata lugens) damages the rice plant through direct feeding and by transmitting the grassy stunt virus disease. When present in large numbers the insect causes complete drying of the plant, a condition called "hopperburn." The brown planthopper occurs in Japan, Korea, Khmer, Taiwan, south China, Malaysia, India, Vietnam, Sri Lanka, Indonesia, Philippines, Guam, Fiji, Solomon Islands, Bangladesh, and Thailand. The planthoppers are rapidly gaining importance in those areas where the HYVs are planted. The number of resistant varieties is quite large (Table 9c), but only two genetically distinct sources have been identified: Bph-1 in Mudgo and bph-2 in ASD-7, underscoring the need for a broader base of genetic resistance.

The white-backed planthopper (Sogatella furcifera) occurs throughout the rice producing areas of the world. It is considered a major pest in Japan, Taiwan, Korea, Punjab (India), central Vietnam, Thailand, Fiji and the Philippines. Under favorable conditions, they multiply rapidly and cause hopperburn. In Fiji, the white-backed planthopper is associated with "rice yellows." In the Philippines it appears a dominant pest in upland rice fields. The resistant sources are given in Table 9c.

The zigzag leafhopper (Recilia dorsalis) is a common pest of rice in South and Southeast Asia, Japan, Taiwan, and the northern areas of Thailand. It damages the plant by sucking the plant sap from the leaf blades. It has been reported to transmit rice dwarf virus in Japan. In the Philippines and Thailand, this insect was reported as a vector of the orange leaf virus. Several resistant sources are shown in Table 9d. Fortunately some of these varieties are also resistant to other insects, and so the resistance to zigzag leafhopper may already be present in some promising breeding lines.

Table 9a. Varieties resistant to green leafhopper, <u>Nephotettix nigropictus</u>.

Variety	Acc. No.	Origin
ASD 7	6303	India
D204-1	6445	India
Hashikalmi	3397	Bangladesh via Surinam
PTB 18	6105	India

Table 9b. Varieties resistant to green leafhopper, <u>Nephotettix virescens</u>.

Variety	Acc. No.	Origin
Abon*	17137	Indonesia
Akung*	17149	"
Andi N. Pokhara*	3707	India
ARC 5752	12119	"
ARC 6102	12216	"
ARC 7059	12316	"
ARC 10656	12559	"
ARC 10746*	12599	"
ARC 10826	12646	"
ASD 7 (Karsamba Red)	6303	"
ASD 8 (Thuyamalli)	6393	"
B 1*	17365	Indonesia
Bageri	16193	Nepal
Bagiamon 202	6611	Bangladesh
Baguamon 14	6590	"

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* Not yet retested.

Table 9b. Cont'd.

Baishbish	5811	Bangladesh
Balap Bureum*	17193	Indonesia
Balap Merah*	17194	"
Balap Putih*	17195	"
Bandja Ili*	17216	"
Bengawan Omas*	17273	"
Berondol*	17285	"
Beton*	17289	"
Bir-co-ru-mao	4348	China
Blaster Gunung*	17308	Indonesia
Bongkar Utang*	17321	"
Brengut*	17328	"
C 8461*	13473	North Borneo
C 8481*	13478	Brunei
Ca 902/b/2/2*	6382	Tchad
Chinsurah 2	6288	India
CI 7338-5*	3990	Philippines
CO 13 x CO 4 6522 B4	19333	Sierra Leone
D 204-1	6445	India
D. I 7*	8589	Bangladesh
DJ 9	8511	"
DJ 90	8479	"
DK 1	8574	"
DM 77	8796	"
DNJ 9	8403	"
DNJ 85	8368	"
Donduni Kunluz*	7535	Afghanistan
Do Khao	11533	Laos
DS 1	8573	Bangladesh
DV 29	8816	"
DV 85*	8839	"
DZ 84	8553	"
DZ 104	8548	"
Eden*	17728	Indonesia
Fatehpur 3	13387	West Pakistan
Gadis Ciamis*	17575	Indonesia
Gaja Baru*	17586	"
Gandasari*	17595	"
Gedi*	17614	"
Gendjah Bang*	17630	"

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*Not yet retested.

Table 9b. Cont'd.

Hathiel*	7730	Sri Lanka
Heenati	15679	"
Hegar Manah*	17733	Indonesia
Indian Pa Lil-46*	19337	Sierra Leone
Idna*	17740	Indonesia
Indel*	17748	"
Inten*	17751	"
Japita*	17759	"
Kalimekri 77/5*	6613	Malaysia
Kuruhondarawala*	7731	Sri Lanka
Laki 383	6576	Bangladesh
Laki 396	6621	"
Laki 462	6607	"
Laki 495	6497	"
Laki 659	6622	"
Lasaw	11184	Philippines
Mango	14749	Ghana
Murungawee	15498	Sri Lanka
Padi Jiongkok*	13430	Malaysia
Pankhari 203	5999	India
PI 184675-2*	7366	Iran
PI 184676*	3511	Iran
Pla Thoneng*	11681	Laos
PTB 18*	6105	India
PTB 18	19312	"
PTB 19 (Athikraya)*	6107	India
PTB 20	19313	India
PTB 21	19314	"
PTB 24*	19317	"
PTB 27 (Kadian)	6101	"
Pulliwi	12067	Sri Lanka
Ram Tulasi*	181	India
Rangun Serta*	18600	Indonesia
Rantai Mas*	18604	"
Red Rice*	3513	Iran
Remadja*	679	Indonesia
Retant*	18632	"
Rondo Jeblot*	18645	"
Roti*	18646	"
Sakotji*	18664	"

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*Not yet retested.

Table 9b. Cont'd.

Sedan Mundur*	18712	Indonesia
Segon Emas*	18727	"
Segon Mega*	18730	"
Segon Omas*	18731	"
Segon Perak*	18736	"
Sempol*	18757	"
Sempor*	18761	"
Seraju*	18775	"
Serang*	18777	"
Sero*	18786	"
Setra*	18793	"
Shanghai*	18798	"
Siam Puteh*	13466	Malaysia
Sidara*	18824	Indonesia
Siem	18832	"
Sigadis	15555	Sri Lanka
Sintawati	18863	Indonesia
Skaro*	20172	"
Sulai	15239	Sri Lanka
T 23*	6433	India
T 142 (Badshabog)*	5894	"
Tilakkachray*	681	Indonesia
Tjeremas*	34	Indonesia via Philippines
UCP 122	8794	Bangladesh
UCP 195	8802	"
# 79*	3390	Africa

* Not yet retested.

Table 9c. Varieties resistant to brown planthopper, _Nilaparvata lugens_.

Variety	Acc. No.	Origin
ARC 12479	22085	India
ARC 5929*	19676	"
ARC 6610*	20419	"
ARC 6626*	20427	"
ARC 6649*	20435	"
Anbaw C7	6069	Burma
Andaragahawewa	11974	Sri Lanka
ASD 7 (Karsamba Red)	6303	India
Babawee	8978	Sri Lanka
Balamawee	7752	"
Balamawee	8919	"
Balamawee	12078	"
Berawee	8967	"
Ca 902/b/2/2*	6382	Tchad
CO.9 (PI 193176)	3690	India
CO.10 (PI 193177)	3691	"
CO13*	3736	"
CO 13*	4897	"
CO 13	10633	"
CO 18*	6331	"
CO 22 (Manavari)	6400	"
D25-42*	13728	"
Dikwee	7814	Sri Lanka via Nigeria
Dikwee 328	12087	Sri Lanka
Gangala	7733	"
H105	158	"
Hamsa*	11489	India
Hathiel	7730	Sri Lanka
Heenukkulama B	11978	"
Hondarawala 378 B	12076	"
Hondarawala 502 B	12075	"
HR-12	19229	India

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* Not yet retested.

Table 9c. Cont'd.

IR26	24154	IRRI
Japan Heenati C	15604	Sri Lanka
Japan Wee	15605	"
Kaluheenati*	7735	"
Kirikunda	15558	"
Kosatawee	11677	"
Kuruhondarawala	7731	"
M 302*	154	"
M 302 x Mas 24	7833	"
M.C.M. 1	19300	India
M.C.M. 2	19301	"
Maha, Murungan, Badulla	12094	Sri Lanka
Malalwariyan	15203	"
Mawee*	12854	"
M. I. 329	12089	"
Madayal B	12001	"
Mahadikwee	11956	"
Malkora A	11716	"
Mathumanhikam	8957	Sri Lanka
MTU 15	233	India
Mudgo	6663	Goa of India
Murunga 307*	3472	Sri Lanka
Murunga 308	3473	"
Murunga Balawee	15725	"
Murungakayan	8955	"
Murungakayan 3	12071	"
Murungakayan 101 B	12072	"
Murungakayan 304 B	12073	"
Murungakayan 303 B	12074	"
Murungakayan 302	11097	"
Murungakayan 307	11096	"
Murungakayan 308	11107	"
Ovarkaruppan B	11963	"
Pai-shien	11051	Taiwan
Palasithari 601	12069	Sri Lanka
Pawakkulama B	11983	"
Pannetti	8937	"
Periamorungan B	11935	"
Pirum Karuppan	15513	"
PK 1	11703	"

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*Not yet retested.

Table 9c. Cont'd.

Podimawee	7728	Sri Lanka
Podiwee	11938	"
PTB 18	11052	India
PTB 18*	19312	"
PTB 19 (Athikraya)	6107	"
PTB 20*	19313	"
PTB 20*	19319	"
PTB 21 (Tekkan)	6113	"
PTB 21	11053	"
PTB 21*	19314	"
Rathu Heenati	11730	Sri Lanka
Seruvellai	8990	"
Sinnakayam B	11687	"
Sinnanayan 398	12079	"
Sinnasuappu	11697	"
Sinna Karuppan	11731	"
Sinnavellai A	11946	"
SLO 12 (Thella Garikasanavari)	6300	India
Suduwi 306	11098	Sri Lanka
Sudhubalawee	8900	"
Sudurvi 305*	3475	"
Su-yai 20*	7299	China
Thirissa	7734	Sri Lanka
Tibirewewa B	11969	"
Vellailangayan	8956	
Vellailangalayan	8958	"
Vella Kayan*	15219	"
V 1	7815	"
Warangal Culture 1252	13743	India
Warangal Culture 1253*	11055	"
Warangal Culture 1259 (EK 1259)*	13745	"

*Not yet retested.

Table 9d. Varieties resistant to white-backed planthopper, Sogatella furcifera.

Variety	Acc. No.	Origin
ADT 19 (Sarapalli)	6379	India
ARC 5752	12119	"
ARC 6248	12268	"
ARC 6563	12276	"
ARC 6601	12289	"
ARC 6611	12294	"
ARC 6624	12299	"
ARC 6634	12302	"
ARC 6650	12308	"
ARC 7331	12371	"
ARC 10214	12392	"
ARC 10595	12525	"
ARC 10600	12527	"
ARC 10651	12556	"
BJ 1	3711	"
C 5-17	3746	"
C-20	12869	"
Colombo	6662	Goa of India
Dahanala 2014	3469	Sri Lanka
Djambon	13603	Indonesia
J. B. S. 34	3732	India
Kondinga	13417	Malaysia
Manggar	13605	Indonesia
3-month variety	6716	Guyana
Mudgo	6663	Goa of India
Murungakayan	8955	Sri Lanka
Nang-lee	16739	Vietnam
Padi Budong	13423	Malaysia
Pankhari 203	5999	India
Renda Serah	18627	Indonesia
Ridjah	13613	Indonesia
Saraya	6715	Guyana
Sedan Mundur	18712	Indonesia
Segon	18719	"
Segon Mega	18730	"
Sempor	18760	"

Table 9d. Cont'd.

Sentral Merah	18770	Indonesia
SLO 12 (Thella Garikasanavari)	6300	India
Ta-lee	4267	China
Tau Binho	12871	Sudan
Ubot	19165	Indonesia
Unar	19167	"
Warangal Culture 1240	13742	India
Warangal Culture 1252	13743	"

Table 9e. Varieties resistant to zigzag leafhopper, Recilia dorsalis.

Variety	Acc. No.	Origin
Balamawee	7752	Sri Lanka
DS 1	8573	Pakistan
PTB 21	11053	India
PTB 27	6101	India
Rathu Heenati	11730	Sri Lanka

10. Stem borers

The stem borers occur every year and infest the rice plant from seedling stage to maturity. Damage to the seedlings results in dead leaves (the so-called "dead hearts"). The larvae bore into the stem usually at the nodal region. They feed and develop within the stem and cause the 'white heads.' These insects are extensively distributed over all rice-growing countries.

Borers will continue to be the most important persistent and widespread insect pests of rice. As such they are the pests that most commonly require control. Management of borers is a priority in most pest control recommendations. Currently we are largely dependent on insecticides to minimize borer damage.

Thousands of cultivars have been screened for resistance to two major species: the striped borer (*Chilo suppressalis*) and the yellow borer (*Tryporyza incertulas*). The moderately resistant sources are enumerated in Tables 10a and 10b, respectively. Resistance appears to be primarily the antibiosis type and to a certain extent the non-preference type. The mode of inheritance appears to be multi-genic and complex.

Some of the moderately resistant accessions have been used in the breeding program, and IR26 and IR20 are products of the variety TKM 6, first noticed because of its moderate borer resistance. We are attempting to increase the level of resistance by crossing varieties that each show some resistance. The progeny are screened under severe infestations to find strains with higher levels of resistance.

Because resistance is not the same for all species of borers, we are screening varieties as well as breeding lines under artificial and natural conditions for resistance to two different species. Wide field adaptability depends on the resistance to several borer species. A high level of stable borer resistance could contribute more to rice insect control in the field than any other insect control measure.

Table 10a. Varieties resistant to striped borer, *Chilo suppressalis*.

Variety	Acc. No.	Origin
Bir-co 884	4346	China
BMT 53R 3536	1863	U.S.A.
C 409	6785	Burma
Chianan 2	89	Taiwan
Chiang An Tsao Pai Ku	1577	China
Chua-dau	4785	China
CI 5339*	958	China
CO 13*	4897	India
CO 21	6396	India
DD 48	8620	Bangladesh
DNJ 97	8454	Bangladesh
DV 88	8841	Bangladesh
DZ 41	8563	Bangladesh
Lenkan-mi-thou-goo	4537	China
Patnai 6*	3726	India
PI 160638	1239	China
Su-yai 20	7299	China
Szu Miao	7300	China
Ta-poo-cho-z	4285	China
Taitung 16	99	Taiwan
Ti Ho Hung	1226	China

* With more than one Acc. No.

Table 10b. Varieties resistant to yellow stem borer, *Tryporyza incertulas*.

Variety	Acc. No.	Origin
Bali	17197	Indonesia
Bali Gropak	17179	Indonesia
Bandjara	17219	Indonesia
C4-63 (green base)	16331	Philippines
Kipusa	5467	Africa
Pai Chung Shih Pa	1268	China
RD-5	24141	Thailand
Thailand x Norin	803	India
TKM6	237	India
WC 1251	11054	India
WC 1253	11055	India
WC 1263	11057	India

11. Whorl maggot

The rice whorl maggot (Hydrellia philippina) is widely distributed in Southeast Asia. It feeds on the inner margin within the whorl of the still unopened youngest leaves and scrapesoff the tissues, leaving only the two epidermal layers. The damaged leaves are shrivelled and whitish. The damage appears to be increasing and spreading over a wider area.

About 5,000 accessions have been tested in the field for maggot resistance. A few have been screened in the greenhouse under artificial conditions. However, only moderate levels of resistance have been found (Table 11).

Moderate levels of resistance may well be adequate to prevent yield loss. Since the greenhouse screening technique is not yet very efficient, field screening might be adequate.

Table 11. Varieties moderately resistant to whorl maggot, *Hydrellia philippina*.*

Variety	Acc. No.	Origin
ADT 15 (Senkuruvai)	6221	India
Akibae	9216	Japan
ARC 6064	12203	India
ARC 6089	12212	"
ARC 6231	12260	"
ARC 10174	12385	"
ARC 10214	12392	"
ARC 10281	12420	"
ARC 10296	12421	"
ARC 10297	12422	"
ARC 10299	12423	"
ARC 10301	12424	"
ARC 10696	12580	"
ARC 10952	12682	"
ARC 11094	12712	"
ARC 11097	12713	"
ARC 11098	12714	"
Balilla x Sollana	9527	Spain
Bakong	17190	Indonesia
Bangka	17255	"
Binagacay	19389	Philippines
Bluluk	16359	Indonesia
Bulu Sampang	17352	"
California	9279	Hungary
Chen-Tsan-Co	4365	China
Cicih Selem	17434	Indonesia
CO 1	6025	India
CO.9	3690	"
CO 20 (Thella Sannavadlu)	6035	"
Csornuj	9281	Hungary
DA 18 (Pusur)	6045	Pakistan
Dendek	17461	Indonesia
Dete	17463	"

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*All of the listed accessions are MR, only HR-102 is resistant.

Table 11. Cont'd.

Dete	17464	Indonesia
DH 1	9533	Spain
Fuzisaka 2	9282	Japan via Hungary
Genya Rawe	17643	Indonesia
Gin-Shan-Tsan 18	4444	China
Gondang	19278	Indonesia
Haya Norin	9402	Hungary
H. R. 102*	3753	India
H. R. 106	642	"
Hsin Hsin Bir Goo	4657	China
Hsin Huan Thou	4716	"
Ibuki	12749	Japan
Irradiated Taichung 65	9434	Taiwan
JC 198	9200	India
Kendzo	9315	Hungary
Ketan Djinggo	16445	Indonesia
Ketan Gondel	17858	"
Ketan Gropak	17862	"
Ketan Gubat	17863	"
Ketan Gundil	17866	"
Ketan Kasturi	17881	"
Ketan Kopros	17886	"
Ketan Kutuk	17894	"
Ketan Mambang	17908	"
Ketan Odeng	17926	"
Ketan Opjor	17928	"
Ketan Rantai Mas	17945	"
Ketan Rapi Djali	17946	"
Ketan Selandjana	17956	"
Ketan Sundo	17966	Indonesia
Ketan Uci	17977	"
Ketan Untup	17980	"
Kopo	18017	"
Krawang Hadji	18024	"
Koshijiwase	9262	Japan via Hungary
Kuntulan	16489	Indonesia
Lien-Chan-Bir-Gan-Wo-Mau	4542	China
Luang Ray	11511	Laos
Mae Cuoi	12017	Egypt
Mak-bit Khao	11554	Laos

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* Resistant

Table 11. Cont'd.

Ma-li-bin 2	4561	China
MGL 2 (Kayama)	6218	India
Nandi 3	18316	Indonesia
Nandi Batu	18317	"
Nano de Alcantara	9317	Hungary
Norin 19	9396	Japan via Hungary
Norin 33	9377	Japan via Hungary
Oku-masuri	12760	Japan
Originario	9376	Hungary
Oshikari Shiroque	9485	Brazil
Padi Gundil	18366	Indonesia
Padi Hitam	18371	"
Padi Krawing	18377	"
Padi Putih	18393	"
Pare Beureum 1	18452	"
Pare Beureum 1	18453	"
Parambacheera 0.6706	12014	India
Patro	9528	Spain
Perillanel 26014	6117	Sri Lanka
PTB 9 (Thavalakkannan)	6274	India
PTB 21	19314	India
Pulut Masributₛ	18527	Indonesia
RDR 2	613	India
Sampangan Perak	18677	Indonesia
Sanggul	18683	"
Sanpuku	12724	Japan
Sasak Barak	18704	Indonesia
Satrijo	18705	"
Sawanohana	12720	Japan
Secano	9311	Hungary
Segli	18717	Indonesia
Se-Yua-Toon-Yuanpze	4247	China
Sewu	18796	Indonesia
Shua-Nan-Tsan	4587	China
Sir Kuning Gedangan	18886	Indonesia
Si-Sou-Baj-Tao	9318	China via Hungary
Slendora	18902	Indonesia
Slobok	16571	"
Solo	18906	"
Sontok Bogo	18911	"
Sornavari	3443	Africa
Sri Kuning	18921	Indonesia

Table 11. Cont'd.

Sueca x Sollana	9531	Spain
Sushu-roku	12725	Japan
T.3	3705	India
T 1145	6270	"
Teine	12719	Japan
Teluk Bajur	18970	Indonesia
Thailand x Norin	803	India
Tj. Mudja	19140	Indonesia
Tjempo Beton	16583	"
Tjempo Sungut	16634	"
Tjempo Tambak Urang	16635	"
TKM 6	237	India
Toyochikara	12721	Japan
Tsao Wan Ching	1034	China
Vercelli	9467	Italy via Brazil
Woo-Co-Tsan	4545	China

12. Leaf folder

The leaf folder (Cnaphalocrosis medinalis) occurs extensively in all rice growing areas of the tropics. The caterpillars feed on the newly emerged leaves and fold the leaf blades into tubes. White streaks on the leaves indicate areas damaged by feeding. Several leaves on a plant may be damaged.

The leaf folder appears to be an increasingly severe pest. Although we do not know the extent of yield loss it causes, but we anticipate that this insect will soon require control over a wide area if good yields are to be maintained.

Limited testing led to the identification of six accessions as promising sources of resistance (Table 12). The testing work needs to be continued when technical help becomes available. Even moderate resistance would be very helpful to keep this pest from becoming serious and requiring pesticide treatment.

Table 12. Varieties resistant to rice leaf folder, Cnaphalocrosis medinalis.

Variety	Acc. No.	Origin
ARC 5752	12119	India
Hashikalmi	3397	Bangladesh via Surinam
Hom Thong	12969	Laos
Kipusa	5467	Africa
Mudgo	6663	Goa of India
Warangal Culture 1263	11057	India

13. Nitrogen utilization

A. Atmospheric nitrogen fixation in rice rhizosphere - The objective is to identify varieties and lines which could potentially fix more atmospheric nitrogen in the rice rhizosphere. A new assay technique is being carried out on 42 varieties in the greenhouse. Field testing will cover 102 varieties. The nitrogen fixation in situ will be assayed.

B. Utilization of soil nitrogen - The objective is to compare varietal differences in the uptake of soil nitrogen. In the greenhouse 99 varieties were tested with and without nitrogenous fertilizer (labelled with N^{15}). Field testing will include 99 varieties.

14. Nutritive quality of rice — protein and lysine

Between 1966 to 1973, about 12,500 entries from the IRRI rice collection were screened for brown rice protein. Samples were obtained from crops grown on the IRRI farm. Most of the high protein entries were low yielding and some were japonica type. Since environment is known to affect the protein content of the rice grain, the goal was to improve the protein content of milled rice from 7% to 9%, which would increase protein intake at least 10% in the Asian rice diet.

The ratio of protein (mg) to brown rice (based on % protein and 100-grain weight) is being studied as a criterion of high protein content in rice. If it turns out to be a useful criterion, the IRRI collection will be screened for 100-grain weight and percent protein of brown rice in the future. Analysis for protein content alone has little meaning since the high protein entries are very poor in plant type and yield potential.

About 12,500 entries have been screened for lysine content (dye-binding capacity) and the graph of dye binding capacity vs. protein indicated the presence of a few higher lysine lines. Actual lysine analysis by ion-exchange chromatography and replanting of the promising entries showed that the lysine content of protein only varies by ± 0.5 percentage point at any protein level. Since the lysine content of rice protein is already high (about 4%), the increase involved is only about 12%. Hence, breeding for high protein content has more potential for raising nutritive value than breeding for higher lysine content. Only two higher lysine varieties, ARC 10525 and Kolamba 540 from India, were identified.

15. Drought resistance

Drought affects both the level of yield and the stability of yield in upland, rainfed-lowland, and deep-water cultures. The three types of culture make up 60 percent of the rice acreage in South and Southeast Asia. Upland rice occupies 80 percent of the rice acreage in Latin America and 75 percent in West Africa.

Drought resistance is a complex trait consisting of the escape, avoidance, and tolerance mechanisms. The ability to recover quickly after drought is another essential character.

Field testing in the dry season under a simulated upland culture makes possible the evaluation of thousands of cultivars and breeding lines in one season. About 80 outstanding sources of field resistance to drought have been identified from more than 2,000 cultivars screened to date (Table 15a) and utilized in IRRI's breeding program for upland rice. The component traits involved in field resistance appear to be largely of the avoidance type: deep and thick roots, plasticity in leaf rolling and unrolling as an indication of quick stomatal response to internal water stress, and heat tolerance. Varietal differences in recovery are also evaluated in the field experiments. Systematic field testing will eventually cover the bulk of the entire collection. The African rices (O. glaberrima) included.

Plant physiologists are also studying drought resistance in the greenhouse using large boxes of soil which represent different levels of constant water table. The findings (Table 15b) agree with field tests (Table 15a).

Root systems of resistant and susceptible cultivars are compared in boxes or tubes of soil. Extensive root systems, consisting of many long and thick roots, are associated with drought resistance.

Tolerance to and recovery from constant levels of water stress at different stages of plant growth are investigated by agronomists in the greenhouse. A number of varieties and lines have been found promising as tolerant genotypes (Table 15c). Testing techniques are being improved.

Efforts are being continued to further collect drought-resistant varieties from areas where drought frequently occurs or where upland rice is extensively cultivated. Such a segment of the germ plasm collection showed the greatest increase in size -- more than a ten-fold since field collections began in 1971.

Table 15a. Varieties resistant to drought in field tests.

Variety	Acc. No.	Origin
Ba Djang Nhu	19599	Vietnam
Ba Djang Ploi	19600	Vietnam
Bantia	6454	Liberia
Binirhen Str. 366	5427	Philippines
Chao Meth Nhay	11795	Laos
Dam Boung	11811	Laos
Dam Ngo	11632	Laos
Deng Mak Fay	12910	Laos
Deng Ngoua	11823	Laos
Dular*	636	India/Bangladesh
Elliot	6457	Liberia
Gamanpou	16082	Ivory Coast
Gbante	16081	Ivory Coast
Khao Kieng	11622	Laos
Hao Khao	11914	Laos
Kap Nhay	11640	Laos
Khao Deng	12927	Laos
Khao Eo	11639	Laos
Khao Hay	11788	Laos
Khao Luong	11832	Laos
Khao Nok	12902	Laos
Khao Tam	11631	Laos
Khaotong	11652	Laos
Khao Pane	12928	Laos
Khao Phoi	11623	Laos
Khao Sam Deuane	11661	Laos
Khao Tong	11621	Laos
Khao Vay	11913	Laos
Khao Xiou	11925	Laos
Khao Y Tam	11650	Laos
KH. Chepheum	11802	Laos
KH. Malenh	11812	Laos
Kinampupoy	5995	Philippines
Kouimlipou	16092	Ivory Coast
Kumayat	5428	Philippines
KU 78	15020	Thailand
KU 86	15027	Thailand
LAC 5	14948	Liberia
Lay Ngenh	11625	Laos
Lay Sort	12906	Laos
Ligerito	19918	Colombia
Ligerito	19919	Colombia
Ligerito	19920	Colombia
Mack Bouap	11653	Laos
Mack Bouap	11655	Laos

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* Also rated as drought-resistant by plant physiologists.

Table 15a (continued)

Variety	Acc. No.	Origin
Mack Hing Hom	11658	Laos
Mack O	11646	Laos
Mack Tay Deng	11659	Laos
Mah Nam Pai	23756	Thailand
Mah Reng	23757	Thailand
Mai Kai	23758	Thailand
Mak Kheua	12917	Laos
Malandi II	19454	Philippines
Maligaya 5	759	Philippines
Ma Nam 276-3-1	23759	Thailand
Ma Wai	23761	Thailand
Meth Nai	11636	Laos
Ml-48*	359	Philippines
Nam Mack	11635	Laos
Nga Xang Khao	11649	Laos
Nga Xang Lay	11791	Laos
N 22	4819	India
OS4*	11335	West Africa
Padi Ansisiyuk	14386	Malaysia
Padi Pupurong	14387	Malaysia
Padi Sinilop	14384	Malaysia
Padi Tambayungan	14382	Malaysia
Padi Tatakin	14390	Malaysia
Pho Kha	11626	Laos
Pinortuna	19475	Philippines
Pulot	19476	Philippines
R 75	15076	Congo Leop.
Sankok	12103	Vietnam
Seratus Malam	14415	Indonesia
Sran Kraham	16959	Cambodia
Susono-mochi	7689	Japan
Tosahata-mochi	7693	Japan
Tiale	19492	Philippines
Tres Marias	19495	Philippines
Xiou Kao	11634	Laos
1-EB	14854	Liberia
1-G	14856	Liberia
1-K	14857	Liberia
7-AA	14808	Liberia
7-B	14862	Liberia
8-A	14863	Liberia
8-CD	14866	Liberia
9-BB	14830	Liberia
9-D	14811	Liberia
10-A1	14867	Liberia
10-C	14868	Liberia

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* Also rated as drought-resistant by plant physiologists.

Table 15a (continued)

Variety	Acc. No.	Origin
11-B	14869	Liberia
13-A	14833	Liberia
18-A	14836	Liberia
19-C	14837	Liberia
20-A	14838	Liberia
28-A	14844	Liberia
30-C	14846	Liberia
30-E	14848	Liberia
31-E	14849	Liberia
63-83	14725	Ivory Coast
142	14882	Liberia
270	14914	Liberia
279	14916	Liberia
280	14917	Liberia
421	14918	Liberia
428	14919	Liberia
462	14921	Liberia
551	14935	Liberia
553	14937	Liberia
558	L4941	Liberia
560	14942	Liberia
562	14943	Liberia
610	14944	Liberia

Table 15b. Drought-resistant varieties.

Variety	Acc. No.	Origin	Rating in Field test*	Rating in Constant water-table box**
Azmil	11375	Philippines	MR	R
E425	11334	West Africa	MR	R
Miltex	291	Philippines	I	R
Palawan	353	Philippines	MR	R

* Rated by plant breeders.
** Rated by plant physiologists.

Table 15c. Varieties and lines having promise in drought tolerance tests*.

Variety or line	Acc. No.	Origin (for variety) or parentage (for line)
E425	11334	Africa
MRC 172-9	26273	Philippines
IR5	9926	Peta/Tangkai Rotan
IR442-2-58		IR95-31-4/Leb Mue Nahng
IR879-314-2		$IR8^2$//$Peta^3$/Dawn
IR937-55-3		$IR8^2$//Dawn/TN1
IR1416-131-5		IR400-28-4-5/Tetep
IR1480-147-3		IR790-28-1-3/IR825-28-4-3
IR1529-72-5		IR305-3-17-1-3/IR661-1-140-3
IR1529-430-3		"
IR1529-677-2		"
IR1531-86-2		IR332-2-10-1-2-1/IR127-80-1-10
IR1545-339		IR24/DZ 192
IR1646-623-3		IR930-33-1/IR441-19-1-3-2-2
IR1721-11-6		$IR24^3$/*O. nivara*

* Identified by agronomists.

16. Cold tolerance

Approximately 7 million hectares are under rice in South and Southeast Asia where the HYVs can not be cultivated because of low temperature. These include the high elevation tropical areas where rice may be cultivated throughout the year; high elevation subtropical areas where rice is cultivated during the summer months only; and low elevation subtropical areas where rice is grown throughout the year but cool temperatures are a restraint only during the winter months. Because such areas are relatively small and widely scattered, cold tolerance is a relatively low priority breeding project at IRRI.

Systematic screening has not been greatly increased in size because of the low priority of the problem and the knowledge that varieties collected from cool-temperature areas should be cold tolerant. If and when more information becomes available on the specific facets of cold tolerance, systematic screening may prove more worthwhile.

Attention has been given to the collection of germ plasm from high elevation areas in the tropics, though there is not great urgency in covering all areas at once. The tolerant types are not being rapidly replaced by HYVs and this is not likely to happen within the next 5 years. However, there should be a contingency plan for making a thorough collection of these materials should improved varieties gain a foothold in the cooler areas.

Table 16. Varieties tolerant to cold water or to cool air.

Variety	Acc. no.	Origin
	Cold Water	
JP 5	13382	Pakistan
Jumula 2	13375	Nepal
Raja Imut	24171	Indonesia
Sug	24172	Kashmir
Remei	10903	Japan
Caloro	150	U.S.A.
	Cold Air	
China 1039	24168	China via Kashmir
Jumula 2	13375	Nepal
Jarak	24942	Indonesia
Kulu	11337	Australia
Sug	24172	Kashmir
Remei	10903	Japan
Boro varieties (many)		Bangladesh
Szegedi-szalchalus	16294	Hungary
Mountain Province varieties (many)		Philippines
Shirkati	14528	Afghanistan

17. Problem rice soils

Soil problems are among the main obstacles to increasing the productivity of rice lands and to extending the area under rice. They affect millions of hectares in the tropics which are climatically well suited to rice cultivation.

The main problems are salinity/alkalinity (10 m ha), salinity of coastal soils (26 m ha), iron toxicity (8 to 15 m ha), zinc deficiency (10 m ha), phosphorus deficiency (10 to 15 m ha), and iron deficiency in upland rice (10 m ha). Since poor countries cannot afford the reclamation of these soils, alternative methods of using them efficiently must be explored. One method is selecting and breeding varieties suited to adverse soil conditions.

During the past two years we have screened over 100 varieties and selections for resistance to salinity, alkalinity, iron toxicity, and deficiencies of phosphorus, iron, or zinc, and noted striking varietal differences. A more extensive and systematic program of screening is planned in the GEU program. The first step is the collection of varieties from the problem soil areas. The geographical areas are as follows:

Soil problem	Geographical area
Salinity/alkalinity	Pakistan, Punjab, Haryana, Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Andhra Pradesh in India; Khorat in Thailand; Mandalay in Burma; Iran; Iraq; Egypt; Chad; Peru.
Coastal salinity	Maharastra, Karnataka, Tamilnadu, Andhra Pradesh, Orissa and West Bengal in India; the Irrawaddy delta in Burma; southwest Thailand; western Malaysia; eastern Sumatra, Kalimantan and south Sulawesi in Indonesia; the coastal fringes of the Indo-China peninsula; the western coast of Africa; the northern coast of South America; the coastal plains of Malagasy; and the coastal soils of Luzon, Bicol, Visayas, and Mindanao in the Philippines.
Iron toxicity	The Mekong delta in Indo-China; Ongkarak (Thailand); eastern Malaysia; western Sumatra, and Kalimantan (Indonesia); Sierra Leone; Senegal; Liberia; Nigeria; Malagasy; Karnataka, Orissa, and Manipur in India; and southwest Sri Lanka.

Soil problem	Geographical area
Zinc deficiency	Most sodic, calcareous, and fresh water marshy soils. (Map in preparation).
Phosphorus deficiency	More or less the same as the iron-toxic areas.
Iron deficiency	Upland rice areas especially where the soils are neutral or slightly acid.

Table 17. Varieties highly resistant to different adverse factors in the soil.

Adverse factor	Resistant variety	Acc. no.	Origin
Alkalinity	Pokkali	8948	India via Sri Lanka
Aluminum and manganese toxicity	M1-48	359	Philippines
Iron deficiency	M1-48	359	Philippines
Iron toxicity	Pokkali	8948	India via Sri Lanka
Phosphorus deficiency	H-4	155	Sri Lanka
Salinity	Pokkali	8948	India via Sri Lanka
Zinc deficiency	H-4	155	Sri Lanka
	Pokkali	8948	India via Sri Lanka

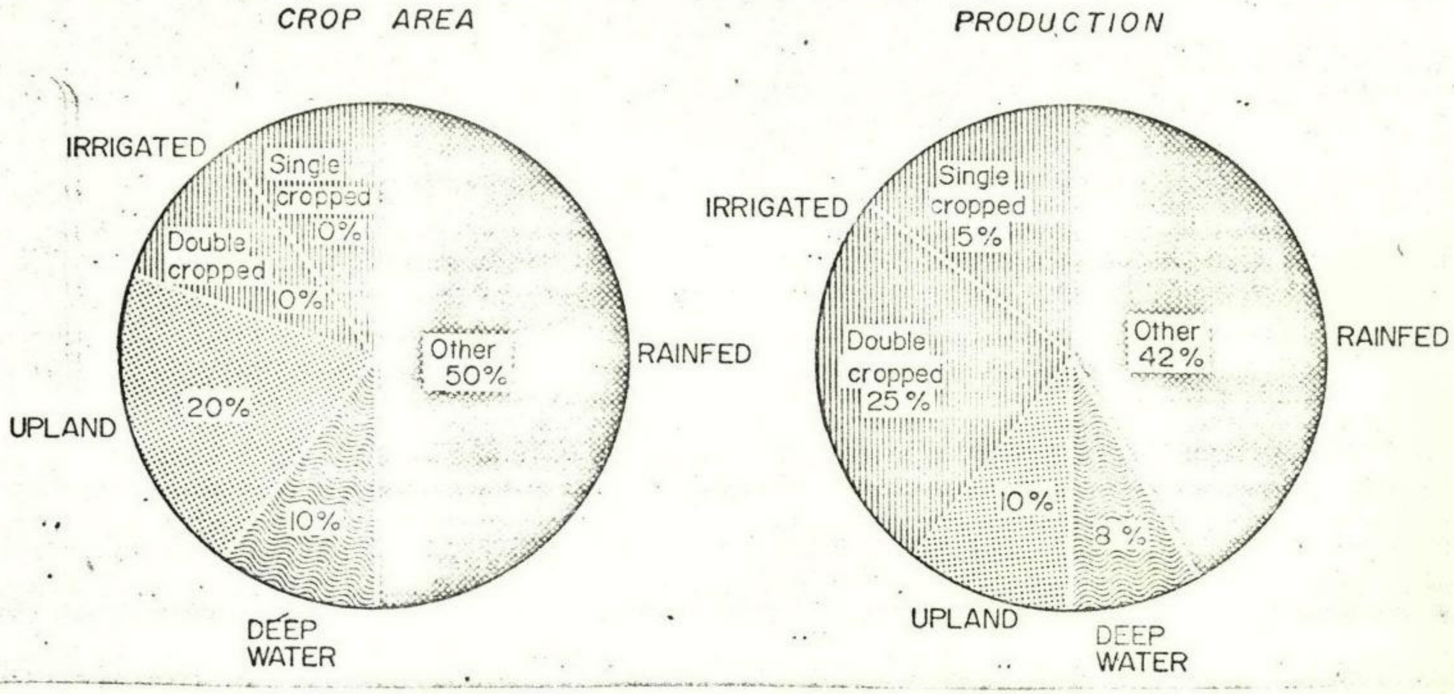


Fig. 7a. Estimate of percent rice crop area and production by specified land type in South and Southeast Asia, mid 1960's

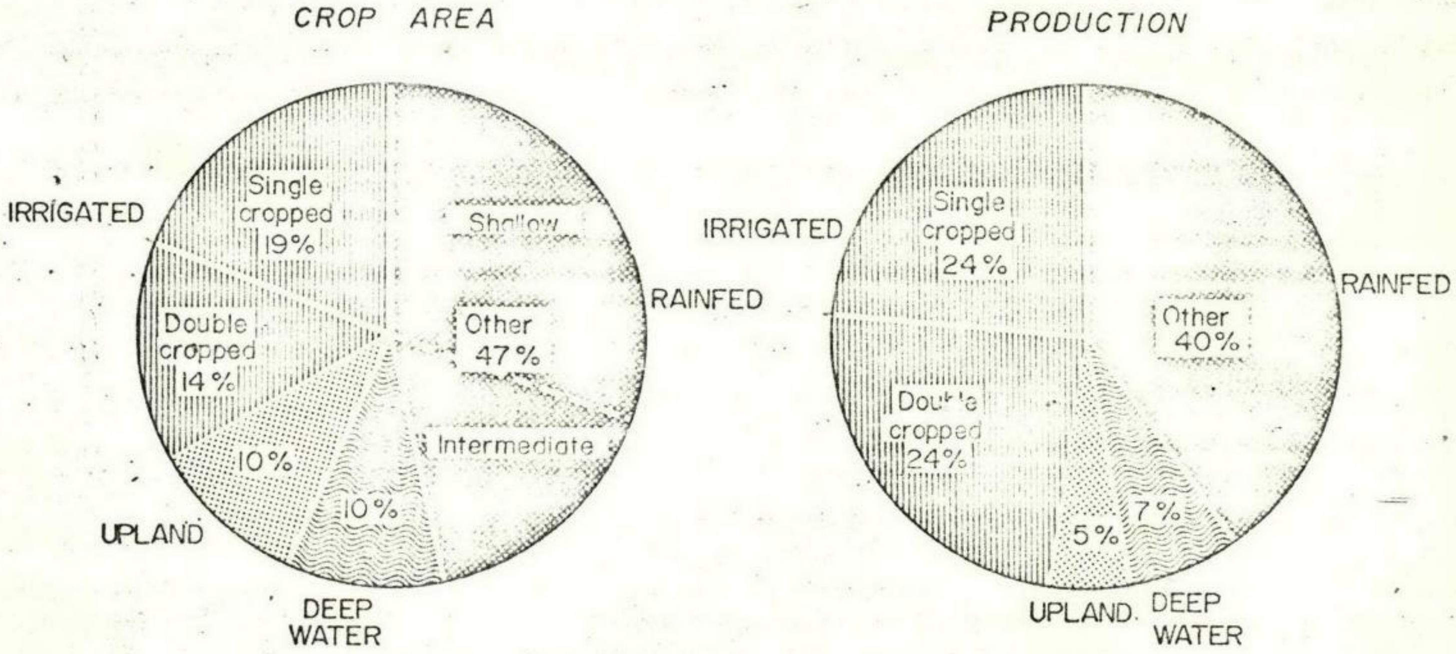


Fig. 7b. Estimate of percent rice crop area and production by specified land type in South and Southeast Asia, early 1970's

Rice

ATTACHMENT 4

YIELD PROJECTIONS TO 1985

One common way of evaluating the recent increases in annual food grain production and yield is to compare these increases with the long-run trend in growth rate. However, any change in trend is extremely difficult to identify even over a period of one decade because of the sharp fluctuations in yield due to weather. Thus, whether or not there has been an increase in production, trend is debatable. But the new rice technology has made it possible to maintain past trends in production at a time when it was becoming increasingly difficult and more costly to develop new land areas for cultivation.

Another way to view the contribution of the new rice technology to production is to ask what the trend in yield might have been without the new varieties. Table 1, based on Philippine data, indicates that production attributable to the increased yield of the modern varieties was about 20 percent after a period of 7 years, or about 2.7 percent compounded annually.

Growth in production has been maintained not simply by applying fertilizer to new varieties, but by a rather complex shift in factors. Figure 1 illustrates the contribution of yield and area to increased rice production. The rate of change in all four factors determines the rate of growth in production. The new rice technology contributes to production growth: (a) through varieties which respond to an increased level of inputs, (b) by stimulating irrigation investment and (c) through the development of short season varieties which makes it possible to increase cropping intensity. Table 2 shows how each of the four factors in Figure 1 has contributed to production increase in the Philippines. While the yield growth is 3.1 percent per annum in the period 1965 to 1972, the contribution of irrigation development (better quality of land) accounts for 1/3 of this. Furthermore, the decline in land area (mostly upland rice) has been more than offset by an increase in double cropped area, so that the total cropped area (first plus second crop) has remained almost constant.

The contribution of area and yield to rice production growth is shown for South and Southeast Asia in Table 3. Yields have not risen as rapidly nor the net growth in land area declined as much in these two regions as a whole compared with the Philippines. However, Figure 2 indicates that the shifts in land area, area irrigated, and area double cropped are occurring in much the same direction as in the Philippines. That is to say, the area in upland rice appears to be declining while the area irrigated and double cropped is expanding.

In projecting the annual growth in yield, we have used the classification of land based on water control conditions shown in Figure 2. The Philippines is the only country in South and Southeast Asia which reports yield data annually for irrigated, rainfed, and upland areas. A five-year average of yields centered in 1965 and 1972 shows that over this eight-year period yields rose by 2.5 percent in the irrigated areas and by 2 percent in both the rainfed and upland areas. Based on these figures and our judgment as to conditions in the rest of Asia, we projected the annual yield increases shown in Table 4. We anticipate that varieties better suited to rainfed, upland, and deep water conditions will be released over the next decade, but because of the generally lower level of inputs used in these unirrigated areas, growth rates will continue to be lower than for the irrigated areas. In general, we would expect under favorable conditions a gain in total production of 3 percent per annum keeping pace with the growth in demand. One half to two thirds of this growth will come from higher yields and the remainder from expansion in the area double cropped.

Table 1. Percent area, production, and yield of modern varieties (MV) and percent gain in production attributable to MV annually, Philippines, 1967/68 - 1971/72.

Year	(1) Total area in MV (%)	(2) Total production in MV (%)	(3) Yield gain of MV over TV (%)	(4) Gain in production due to MV Col. (1) x Col. (2) (%)
1967/68	21	27	35	7
1968/69	41	41	33	13
1969/70	44	49	25	11
1970/71	50	55	20	10
1971/72	56	63	34	19
1972/73	54	62	39	21

Source: Bureau of Agricultural Economics.

Table 2. Growth in production, area, and yield of rice, Philippines, 1960-73.[a]

	1960-65	1965-73	1960-73
Growth rates:			
Production	1.8	3.4	2.8
Area	-0.4	0.6	0.2
Yield	2.5	2.8	2.7
Land Area	-0.6	-1.2	-1.8
Double Cropping	0.2	1.8	2.0
Quality of Land[b]	0.3	0.6	0.9
Residual[c]	2.2	2.2	1.8

Source of data: [a] Philippine Government, Bureau of Agricultural Economics, based on 5-year averages.

[b] Proportion of area in upland, rainfed, and irrigated rice.

[c] Fertilizer, HYV's, etc.

Table 3. Annual growth in rice production, area and yield in South and Southeast Asia.

	Production		Area		Yield	
	1953-63	1963-73	1953-63	1963-73	1953-63	1963-73
Southeast Asia	3.0	2.6	1.6	0.7	1.4	2.0
South Asia	3.6	1.8	1.2	0.7	2.3	1.1
Total	3.3	2.2	1.3	0.7	2.0	1.5

Source: FAO, based on 4-year averages.

Table 4. Estimated annual percent growth in yield per hectare of rice due to new varieties and improved technology, 1976 to 1985.

Ecological Zone	Input Level Low	High
Irrigated	2	3
Rainfed	1-1/2	2-1/2
Upland	1	2
Deepwater	1	2

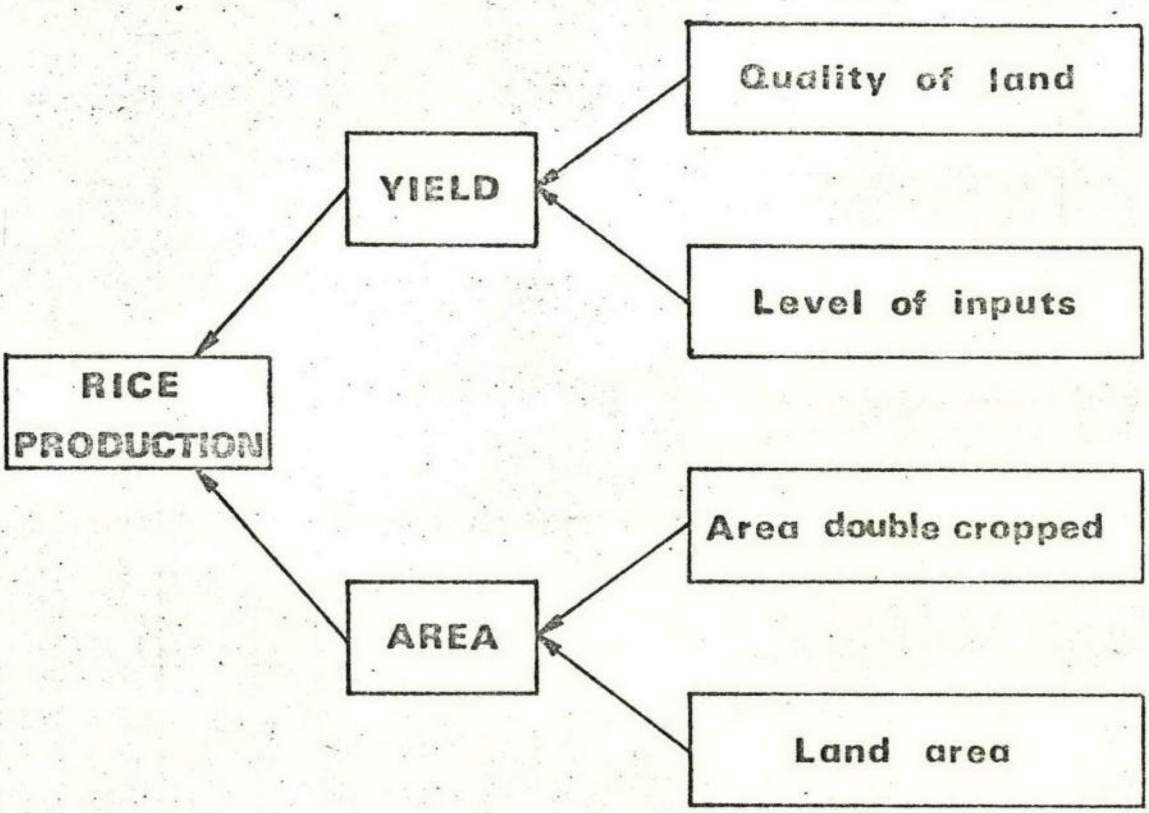


Fig. 1 Contribution of yield and area to rice production.

→ with letter dated January 24, 1976

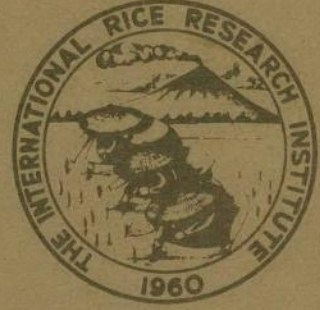
ATTACHMENT 1

THE INTERNATIONAL RICE RESEARCH INSTITUTE

W

RESEARCH AND TRAINING PROGRAMS

OBJECTIVES, ACCOMPLISHMENTS, AND FUTURE PLANS



Prepared for
QUINQUENNIAL REVIEW OF IRRI'S PROGRAMS
November 22 - December 14, 1975

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DIRECTOR'S FOREWORD

GUIDELINES FOR THE DEVELOPMENT OF IRRI'S RESEARCH AND TRAINING PROGRAMS[1]

The International Rice Research Institute (IRRI) was established in 1960 under the joint sponsorship of the Government of the Philippines and the Ford and Rockefeller Foundations. The purpose of the Institute as identified in the Articles of Incorporation of the Institute are as follows:

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

1. To conduct basic research on the rice plant, on all phases of rice production, management, distribution, and utilization with a view of attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas through improvement in quality and quantity of rice;
2. To publish and disseminate research findings and recommendations of the Institute;
3. To distribute improved plant materials to regional and international research centers where they might be of significant value or use in breeding or improvement programs;
4. To develop and educate promising young scientists, primarily from South and Southeast Asia, along lines connected with or relating to rice production, distribution and utilization,

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[1] N. C. Brady

through a resident training program under the guidance of well-trained and distinguished scientists;

5. To establish, maintain and operate an information center and library which will provide, among others, for interested scientists and scholars everywhere, a collection of the world's literature on rice;
6. To organize or hold periodic conferences, forums and seminars, where international, regional, local or otherwise, for the purpose of discussing current problems.

The Institute is administered by a 15-member self-perpetuating Board of Trustees who make basic policies aimed at achieving these objectives. There are 48 senior staff positions at the headquarters in Los Baños, 36 of whom are senior scientists. They are complemented by IRRI's international (outreach) program staff which currently involves 20 senior staff positions.

The Ford and Rockefeller Foundations have been joined by 9 national and international organizations as financial donors to the Institute. These donors cooperate through an informal association, the Consultative Group on International Agricultural Research (CGIAR).

The first decade

The first decade or so of IRRI has been characterized by the Institute's first director, Dr. Robert F. Chandler, Jr., as having the following characteristics:

1. It was "a complete plant science research institute devoted exclusively to rice."

2. It emphasized from its inception problem-oriented research without at the same time entirely eliminating more basically-oriented research.
3. Its program implementation required "a team approach to the solution of rice-growing problems."
4. It had a truly international staff, scientists from seven countries making up the initial staff complement.
5. It had truly international program concepts and scope which involved training as well as research.
6. The Board of Trustees and the donors gave the director and his staff great flexibility and freedom to develop the research and training programs of the Institute.

The procedure for program development was rather informal during those early years. A highly qualified staff was recruited and given maximum opportunity to develop their respective programs. Informal discussions and frequent interchanges between the director and his staff in the field, in the laboratory, in the corridors, and around the coffee table were the primary vehicle for decisions relating to program development. This interchange helped develop a good combination of scientific achievement and of dedication to the goal of helping farmers increase their rice production.

Whatever the mechanism for decisions on program goals, the Institute enjoyed a high degree of success during its first decade. The role played by IRRI scientists in helping to "re-engineer" tropical rices is well known. Its first varietal release, IR8, was proclaimed a "miracle" rice because of its ability to respond to water and chemical inputs. This accomplishment was so striking as to give a false sense of security to many who did not fully understand the complexities of the biological as well as social and economic problems to be solved if widespread increases in rice production were to become a reality. Fortunately, rice researchers both at IRRI and in the national programs took advantage of the temporary respite given by IR8 and its companions in national programs to begin the development of rices and associated technologies which would be widely adapted to the various ecological situations where rice is grown.

One of the fortunate consequences of the publicity given to developments at IRRI and at its sister institution, CIMMYT, was the growing faith in the potential of research to help solve the world food problem. Funds from both the developing nations and from outside donors were made available to increase the quantity and improve the quality of agricultural research. National research capabilities were strengthened and expanded. New international agricultural research centers were established by an informal Consultative Group on International Agricultural Research (CGIAR). This association provides an international focus on agricultural research and is now funding the work of international research centers.

Program reevaluation

Two major factors have forced some changes in the program orientation at IRRI and in the methods used to make decisions on this orientation. First, the increasing complexity of IRRI's programs and of the institutional framework in which they are to be planned and implemented has forced a more formal approach to program planning than that which characterized the first decade of the institute. The size of IRRI's staff, program and budget for the core activities at IRRI and for cooperative programs overseas increased markedly over the years. The number of donors increased from two to nine, and along with this increase came an even greater increase in fiscal and program management problems. The creation of the CGIAR brought with it requirements for standardization of budget procedures and of program justification. Such standardization, while wholly justified from the standpoint of the CGIAR, has brought about a change in program planning as well as program review procedures.

The second and perhaps even more important reason for program reevaluation at IRRI are the opportunities and challenges stemming from the marked differences between potential and actual performance of the new rices and of their associated technology. The opportunities come from the established potential of the rice plant to produce several fold times as much as is actually being produced in farmers' fields. They come from the realization of the marked genetic variation in the world's rices and the potential this offers to develop rices with specific suitability for the different ecological regions in which they are grown.

Another opportunity is the prospects of greater production through rice cropping systems which can fully utilize the climatic soil and water resources in rice growing areas. Research in national centers and at IRRI has demonstrated the potential but this potential has not been utilized under conditions faced by farmers.

One of the challenges is to help move to the farmers' field the rice production potential which is known to exist. In the Philippines, farmers' yields are 1/3 to 1/2 of those which are common at experiment stations, and 1/5 the maximum yields which have been obtained. Similar differences exist elsewhere. Scientists are challenged to determine why this difference exists and what can be done to eliminate it.

Analysis of current programs

The first step taken to reevaluate current programs and to develop future program orientation was to classify and quantify research now under way at IRRI. Utilizing the framework of interdisciplinary work already in progress, a problem-oriented classification scheme was established. The work was classified in terms of eleven major research and training problems which in turn were broken down into 45 problem areas. The specific problems and problem areas are shown in table 1. along with the percentage distribution of the 1976 research and training budget being allocated to the major research problems.

Constraints on crop yields and production

The second step for program evaluation and reorientation is to ascertain factors constraining crop yields and production, and to determine what might be done to remove these constraints. Many of the major constraints are already known. Diseases, insect and weed damage, water management, and nutrient deficiencies or toxicities are examples. Unfortunately, however, the relative importance of these constraints, their significance in different ecological situations and their interaction with equally constraining economic and social factors are not known. Furthermore, since most research has been done at experiment stations under conditions of at least partial control of limit factors, the technology developed at these stations may not be effective on the farmers' fields. Thus, in addition to the traditional "lag in adoption" factor which requires additional extension education inputs, there is a "lack of knowledge" factor which requires research under conditions wherein the limiting factor exists, i.e. on the farmer's field.

To obtain a better picture of the agro-economic constraints on rice yields and production, IRRI scientists took two steps. They formulated an interdisciplinary approach here in the Philippines to develop and test out methods of ascertaining and quantifying agro-economic constraints, and they cooperated with counterpart scientists in a number of national programs to develop a network of collaborating scientists to work on this problem. Each national group run its own experiments but there is international cooperation in planning the tests, in training to do the research, and in comparing and publishing the results once they have been obtained. In all cases, emphasis is placed on studies on farmers' fields.

Interdisciplinary approaches

The problems faced by farmers are so varied and complex as to demand interdisciplinary approaches to their solution. During the past two years, IRRI has formalized somewhat long existing interdisciplinary efforts to attack rice problems. The approach IRRI is using was explained in the institute's "Research Highlights for 1974" as follows:

> "Our two largest teams are those concerned with the Genetic Evaluation and Utilization (GEU) program and with the Cropping Systems program. Together, they account for more than half of IRRI's total research and training efforts. The GEU program illustrates how the approach is being used.
>
> Genetic Evaluation and Utilization (GEU) program
>
> The GEU program is an interdisciplinary rice improvement effort linked with similar national programs in Asia, Africa, and Latin America, to jointly develop and evaluate improved rices and technology for all rice-growing areas. The GEU program builds on the success of the semidwarf varieties that have so remarkably increased production in those areas where farmers are assured of water control and adequate chemical inputs.

The GEU teams

Through the GEU program, nine interdisciplinary teams of plant breeders and problem-area scientists, such as pathologists, entomologists, agronomists, and soil chemists, are working together to develop rices that are genetically adapted to each of the major types of growing conditions in which rice is produced.

The problem areas for which GEU teams are seeking improved rice are:

- o agronomic characteristics;
- o resistance to insects;
- o resistance to diseases;
- o resistance to drought;
- o tolerance to adverse soils;
- o tolerance to deep water and floods;
- o tolerance to extreme temperatures (cold or hot);
- o grain quality; and
- o higher levels of protein

To develop improved rices, each team first identifies varieties that can withstand the major constraints to rice production within its specific problem area. Through crossbreeding, they develop large numbers of experimental lines that are resistant or tolerant to these constraints, and that have other favorable characters as well (particularly high and stable yield potential and pest resistance).

Each team member brings his specialized background knowledge into the breeding and evaluation program."

Collaboration with National Programs

IRRI scientists collaborate with their counterparts in national programs in several ways. Upon request they help strengthen the rice personnel and programs of existing institutions. In some cases, IRRI staff are assigned to work in national rice research organizations to expedite this process.

In other countries with existing strong research capabilities, IRRI's relationship is that of a collaborator. We jointly plan research and training activities of mutual benefit, some of it being done in the cooperating country and some at IRRI. This permits IRRI to work with national research scientists on problems which can be attacked better in ecological and pest hazard situations different from those at Los Baños. Research on deep water in collaboration with Thailand and on gall midge in cooperation with India are cases in point.

Networks

Some research problems can best be attacked by collaborative efforts of scientists from several countries. This is being attempted through a series of networks as described in excerpts from IRRI's Research Highlight for 1974. "The third major thrust at IRRI is to initiate and expand international networks, uniting the research and development efforts of scientists from a number of cooperating countries.

Four such collaborative networks have been established among cooperating biological and social scientists across the rice-growing world:

1. the International Rice Testing Program, which is the evaluation component of an international GEU effort;
2. the International Agro-Economic Network;
3. the International Cropping Systems Network; and
4. the Agricultural Machinery Development Network."

International Rice Testing Program (IRTP)

Elite rices generated by the GEU program and by national rice improvement programs are evaluated under a worldwide range of environmental conditions through the International Rice Testing Program (IRTP).

Each national program can nominate its best parent materials, breeding lines, and varieties for global evaluation in the 12 yield and screening nurseries. Additional problem-area nurseries may be initiated as the need arises.

Worldwide testing shows how different rices react to diverse pests, diseases, and environmental conditions, and speeds up the identification of rices with yield stability. It spreads new germ plasm to broaden the genetic base of the world's rice crop.

The operation of the program is quite simple. IRRI, as IRTP coordinator, receives seeds of varieties or lines that cooperators in national centers have nominated for inclusion in the program.

We multiply the seed and then compile it into sets, which are distributed to cooperators in country programs. The field tests are run by scientists in national programs who are familiar with local environmental conditions and with the habits, customs, and resources of local farmers.

These scientists evaluate and record how each rice yields and how each reacts to adverse biological factors, such as diseases, drought, or cold. Results are used within each national program, and duplicate sets of data from all locations are sent to IRRI to be rapidly analyzed, compiled, published, and distributed. Rice scientists around the world then study the information, select the best materials for their programs, and request seed.

The program's effectiveness is largely determined by the way that cooperators use the germ plasm and test information to strengthen their national programs.

International Rice Agro-economic Network (IRAEN)

IRRI is collaborating with scientists in several rice-growing countries to develop methodology to monitor problems that slow down the farm adoption of improved rice varieties and technology through the IRAEN.

Economists and agronomists in Indonesia, Thailand, and the Philippines are coordinating research through the IRAEN. Other nations are expected to participate in future research. They conduct experiments on farmers' fields, survey farmers to determine biological and socio-economic constraints, analyze markets and input prices, and relay their findings back to scientists in national research programs and at IRRI.

The agro-economic teams are trying to determine answers to such problems as why rice production has substantially increased in many regions where the new varieties are planted, but not in others.

Or, why many farmers who have accepted the new rice varieties do not use accompanying chemical inputs and cultural practices. These farmers' yields may have increased, but they still lag far behind potential yields proved possible in experiments.

Once answers are determined, the scientists can then tailor research to develop the varieties and technology to overcome the production constraints.

The network is a step toward an international system through which scientists can continuously monitor the adoption of improved rice technology, and can devise strategies to speed adoption. From the knowledge gained through the network, scientists will evaluate the probable impact of alternative research and development strategies.

International Cropping Systems Network

Although rice is generally the staple crop of small farmers in Asia, it is seldom their only food crop. Farmers can intercrop, or follow, rice with other food crops such as corn, soybean, mung, sweet potato, cassava, or sorghum.

Through the International Cropping Systems Network, scientists are testing different cropping patterns in farmers' fields in Bangladesh, Indonesia, Vietnam and the Philippines.

To ensure that the technology developed will be within the management capabilities of small farmers, cropping systems research trials are conducted in farmers' fields, under farmer management.

The experimental sites represent the environmental conditions of specific "agro-climatic zones," or areas of similar soil, climatic, and cultural conditions. Knowledge gained at each experimental site can then be shared and used throughout the agro-climatic zone, speeding the transfer of technology among nations.

Because we are studying rice-based farming patterns, the Cropping Systems Network must be coordinated with the GEU and with the International Rice Testing programs, and the Agro-Economics and Farm Machinery Development Networks.

Cropping patterns revolve around the best available rice varieties for each agro-climatic zone. As scientists continue to shorten the growth durations of improved rices, the farmers' potential to produce more food increases. For example, modern varieties such as IR28 and IR30 mature in 115 days -- from 1 to 2 months earlier than traditional varieties. The short growing seasons leave the farmer adequate time and soil moisture during the late monsoon season to grow other crops.

Work plans for the network are developed jointly with scientists from cooperating national programs. A cropping systems working group has met at IRRI to determine common guidelines for cooperative research.

Farm Machinery Development Network

To intensify food production, farmers in the developing nations need tools and technology to speed certain production practices, such as land preparation, threshing, and drying. The need will increase as more farmers shift to short-season varieties and multiple cropping.

Much of the machinery developed for large-scale farming in the more developed countries is not suited to the needs of farmers in the rice-producing nations. The machines may be too costly and complex. Or, they may be far too large to meet the needs of farmers with less than 10 ha. Furthermore, they cannot be economically manufactured in low volume in the developing countries because they are designed for capital-intensive mass production. They are hard to service and to maintain because of difficulties in obtaining spare parts.

To help fill this technology gap, IRRI cooperates with a network of national research organizations, manufacturers, and engineers in Asia, Latin America, and Africa.

The philosophy of the network is to develop appropriate mechanization technology for small farms and to encourage local manufacture of suitable farm machines by small metalworking firms.

How the program works. IRRI scientists identify the most pressing production problems in farmers' fields and develop appropriate farm machines to overcome the production constraints.

To encourage local production, IRRI release the designs free to cooperating manufacturers who want to produce and sell the machines.

Local manufacture of farm equipment generates employment. Equally important, indigenous production saves foreign exchange in the developing nations.

IRRI scientists maintain cooperative relationships with local manufacturers. We have found that small metal-working shops often modify the basic IRRI designs to better suit the machines to their specific local conditions.

IRRI provides ongoing technical consultation to ensure machine "quality and performance."

The formation and function of the networks

Perhaps the most unique aspect of the network concept being utilized by IRRI is the degree of involvement of scientists in national programs in setting up and implementing the network. The procedure by which this is done is illustrated by the statement of procedure to be used in the cropping systems network.

"The expanded cropping systems research program at IRRI is based upon the concept that field research must be done under different agro-climatic conditions if principles applicable over wide areas are to be established. For those agro-climatic situations located other than at or near IRRI headquarters, the research will be planned and implemented in collaboration with country scientists. Hopefully, this collaborative research will be tied in closely with overall national cropping systems programs so the results of the collaborative research can be quickly fed into national systems.

The general procedure which will be followed in developing plans for the basic experimental approach to be used at each location is as follows:

1. On the basis of existing agro-climatic knowledge or of such knowledge that might be gained through specific short-term agro-climatological studies, preliminary selections will be made of agro-climatic zones in which research should be initiated.
2. The project leader and/or network coordinator will have preliminary discussions with appropriate national research administrators and scientists to ascertain their interest in participating in the network program. If there is genuine interest on the part of the national leaders to develop a collaborative program, IRRI representatives will work with them to identify the scientists who would serve as program collaborators with whom the details of the collaborative

program are to be worked out.

3. To develop general plans for collaborative experiments to be implemented in the different agro-climatic zones, IRRI will invite the collaborating scientists to participate in a preliminary planning workshop. Other workshop participants may also be invited if specific expertise not readily available from IRRI or from the cooperating countries is needed.
4. On the basis of general plans developed at the planning workshop, the IRRI program leader and network coordinator will develop more specific plans with each country, including the outside budgetary requirements, if any, that may be needed to implement the program. These negotiations will be on a country basis since the financial and seasonal requirements for research will likely differ from one country to another. Concerted efforts will be made to obtain resources for the cooperators from within the country.
5. With the assistance of IRRI's network coordinator, the jointly planned research will be initiated and implemented in each of the cooperating countries.
6. Meetings or workshops will be held at least annually to review research results, to evaluate and where appropriate modify the general research program and to develop jointly annual work plans. As with the initial planning workshop, participants will include, in addition to the collaborators and IRRI

scientists, selected outside scientists with expertise needed on specific topics. While perhaps two of these outside participants may be regular invitees, more often, they will be ad hoc participants, providing expertise for only a given meeting.

It is hoped that these annual planning sessions can be held in conjunction with symposia or conferences on cropping systems at IRRI to which a broader audience of scientists will be invited. The annual work planning session could be held before or after such symposia.

7. If funds are available, it would be desirable to hold additional meetings of the collaborators at locations within the cooperating countries where the collaborative research work is under way. It is expected that these meetings would be held in a different country each year and would give the cooperators an opportunity to see each other's work and thereby learn from each other."

General guiding principles

There are several guiding principles with IRRI uses to judge the relevance and importance of different research/training areas. Included are the following:

1. IRRI's primary research/training efforts should be oriented to helping the small rice farmer and, in turn, the low income farmers who consume rice. This requires program orientation toward fierce farmers and consumers in addition

to emphasis on the rice plant and the rice crop. Programs such as those dealing with GEU and cropping systems have such orientation.

2. IRRI's research/training efforts should be production oriented, giving emphasis to other problems only insofar as they have at least an indirect bearing on rice production. An institute of the size of IRRI would lose its effectiveness if it did not maintain a rather sharp focus on production problems.
3. IRRI's research/training efforts should focus on those problems for which we have expertise to help solve and on which we may be able to work more efficiently or effectively than others. In general, if others are better qualified to do the work we encourage them to do so. However, this principle helps reduce IRRI's competition with others in subject areas wherein adequate expertise and managerial ability already exist to carry out a given research/training activity.
4. IRRI's research/training activities must be aimed primarily at problem-solving. They include only those basically oriented activities needed to solve the problem. We encourage basic research, however by collaborating with others in both developing and the more developed countries who may have the expertise resources and orientation to basic research.

5. <u>IRRI's research/training programs' orientation is determined by combined inputs from IRRI's scientists, administrators, and Board of Trustees as influenced and guided by visiting scientists and administrators, donor representatives and special review teams</u>. Implementation of research once conceived and planned however, is done by the scientists.
6. <u>IRRI's research/training efforts should be such as to favorably influence the production of rice in countries throughout the world where this crop is grown</u>. This influence can be best actualized through the development of effective working relationships with scientists in national programs. Simultaneously, it is IRRI's goal to act as a catalyst to encourage scientists from different countries to work together.

INTRODUCTION

INTRODUCTION

Rice is the world's most important food crop and serves as the staple diet of over half of the world's population. It is grown on over 130-million hectares, the largest area under any single crop. Ninety percent of the total area under rice is in the developing tropical and subtropical countries where population densities are among the highest and per capita incomes among the lowest in the world. In these areas rice has been traditionally grown as a subsistence crop with few production inputs. Consequently average rice yields generally range between 1.2 to 1.8 t/ha in contrast to about 5.0 t/ha or more in the developed countries.

Visualizing the potentials for improving the rice production in the developing countries and the impact it will have on the vast humanity in these areas, the International Rice Research Institute (IRRI) was established in 1962. Initially, IRRI concentrated on increasing the yield of high quality rice, especially that grown under irrigated conditions. In recent years work has been broadened to include research on rainfed and upland rice and on cropping systems in which rice is grown.

IRRI has two primary functions - research and training. These are implemented thru: (1) the core program and (2) the outreach or cooperative country programs.

The core program is conducted mostly at Los Baños. It includes the centrally planned and coordinated research aimed at increasing rice yield potentials and removing constraints on yields. This research is expected to have wide adaptability and to be useable by all countries where rice is grown. A few components of the core program conceived with agroclimatic conditions and problems that do not occur at Los Baños are carried out at other locations in the Philippines and abroad.

The cooperative country programs are developed to permit formalization of two-way cooperation on rice research, to provide assistance to the country programs in specific research and training areas, and to carry out core activities which can not be done in the Philippines.

With its group of dedicated scientists, availability of modern research facilities and cooperation of scientists working in various rice growing areas, IRRI has made impressive technological advances in rice production. The development of a series of high yielding, pest and disease resistant varieties and the complementary production practices have brought about significant yield increases in many areas. These accomplishments have demonstrated that rice yields in the tropics can be truly increased and have acted as a catalyst for more intensive research.

In the initial stages, the IRRI program was organized with regard to various scientific disciplines, such as agronomy, entomology, plant pathology, plant physiology, etc. But as we progressed in our various research endeavours the need for greater interdisciplinary research coordination became more and more obvious. The low rice yields in the tropics and subtropics are due to a diverse series of causes and problems outside the control of the average farmer. In many instances rice is grown where no other crops will grow. These include areas with rainfall as a sole source of water, valleys and lake shores where water accumulates to a depth of several feet, terraces on mountain slopes, and in soils that are only marginally suitable even for rice. The problem is further exacerbated by a series of pests and diseases which abound the warm and humid environment optimum for rice cultivation.

Thus, an integrated development on all these aspects is essential to obtain a sustained increase in rice production. Therefore, we reorganized our research efforts to provide more integration and formal collaboration of inputs by the various scientists into the following programs:

RESEARCH PROBLEM AREAS

100 GENETIC EVALUATION AND UTILIZATION OF RICE
    101 Germ Plasm Resource and Conservation
    102 Agronomic Characteristics
    103 Grain Quality
    104 Disease Resistance
    105 Insect Resistance
    106 Protein Content
    107 Drought Resistance
    108 Adverse Soil Tolerance
    109 Deep Water and Flood Tolerance
    110 Temperature Tolerance
    111 International Testing Program
    112 Integrated Breeding Program
200 CONTROL AND MANAGEMENT OF RICE PESTS
    201 Diseases
    202 Insects
    203 Weeds
    204 Others

300 IRRIGATION WATER MANAGEMENT

400 SOIL AND CROP MANAGEMENT FOR RICE

    401 Soil Characterization

    402 Nutrient Supply and Management

    403 Soil-Water-Plant Relations

500 ENVIRONMENT AND ITS INFLUENCE

600 POST-HARVEST MANAGEMENT OF RICE

    601 Drying

    602 Processing

    603 Distribution and Marketing

700 CONSTRAINTS ON RICE PRODUCTION

    701 Socio-Economic Constraints

    702 Management Constraints

    703 Institutional and Policy Constraints

800 INCREASING RICE YIELD POTENTIALS

    801 Basic Research

    802 Others

900 CROPPING SYSTEMS

    901 Environment and its Influences

    902 Pest Control

    903 Soil and Crop Management

    904 Socio-Economic Constraints

1000 MACHINERY DEVELOPMENT AND MANAGEMENT
    1001 Control and Management of Pest
    1002 Irrigation Water Management
    1003 Soil and Crop Management
    1004 Post Harvest Management
    1005 Cropping Systems
1100 CONSEQUENCES OF NEW TECHNOLOGY

RESEARCH PROBLEM AREAS

100 GENETIC EVALUATION AND UTILIZATION

101 Germ plasm collection and maintenance

Assemblage of rice germ plasm on a world wide basis, to acquire new collections including appropriate participation in collections, to increase seed stocks, characterize and preserve the acquired samples, proper cataloguing of the acquired accessions, identification and removal of duplicates, to provide duplicate storage to other seed banks, to rejuvenate seed stocks when needed, to provide seed to various researchers throughout the world.

102 Agronomic characteristics

Agronomic characteristics of the improved rice plant that ensure productivity and adaptability under varying cultural and ecological conditions. The main characteristics to be investigated are: dwarf and semi-dwarf statures, high tillering capacity, relatively short, dark-green and upright leaves, early vegetative vigor, appropriate growth durations, photoperiod sensitivity, threshability, but non-shattering grains and grain dormancy.

103 Grain quality

Grain size and shape, milling quality and high recovery of head rice, absence of white belly, appropriate amylose content (waxy, low, medium and high amylose contents), gel consistency, cooking and eating quality. Physicochemical description of grain qualities preferred by consumers, effect of environmental conditions on these qualities.

Development of simple, rapid and reliable tests for these characteristics. Effect of various pre-harvest and post-harvest operations on grain quality (for example: time of harvest, parboiling, etc.).

104 Disease resistance

Standardization techniques and evaluation of the rice germ plasm for resistance to common diseases. Nature and cause of resistance, inheritance of resistance, diverse sources of resistance. Stability of resistance -- horizontal resistance, international disease nurseries to determine pathogen races and effect of environmental factors on resistance and breeding for resistance.

105 Insect resistance

Sources of resistance to common insect pests in the rice germ plasm collection. Nature (non-preference, antibiosis, tolerance) and cause (biophysical, biochemical) of varietal resistance, insect biotypes, genetics of resistance to the current insect populations and to new biotypes. To develop isogenic and multi-genic resistant lines. Lines resistant to several insect pests species. Breeding for insect resistance.

106 Protein content

To improve the protein content of milled rice while maintaining grain yield, grain quality, and other desirable characteristics. The effects of genotype, environment and their interactions on protein content. Effect of protein contents on grain quality. Inheritance of protein content.

107 Drought resistance

Screening of varieties for drought resistance. Evaluation of drought resistance at different stages of plant growth. Physiological base of drought scape, avoidance, tolerance and recovery in different varieties. Effect of drought on plants. Role of root elongation stomatal closer, rolling of leaves and presence of waxy layer on leaf surface in drought tolerance.

Breeding for drought resistance, evaluation of selected lines/ breeding materials under different agro-climatic conditions. International upland rice trials.

108 Adverse soil tolerance

Screening of varieties for their tolerance to common adverse soils. Plant characters attributing tolerance to adverse soils. Inheritance of tolerance to adverse soils. Effects of different agroclimatic conditions on tolerance of plants to adverse soils. Breeding for tolerance to adverse soils.

109 Deep water and flood tolerance

Determination of factors limiting grain yields of deep water rice and conceptualize the "improved plant type" for deep water rice.

Screening of rice varieties for their ability to elongate with increasing depths of water and to tolerate submergence. Mechanism and inheritance of deep water and flood tolerance. Breeding for deep and flood tolerance. Emphasis will be to develop semi-dwarf and intermediate height varieties with "elongation genes" for growing in 1-5 m deep water, and with other desirable attributes such as appropriate photoperiod sensitivity and resistance to pests, diseases, adverse soils, drought and other common problems.

110 Temperature tolerance

Screening of rice varieties for their tolerance to high as well as low temperatures at different stages of plant growth. Effect of non-optimum temperatures on plant growth, sterility and other yield components. Inheritance of temperature tolerance. Breeding for temperature tolerance.

200 CONTROL AND MANAGEMENT OF RICE PESTS

201 Diseases

Survey to determine relative importance of various diseases (virus, bacterial and fungal). The life cycle of various diseases and their alternate host plants, epidemiology of diseases, occurrence of pathogen races. Forecasting of disease epidemics. Assessment of yield losses. Various methods of disease control (excluding varietal resistance).

202 Insects

Life cycle and bionomics of various rice pests, their population dynamics and factors of abundance. Techniques for field sampling of pest populations, assessments of yield losses caused by insects and forecasting of pests occurrence.

Biological, Cultural, Insecticidal and Autocidal (sex pheromone, sex sterilant, etc.) methods of insect control. Integrated method of pest control or population management.

203 Weeds

Weed fauna of rice fields of different water regimes, and agro-climatic conditions. Life cycle of weeds, mode of spread. Cultural, biological and chemical methods of weed control. Integrated method of weed control. Degradation of herbicides.

300 IRRIGATION WATER MANAGEMENT

301 Irrigation systems

Efficiency of different irrigation systems -- canal, pump, irrigation systems from ponds, lakes, rivers, subterranean water, manual or animal powered lift of water from various sources. Government vs. private operated irrigated systems. Adequacy, frequency and economics of water supply in each system. Maintenance of canals and their distributaries. Instrumentation for measuring water flow.

302 Farm delivery systems

Gravity delivery systems vs. water-lift delivery systems. Rotational and continuous irrigation, adequacy of water availability, water distribution in fields located near and away from distribution canals. Socio-economic factors affecting water allotments to different farms.

303 Response of crop to irrigation

Impact of water stress on yields, time and duration of moisture stress. Interrelationships between solar radiation, soil properties, temperature, variety of rice and moisture stress. Loss of nitrogen during moisture stress. Efficient and timely land preparation.

Models for appropriate water needs under different agro-climatic conditions.

400 SOILS AND CROP MANAGEMENT FOR RICE

401 Soil characterization

Chemical kinetics of upland, flooded and problem soils. Chemical, physico-chemical and biochemical changes occurring in soils on alternate flooding and drainage. Amelioration of problem soils. Chemical changes in soils subjected to different organic matter incorporation and water management practices. Nitrogen transformation in soils.

402 Fertility and management

Nitrogen efficiency in flooded and upland rice fields, devising management practices for increased fertilizer efficiency in rice, effect of cultural practices on moisture and nutrient conservation. Fertility changes under intensive cropping. Microbial fixation of nitrogen in rice rhizosphere -- differences in nitrogen fixation in the rhizosphere of different varieties, identification of nitrogen-fixing microbes and methods to enhance their efficiency. Nitrogen immobilization and remineralization of straw amended soil. Effect of various agro-climatic conditions on fertilizer efficiency.

403 Soil-water plant relations

Description of the soil, plant and atmospheric water status under which rice is grown. Physiological effects of water deficits on the growth and yield of rice. Water requirements of the rice plant under diverse agro-climatic conditions. Interactions of drought, soil, temperature and other factors.

404 Tillage

Land preparation. Effect of various tillage operations on soil texture, conservation of nutrients and moisture. Puddled vs. non-puddled soils, appropriate management of different kinds of soil.

405 Crop culture

Methods to increase rice productivity per hectare per day where water control is good. Studies involve early maturing varieties, zero minimum tillage techniques, direct-seeding, transplanting, and ratooning of rice.

500 ENVIRONMENT AND ITS INFLUENCE

501 Descriptions of environment

Geographical distribution of rice. Physical parameters of the distinct environments in which rice is produced. Weather characteristics of the major rice producing areas of the world. Descriptions of the microclimate and macroclimate in a variety of rice environments, to compare the two, and to establish patterns for reference by the biological scientists.

502 Crop response to the environment

Effects of major climatic factors such as temperature, rainfall, solar radiation and day length on growth and yields of rice. Effects of water supply, simulated rainfall and water table depth on root characteristics of rice varieties. Effect of climatic factors on field reactions to diseases and insects, and protein content in lowland and upland rice. Effects of light and temperature on photosynthesis and rhizosphere nitrogen fixation.

503 Agroclimate and farm productivity

Delineation of agroclimatic rice zones by both weather characteristics and socio-economic environment. Description of the physical and economic environments of rice farms in selected major rice producing areas. Basic statistics related to rice production, land use, fertilizer use, rice consumptions, and use of new technology for important rice nations.

600 POST HARVEST MANAGEMENT OF RICE

601 Storage

Qualitative and quantitative nature and pattern of grain losses during storage as paddy and/or milled rice. Technical and economic characteristics of currently employed grain storage techniques at the farm, mill, and marketing stages of the post-harvest sequence of operations.

602 Processing

Evaluation of alternative processing technologies to determine their economic and technical efficiency, their utility in relation to household milling requirements in rural areas, the potential for improved milling recoveries, the incentive structure facing rice milling on the resulting quality and quantity of milled rice and by product utilization.

603 Distribution and marketing

Economic and technological impediments and incentives perceived by farmers, millers, and marketing agents and their overall impact on the availability of consumable rice. Determination of the extent to which technical and economic production and marketing system result in a greater marketable surplus of rice being made available to urban as contrasted to rural consumers.

700 CONSTRAINTS ON RICE YIELDS

701 Socio-economic constraints

Socio-economic environments impeding farmers from utilizing the best available rice technology.

702 Management constraints

Biophysical factors which limit yield in farmers' fields. For example: problem soils, abundance of pests and diseases, non-availability of irrigation water, etc. Methodology for measuring farmers' yields, potential yields and the factors responsible for the differences between these two.

703 Institutional and policy constraints

Government policies regarding price of rice. Availability of credits and various farm inputs -- fertilizers, pesticides, etc. Relative cost of increasing rice production through expanding cultivation compared to increasing intensity of production.

800 INCREASING RICE YIELD POTENTIALS

801 Basic research

The current knowledge on physiology rice yields indicates that rice yield can reach about 16 t/ha in dry season and 9 t/ha in wet season. The various factors that can contribute to increase the maximum current yields of about 10 t/ha during dry season and 7 t/ha during wet season will be investigated. Some of these are sink size (grain number per sq m x 1,000 grain weight), duration of panicle development, heavy grains, hormonal control of partitioning of photosynthetate between young panicles and leaves before anthesis and increasing panicle size by hormonal control. To increase photosynthetic efficiency, preferably by controlling photorespiration.

802 Others

900 CROPPING SYSTEMS

901 Environment and its influence

Delineation and mapping of different agro-climatic zones in potential cropping systems (using rice as at least one crop) areas. The major emphasis will be on amount and distribution of rainfall, water regimes, soil characteristics, temperature and wind velocity. Survey of institutional environment -- market, farm size, labor availability, etc. Utilization of this information for modelling different cropping systems.

902 Pest control

Occurrence and intensity of various pests -- insects, mites, nematodes, weeds, rodents, birds, etc. Effect of different cropping systems and cultural practices on pest populations. Factors of abundance for different pests. Assessment yield losses and determinations of thresholds of pest populations. Role of resistant varieties and cultural practices in pest control. Pesticidal control. Pest management under different agro-climatic conditions.

903 Soil and crop management

Development of cropping patterns for different agro-climatic zones. Relay and intercroppings. Effect of various cropping patterns and cultural practices on soil fertility and on physical and chemical characteristics of soil. Appropriate soil management practices. Crop residual effects. Nitrogen transformation in rice fields in relation to the previous upland crops. Effect of flooding on rhizobium. Efficient use of water.

904 Socio-economic constraints

Socio-economic surveys of major agro-climatic zones to support analytical research on cropping systems. Acceptance and marketability of crops being used in cropping systems, cost and returns of various cropping patterns. Demand and price analysis of major upland crops. Systems analysis of cropping system at farm level and in major agro-climatic zones.

905 Cropping systems network

To establish a network of experimental sites in selected agro-climatic zones to test various aspects of different cropping systems and to train research and extension workers.

1000 MACHINERY DEVELOPMENT AND EVALUATION

1001 Systems analysis

To integrate and analyze in a series of models all relevant environmental, economic, technical and institutional factors affecting rice production and post-production decisions related to output and resource use. To identify and quantify the nature and degree of constraints which may be alleviated through the introduction and use of improved technologies and management, including mechanization.

1002 Control and management of pests

To develop machines and methods to improve the efficiency and reduce the costs of controlling pests and diseases in the production and processing of paddy.

1003 Irrigation and water management

Development of machines and techniques to improve the measurement, control, distribution, and utilization of irrigation water for rice and crops grown in conjunction with rice.

1004 Soil and crop management

Development of efficient and low cost machines to improve resource productivity in land preparation, planting, fertilizer application, and harvesting of rice.

1005 Post harvest management

Development of improved small-scale processing equipment -- threshers, driers, mills.

1100 CONSEQUENCES OF NEW TECHNOLOGY

1101 Output and productivity

Interrelationships between rice production, other crops production, non-farm activities, and expenditures. Examine in less detail similar information for a broader cross section of farm units. Calculate the share of income going to land owners, labor and capital suppliers. Determine whether this is different for different technologies. Estimate the relevant demand and supply elasticities needed for closer empirical analysis of the impact of new technology within the context of a model already developed.

1102 Income distribution

Share of income going to land owners, tenants, labor and capital suppliers.

1103 Product and input market linkages

Demand and supply elasticities. Relationships of inputs, production, processing and product demand and the impact of alternative technological developments on the distribution of outputs from the rice sector.

GENETIC EVALUATION AND UTILIZATION

In recent years, many improved plant-type rice varieties have been released in the developing countries but still the lack of appropriate varieties appears to be a main cause of low rice yields. The short and stiff strawed, non-lodging, responsive to nitrogen and non-photoperiod sensitive varieties, exemplified by IR8, have demonstrated that truly high yields of rice can be obtained in the tropics and subtropics, and in several areas have affected substantial increases in rice production. However, much of the rice in developing countries is grown under such adverse problems as heavy incidence of pests and diseases, drought or inundated conditions, problem soils, and sub-optimum temperatures, etc., to which most of these varieties are not adequately adapted. As a consequence their cultivation has expanded to only about 25-30 percent of the rice area, which is apparently more suitable to these varieties in the developing countries. Even in much of this area, the newly developed insect and disease resistant varieties are fast replacing these earlier high yielding varieties which were not resistant.

To further expand the cultivation of modern high yielding varieties and to provide stability at higher yields even in their current areas of production, it is essential to incorporate in them genetic resistance or tolerance to various problems under which they are grown. To accomplish this, coordinated efforts by scientists representing different disciplines is necessary. Although IRRI scientists have worked together in such studies all along, to further encourage such interdisciplinary team approach, a formal Genetic Evaluation and Utilization (GEU) program was developed about two years ago. This program embodies an Institute

GENETIC EVALUATION
AND UTILIZATION

wide approach to evaluating and utilizing the genetic potential of the plant. It is subdivided into various problem areas and an interdisciplinary team consisting of a plant breeder (PB) and one or more problem area scientists (PA) provides leadership for each problem area (Fig. 1). Their objectives and general operational pattern are:

1. Joint planning and review with continuing coordination.
2. Development of efficient methods of screening.
3. Maintenance and cataloging of world's rice germ plasm.
4. Screening world collection to identify parent materials.
5. Understanding of nature and causes of pest resistance.
6. Development of biotypes capable of survival on resistant plants.
7. Genetic studies to identify diverse sources of pest resistance.
8. Development of improved sources of pest resistance.
9. Large scale hybridization.
10. Screening of hybrid materials.
11. Field evaluation and selection of breeding lines including yield trials.
12. Evaluation of selected collections and breeding lines in international nurseries.
13. Dissemination of genetic materials.
14. Release of improved lines.

The plant breeders continue to be the common core of the institute's breeding program. The problem area scientists contribute primarily through screening and testing and through special host-parasite studies (Fig. 2). This system not only allows an integration of the inputs of various problem area specialists, but the multi-discipline and multi-location testing is also expected to act as guards against release of varieties more susceptible to certain problems than the existing ones.

More specific information on each of the GEU projects is discussed in the following pages.

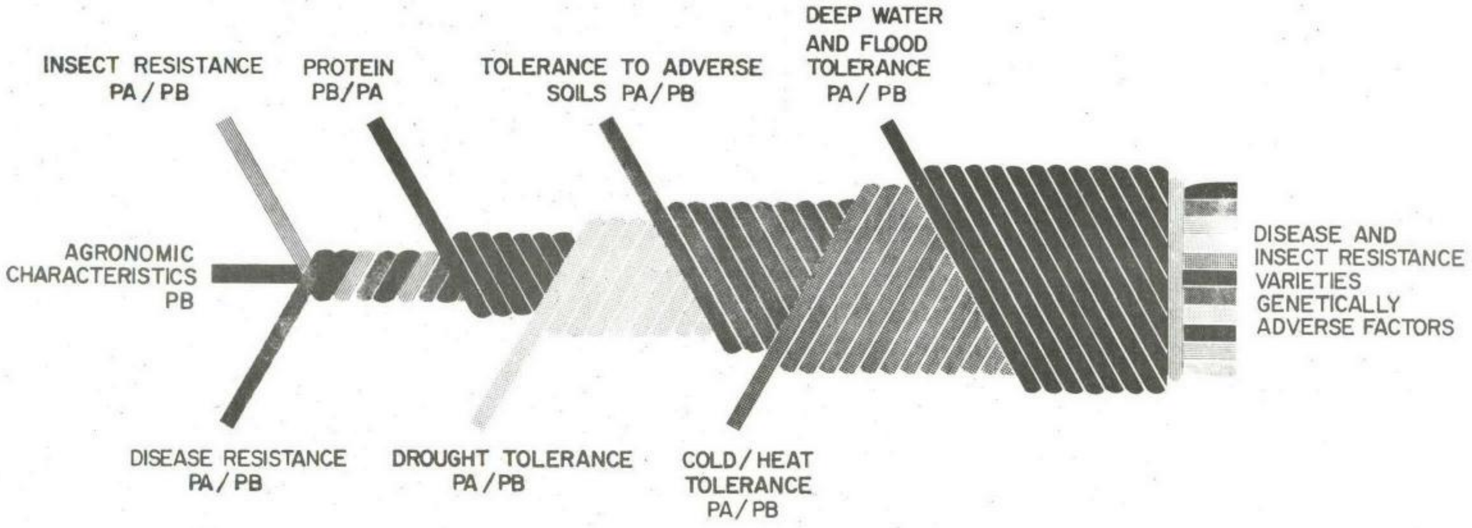

Fig. 1. The building of modern rice varieties. Disease and insect resistance and superior agronomic characteristics are the core for all varieties developed through the Genetic Evaluation and Utilization (GEU) program. Plant breeders (PB) and problem-area scientists (PA) are working together to incorporate the genetic ability to withstand other production constraints (IRRI 1973).

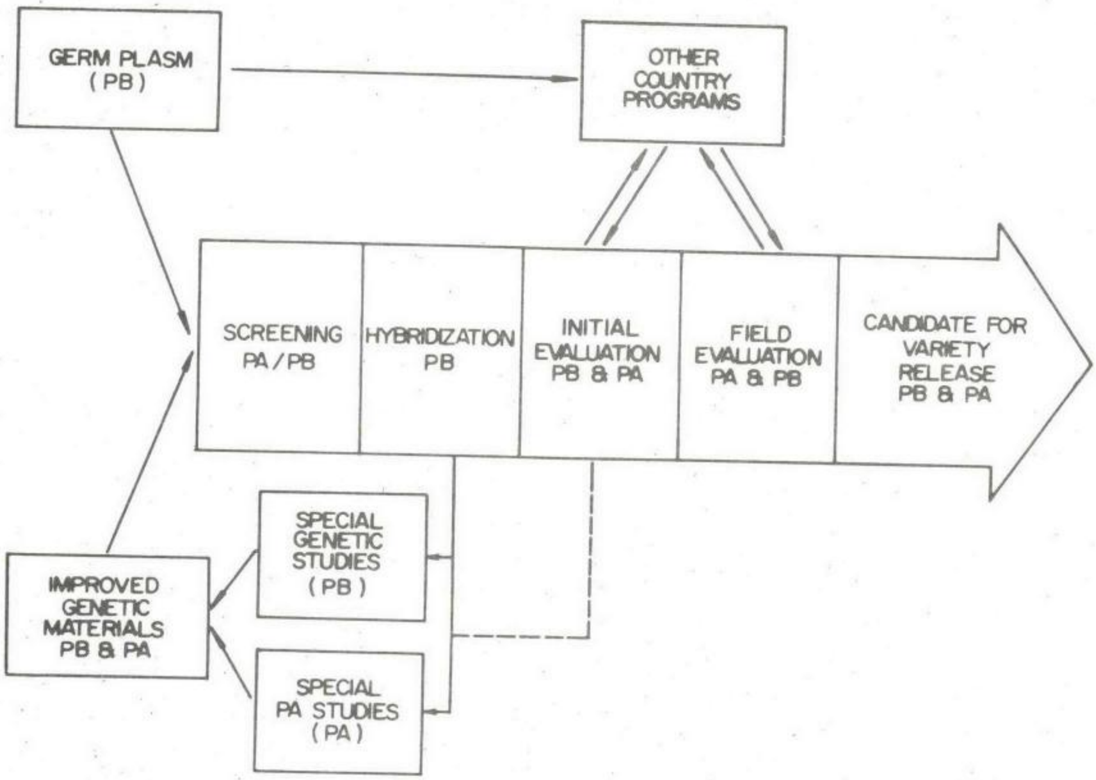

FIG. 2. GENERAL OPERATIONAL PROCEDURE OF GEU

GERM PLASM RESOURCES AND CONSERVATION[1]

Objectives and justification:

Genetic diversity is the foundation of all plant breeding programs. New genetic inputs are constantly needed to meet the ever increasing demand for food, to improve crop quality, and to stabilize crop production. We are fortunate to find in the two cultivated species, O. sativa and O. glaberrima, sufficient genetic variations to serve most of the needs of rice breeders. The wild taxa in the genus Oryza and possibly other closely related genera offer additional sources of potentially useful genes for rice researchers.

When IRRI was being established, the rice germ plasm bank project was conceived to:

1. Assemble at one international center the world's available stocks of rice germ plasm for basic and applied studies that will improve the crop.
2. Produce and preserve sufficient seed of each accession at IRRI and elsewhere to help conserve the world's dwindling stock of rice germ plasm.
3. Develop a morpho-agronomic description of accessions in the IRRI collection for a detailed catalog.
4. Supply rice researchers with needed seed, plant material, and technical information. With the collaboration of national and international institutions, the major national collections of the world were quickly acquired within a period of five years.

GERM PLASM RESOURCE AND CONSERVATION

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[1] Project Leader - T. T. Chang, Geneticist, and Genetic Resources Program Leader.

The development of many high-yielding varieties in various parts of the world during the mid 1960's heralded an urgent need to conserve numerous unimproved or slightly improved varieties which were being replaced by the HYV's in various areas. The 100 rice breeders present at the Rice Breeding Symposium in 1971 urged IRRI to assume global responsibilities for the genetic conservation of rice. IRRI has agreed to assume the role of initiating and coordinating the various activities related to genetic conservation.

After intensive field collections began in 1972, IRRI has taken on the major responsibility, as the genetic resources center for rice, in preserving the entire spectrum of collected samples through a network of collaborating institutions.

Summary of accomplishments:

Assemblage of germ plasm:

From existing national and state collections - Beginning from the establishment of the germ plasm bank, we made conscientious efforts to solicit and gather the germ plasm existing in different national and state collections. We have little over 20,000 accessions coming from such sources, consisting mainly of the principal commercial varieties, obsolete varieties, breeding stocks, and a limited number of minor varieties. This assemblage could represent the major rice producing areas of the world except for China, Burma, India, Indonesia, Japan, North Vietnam, North Korea, and U.S.S.R. However, this group is deficient in unimproved varieties having special features such as tolerance to climatic stresses or nutrient deficiencies, and the African rices (O. glaberrima).

From field collections - Since 1971 twelve countries in tropical Asia have collaborated with IRRI in field collection activities. In Bangladesh, Burma, Cambodia, Indonesia, Philippines, South Vietnam and Sri Lanka, one of the IRRI scientists joined the national workers in canvassing those areas which were known to be rich in germ plasm. Workers in Laos, Malaysia (East), Nepal, Pakistan, Philippines and Thailand also collected thousands of cultivars with technical inputs or supplies from IRRI. Financial resources for the collection activities came from the national centers and one of the outside donors: The Rockefeller Foundation, the Ford Foundation, USAID or USDA. The diverse scheme of collaboration and funding is a unique feature of the rice conservation program.

During the period from mid 1971 to late 1975, a total of 13,559 seed samples were collected of which about 5,500 samples were collected with IRRI's direct participation. About 4,170 samples were reputed to have one or more special features (Table 1). Moreover, 84 samples of wild taxa were collected. Through such participation, IRRI was able to obtain a duplicate set of the collected samples.

FAO and IRAT officers in West Africa made extensive collections for both the African and Asian rices in Ivory Coast, Liberia, Mali, Niger and Sierra Leone during 1972-74. About 2,940 seed samples were furnished to IRRI.

We have established good rapport with Japanese plant explorers who travelled extensively in India, Indochina, Nepal and Sri Lanka in recent years. The Japanese workers provided IRRI with 1,135 cultivars and 57 populations of wild taxa.

During the period from 1972 to 1975 we received a total of 23,678 seed samples of O. sativa cultivars and 777 samples of O. glaberrima. About 1,500 samples turned out to be dead seed, while 2,470 samples were obviously duplicate accessions.

Present scope of the IRRI germ plasm bank - At the end of the third quarter of 1975, our bank has 30,327 distinct and registered accessions of O. sativa cultivars and breeding lines. In addition, five thousand seed samples have yet to be registered either because they have not been grown or are likely to be duplicate samples of earlier accessions.

African rices (O. glaberrima) amount to 900 accessions. The bank has 1,170 populations of wild taxa and 642 genetic testers and mutants.

Characterization of conserved stocks:

We systematically collect 37 items of morpho-agronomic data on O. sativa cultivars and breeding lines. The field recording along with seed increase is spread over two seasons. We have completed the characterization of 25,426 accessions. The systematic description of O. glaberrima samples has been initiated. We re-identify every incoming wild taxon and keep a herbarium specimen of each sample.

Morpho-agronomic data of 8,628 accessions, along with reactions to two major diseases and one insect, were entered on IBM cards and the computer-printed catalog came out in 1970. Efforts are being made to collate the varietal designation and origin, and morpho-agronomic data with other outputs from various GEU tests.

Seed preservation, rejuvenation and distribution

Preservation - Harvested stocks are systematically separated into one portion for short-term storage (2-3 years, at 22°C 60-80%RH) and another

250-g lot for medium-term storage (10-15 years with 8-9% seed moisture content, at 2-3°C 60-75%RH). About 25,000 accessions are kept in medium-term storage. The viability of 12-year-old tropical varieties is above 90 percent while that of temperate-zone varieties (mainly japonicas) has dropped to 50 percent. Long-term facilities for storing seeds packed in vacuum cans and kept under sub-freezing temperature are urgently needed.

We have sent duplicate seed samples of 18,780 accessions to the U.S. National Seed Laboratory at Ft. Collins, Colorado, for storage. We shall continue to send new samples to Ft. Collins for duplicate storage.

Rejuvenation - To replenish the seeds of depleted stocks, we multiply seed in rejuvenation plots. Such plots amounted to a few hundred until 1974. During 1974, 1,047 plots were grown for seed rejuvenation; 1,845 plots in 1975.

Many incoming samples have such low germinability that we find it necessary to increase the stocks from a small number of viable seeds. During 1974-75 we grow 1,320 rows of initial seed increase.

The need to rejuvenate thousands of japonica types early in 1976 is imminent.

We have had a difficult time in increasing the seedstocks of O. glaberrima samples at Los Baños. Because the African rices are highly susceptible to the virus diseases and their insect vectors and because of their lodging susceptibility, three successive plantings made during 1973-74 were total failures. The need to rejuvenate the African rices in their adapted habitat somewhere in West Africa is obvious.

Seed distribution - From the very beginning of the germ plasm bank operations, seed distribution for use by rice researchers has been a major function of the bank. Several seedstocks sent from the bank have become major varieties in the Dominican Republic, India, Brazil, Nepal, and South Vietnam. In addition, the semidwarf varieties from Taiwan constitute the major parent in the breeding programs of Bangladesh, Colombia, India, Indonesia, Nigeria, Surinam, Thailand, and the U.S.

Seeds drawn from the IRRI bank have restored thousands of varieties to the national collections of Indonesia, Malaysia, Sri Lanka, South Vietnam, and Tanzania.

During 1974-75, we provided 4,800 seed samples of O. sativa to 229 foreign researchers. Similarly, 771 packages of wild taxa were supplied to 26 rice workers. The stocks of the wild taxa are nearly depleted. To sum up, since 1962 we have sent 47,761 samples abroad in response to 1,364 requests.

Within IRRI the expansion of GEU operations are evident from the following numbers of seed samples supplied by the bank: 2,700 in 1972; 7,016 in 1973; 20,498 in 1974; and 21,099 in the first nine months of 1975. We also supply seeds of special types for the appropriate GEU tests as soon as sufficient seed is available and before characterization is completed.

Assistance to national programs - We have trained genetic stock officers for Bangladesh, Malaysia, Pakistan and Thailand and will continue the resident training program at Los Baños.

We have prepared two manuals which were designed to aid rice workers in performing a better job of genetic conservation: Manual for Field

Collectors of Rice (1972) and Manual on the Genetic Conservation of Rice Germ Plasm for Evaluation and Utilization (in press).

IRRI assisted Burma and Indonesia in acquiring refrigerated seed storage facilities. IRRI staff has also advised several national centers on the procedures and physical facilities required for genetic conservation programs.

IRRI's assistance in these areas is designed to improve the capability of the national research centers in continuing their genetic conservation efforts.

Future plans:

Work in the following areas will be continued, expanded, or improved during the next five years.

Field Collection

We need to continue a systematic canvassing of indigenous germ plasm in the following countries or regions:

1. Bangladesh - transplanted aman and floating varieties with special features; aus varieties; wild species.
2. Burma - hilly areas of the Chins, the Shans, the Kayahs, the Kashins, and the Mons for hill rices; wild species.
3. China - areas little collected in the past.
4. India - remote areas in the sub-Himalayan region (Kashmir, Jammu, H.P., W. Bengal), central India (Ranchi of Bihar, Rewa of M.P., west Orissa, north and west Andhra), Dangs and Konkan, for minor varieties tolerant to adverse ecologic or edaphic factors; wild species.

5. Indonesia - upland varieties of west Java, central Java, east Java; upland types on Kalimantan, Sulawesi, Nuga Tenggara (islands east of Bali) and West Irian; tungro-resistant lowland varieties; wild species.
6. Cambodia - outside Phom Penh and Battambang; floating varieties planted along the shores of the Tonle Sap Lake; wild species.
7. Laos - hilly areas in the plateu area (Plain of Jar) for hill rices; wild species.
8. Nepal, Sikkim and Bhutan - high elevation areas or other special types.
9. Pakistan - Swat Valley for cold-tolerant types; Sind district for salinity- and alkalinity-tolerant types, or heat-tolerant types.
10. Thailand - hilly areas in the north and northeast for hill rices; floating varieties with special features; Khorat area for saline- and alkaline-resistant types; wild species.
11. Malaysia - mainly in the hills of Sarawak for hill rices; northern part of West Malaysia for tungro-resistant varieties.
12. North Vietnam - areas not covered in the past.
13. South Vietnam - remote areas for varieties tolerant to acid-sulfate soil, salinity, or deep water; wild species.
14. Sri Lanka - cultivars that are tolerant to flooding and cool temperatures; wild species.
15. West Africa - _O_. _glaberrima_ races; _O_. _sativa_ cultivars of special ecological merit or tolerant to iron toxicity and phosphorus deficiency. IRRI is seeking the cooperation of IITA, WARDA and IRAT on the assemblage of African germ plasm.

We shall re-collect special types in those areas where GEU tests have identified accessions having special features originated from such areas.

A five-year plan for field collection has been prepared (Table 2).

Preservation

Since IRRI has the responsibility for preserving the entire rice germ plasm, we definitely need to improve and expand our seed storage facilities which are inadequate and over-cramped. Seeds for medium-term storage are presently scattered over two rooms; storage will be further divided into three rooms in 1976. With the anticipated increase in the size of our collection, we cannot cope with the increase without expanded and improved facilities. For use by the germ plasm bank alone, we need the following work and storage areas:

1. Office and lab space for the registration, processing and recording of both incoming and outgoing samples; herbarium.
2. Working area for preparing harvested samples for storage and distribution.
3. Working area for drying and vacuum-canning seeds (for long-term storage).
4. Expanded area for short-term seed storage.
5. Separate storage vaults for medium- and long-term storages. Seeds for long-term storage will be dried to 5% moisture content, vacuum canned, and stored in -20°C temperature. Seed viability is expected to last more than 50 years.

The germ plasm bank facilities should be combined in one building (the proposed Genetic Resources Laboratory) with those of other GEU and IRTP operations so that the flow of rice seeds will be a unified operation.

IRRI will also seek the cooperation of a second seed bank abroad in providing duplicate storage.

Documentation and linkage with GEU components

We shall continue to systematically characterize the recently acquired accessions and update the variety catalog. All data related to varietal origin and designation, morpho-agronomic features, and seedstock information shall be computerized and inter-linked with information emitting from various GEU components. A master records and retrieval system for the entire germ plasm collection will facilitate searching for the desired genes, as well as for seed rejuvenation, seed storage, and seed distribution operations.

Assistance to national rice research centers

We shall continue to train genetic stock officers for national centers that have sizeable holdings of germ plasm. We shall also provide technical assistance on various aspects of genetic conservation.

Improving genetic conservation operations

Statistical analyses of accessions representative of different eco-geographic regions will be made to assess varietal diversity and to facilitate grouping of accessions having common characteristics. Such studies will help field collections in the future.

More refined methods should be developed to facilitate the identification of duplicate samples. Isozyme analysis appears to be one of the promising techniques.

Seed storage experiments shall be conducted to improve storage methods that can be adopted by national centers.

Working toward a global network for genetic conservation

Considering the vast eco-geographic distribution of the cultivated rices and their wild relatives, IRRI alone cannot handle all phases of operation, especially on field collection and rejuvenation of unadapted types. We shall work toward a network in which other international institutions (USDA, IITA, CIAT, NIAS of Japan, and others) will be asked to contribute their efforts and share some of the responsibilities. In addition to the U.S. National Seed Storage Laboratory, other seed banks will be approached to assist on the storage of duplicate seed samples. IRRI will continue to serve as the genetic resources center for rice.

Table 1. Special types of rice varieties acquired from July, 1972, to September, 1975.

Reported features	Samples (no.)
Tolerance to salinity	148
Tolerance to acid soils (lowland)	209
Tolerance to alkaline soils	11
Upland types	2461
Floating or flood-tolerant types	573
High-elevation or cool-tolerant types	639
Resistance to nematodes	5
Resistance to insects	3
Escape from rodent damage	9
Aromatic types	89
Multiple tolerances	30
Total	4177

Table 2. Schedule of IRRI's direct role in field collection activities during the next 5 years (excluding indirect participation in collecting programs of China, India, Pakistan, South and North Vietnam).

Year and Period		Country and Area	Types to be collected	Estimated collection size
1976	1st half	Bangladesh	Aman types	300 - 500
		Indonesia (Java)	Upland rices of the bulu and cere types	250 - 400
		West Africa	Discussion with national and international centers concerned	-
	2nd half	Sri Lanka	Flood-tolerant rices; cool-tolerant types	100 - 200
		Burma	Hill rices; delta varieties; cool-tolerant types; quality rices; wild species	400 - 500
1977	1st half	Indonesia (Kalimantan)	Tidal swamps; upland (ladang and rancah types); wild species	250 - 300
	2nd half	Thailand	Floating rices; hill rices; wild species	150 - 200
		West Africa	All types	500 - 1000
1978	1st half	Indonesia (Sumatra)	Upland; high elevation; tidal swamp (Jambi) varieties	200 - 400
	2nd half	West Africa	All types	500 - 1000
1979	1st half	Indonesia (small islands)	Upland and lowland varieties (bulu and cere); wild species	200 - 300
	2nd half	Malaysia (Sarawak)	Hill rices; acid-sulfate tolerant types	150 - 300
1980	1st half	Australia and South America	Wild races and hybrids between wild and cultivated forms	100 - 300
	2nd half	Cambodia and Laos	Floating rices; long-duration types with pest resistance; wild species	300 - 500

AGRONOMIC CHARACTERISTICS[1]

Justification and objectives:

The yield potential of a variety is dependent upon a set of plant characteristics which are grouped under the general term "plant type." The ideal plant type varies from one growing condition to another. Each growing condition has particular requirements for growth duration, photoperiod sensitivity, threshability and grain dormancy. Traditional cultural practices and methods of harvesting and storage must also be considered.

Our objective is to define and develop the appropriate combinations of agronomic characteristics for each general set of conditions and requirements.

Summary of accomplishments:

Plant type - the characteristics and history of the IR8 plant type are well known. It is short and sturdy (highly responsive to nitrogen fertilizer) with erect leaves that make efficient use of the light. On farms with a relatively high level of management and good water control, it has been accepted and is now demanded. The IR5 plant type, which is somewhat taller and more competitive, is popular in areas of less dependable water control and/or lower levels of fertility and management. It is also popular in areas where harvesting practices cause discrimination against shorter types. Our most recent variety, IR34, is of this type. Our past breeding efforts have focused on these two types and

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[1] Project Leaders - W. R. Coffman, Associate Plant Breeder and
S. K. De Datta, Agronomist

they occupy roughly 25 percent of the worlds rice land. We have sacrificed some of the advantages of the IR8 type in order to incorporate essential disease and insect resistance into our more recent varieties. We also feel that the output of our program has not reflected the demand for the intermediate height IR5 type of variety.

Growth duration - For the expanding rice area under irrigation early varieties (105 days or even less) are in great demand. They are also particularly suitable for multiple cropping systems which either involve several crops of rice per year or one or two crops of rice in rotation with other crops. For rainfed areas where only one crop is possible varieties of medium duration (130 days) seem to be preferred, probably because they usually yield more on a per crop basis than do earlier types. Even later types may be preferred for these areas depending on the rainfall pattern. Most of our varieties and advanced lines distributed have been of medium duration but two recent releases, IR28 and IR30, are early (105-110 days) and one, IR32, is relatively late (140 days).

In certain areas where heavy rain occur for 4-5 month periods, varieties with a longer growth duration (150 days or more) or with photoperiod sensitivity are required. If the vast river deltas of Thailand, Burma, Bangladesh and India rice is planted in May-June before the onset of heavy rains. Photoperiod insensitive types planted in these areas mature in September-October which is a period of heavy rain and standing water. Large acreages can not be harvested during these months because there are no drying facilities. We have begun to emphasize photosensitive types suitable for such areas but they are still early generation. Breeding work is necessarily slow because of the long generation time.

Threshability - Sturdy-strawed varieties which do not lodge must have moderately firm threshability to minimize grain losses during storms, during harvest and even during storage if the bundle method is used. However, very hard threshing types must be avoided as farmers will reject them due to the extra labor required in threshing. Most of our varieties and improved lines have had acceptable threshability.

Grain dormancy - In tropical areas where rains are frequent during the harvesting season and adequate drying facilities are not available, grain dormancy is an essential characteristics. Without it, seed may germinate in the panicle. All of our varieties and improved lines have had a satisfactory degree of grain dormancy.

Future plans:

We plan to carefully monitor the performance and popularity of existing varieties available to farmers and alter our breeding strategy as necessary. It is our present concept that a wide variety of types, representing a continuous range from the high input (HIP) to the nearly zero input (ZIP) type will be required. We use the term "input" to describe the level of fertility, degree of water control and the quality of management. We feel that the greatest gains can probably be made in the intermediate areas of this range for which we use the general term, "low input (LIP)."

These three types are described below in the sense of examples rather than as specific objectives. The tremendous diversity of the rice germ plasm and the fact that there is still some art in crop improvement must be kept in mind.

High Input (HIP) - essentially the IR8 type with short to moderately short (80-110 cm) sturdy stems and short, thick, tough, glabrous, upright leaves. It will be highly responsive to nitrogen fertilizer, and highly resistant to lodging. The short erect leaves will make efficient use of the low light intensity during the monsoon season. It will have excellent early vegetative vigor and a relatively high tillering capacity and be suitable for both direct seeding and transplanting.

Very early maturity will be emphasized for this plant type but the medium and late categories will not be ignored. This type will be insensitive to photoperiod. Threshability will be "modern hard" to minimize losses during typhoons and dormancy will be adequate to prevent sprouting when maturity is reached during rainy weather.

Low input (LIP) - a modified IR5 type. It will have very sturdy stems of intermediate height (115-130 cm) and will respond to moderate amounts of nitrogen fertilizer. The leaves will be less erect than the HIP type, much wider and somewhat longer. They will also be thick and tough (stormproof). This type will have excellent early vegetative virgor and a high tillering capacity. It will be competitive with weeds. It will be able to tiller under the waterlogged conditions prevalent throughout the monsoon tropics and have sufficient seedling size to allow transplanting under such conditions.

Medium and late maturity will be emphasized but early types and photosensitive types will also be developed. Threshability will be "firm" to minimize storm losses and to be compatible with the bundle harvest and storage methods often employed by farmers favoring this type of variety.

Zero input (ZIP) - we do not plan to place emphasis on this type immediately but it is envisioned as a highly competitive plant that could essentially take care of itself. It would not be very different in appearance from many of the best traditional varieties still cultivated on much of the rice land in Asia. It would have stronger straw and stormproof characters such as thick tough leaves and hard threshability. The ZIP type would concede that very little improvement is possible in agronomic type, per se for some rice growing areas. It is envisioned as a carrier of major gains in other areas of GEU such as resistance to diseases and insects, flood tolerance, tolerance to adverse soils, drought tolerance, and improved nutritional and eating quality.

Our immediate objectives, in priority order, are to:

1. empahsize the LIP type until its proportion in the output of our program is approximately representative of the degree of utility of this type among rice farmers.
2. try to regain the ideal HIP type, recognizing that we have made some sacrifice in this area in order to bring in attributes emphasized in other areas of GEU, such as disease and insect resistance.
3. develop prototype varieties that approach the ZIP type and explore their utility.

GRAIN QUALITY[1]

Justification and objectives:

The market price of a variety is determined largely by its grain quality. Grain quality characteristics may affect production in terms of the amount of milled rice recovered from paddy. Local preferences for grain shape and for eating quality are often the major determining factors in the acceptance of new improved varieties for cultivation. Finally, perhaps the best justification for placing major emphasis on grain quality is that the millions of people who eat rice deserve the best quality that we can produce.

Tropical rice is very divergent in physical properties of the grain, such as size and shape, and in the physicochemical properties of the starch. Starch, a polymer of glucose, is the major constituent of milled rice. The amount of its linear fraction (amylose) and its branched fraction (amylopectin) and its gel consistency are major influences on the eating quality of rice.

Our objective is to specifically define the grain quality preferred by the majority of consumers in each of the major rice producing countries and then to develop simple, rapid and reliable tests to identify desirable types. Based on the past findings we are now seeking varieties with inter-

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[1] Project Leaders - W. R. Coffman, Associate Plant Breeder ; B. O. Juliano, Chemist; and G. S. Khush, Plant Breeder

mediate amylose content, or high amylose content with soft gel consistency. We strive for high yield of head rice (whole grain milled rice) and total milled rice (low hull content). Translucency is also considered desirable as are medium long grains. These general objectives do not apply to waxy rice which is a special case.

Finally, in the face of complex and varied requirements and preferences throughout the rice growing world and an almost infinite number of choices of grain sizes, shapes and sundry characteristics of eating quality, we try to use common sense. We emphasize the most generally acceptable types but we do not discriminate completely against any preferred type.

Summary of accomplishments:

We have determined that the ratio of amylose to amylopectin in the starch of the rice grain is a major determining factor of cooking properties. Grains containing starch with 0 or less than one percent amylose (waxy or glutinuous type) are very sticky when cooked. Rices with 12 to 20 percent amylose (low amylose) are tender and cohesive when cooked. Rices with 21-25% amylose (intermediate) are tender but not cohesive when cooked. Rices with more than 25% amylose (high amylose) are dry and fluffy when cooked. In addition, cooked rices with high amylose content but having low gel consistency stay soft after cooling while high amylose types having high gel consistency become hard after cooling. We have developed rapid tests to screen for these properties and we use them to evaluate every line from F3 onwards which amounts to over 50,000 determinations per year. We have determined that the most widely preferred varieties are of intermediate amylose content or, have soft gel consistency if they are the high amylose type.

We have determined that it is not possible to obtain an intermediate amylose type from a cross between a high and a low type. We know that waxiness is conditioned by a single gene but we lack precise information on the inheritance of the three other types of amylose content.

IR8, our first variety, was relatively poor in eating quality. The grain was somewhat chalky and the amylose content (high) and gel consistency (hard) were not desirable. Our varieties and breeding lines have shown a steady improvement in grain appearance. Eating quality has been markedly improved. IR20, IR26 and IR30 have medium gel consistency while IR32 has soft gel consistency. All are high amylose but we now have advanced lines with intermediate amylose content.

We have found that there are numerous changes in the physicochemical properties of rice during storage including a decrease in stickiness of nonwaxy types. We have found that parboiling improves grain translucency and hardness and causes a diffusion of thiamine to the endosperm resulting in a higher thiamine content of milled parboiled rice compared to milled raw rice.

Future plans:

Breeding for intermediate amylose content together with the selection of soft gel consistency lines among high amylose rices will be continued. Inheritance studies of amylose content using single grain analysis of F2 and F3 seeds and backcross seeds will be completed.

A final evaluation of the texture of cooked rice will be carried out to verify the sensitivity of a taste panel in detecting differences in texture of boiled rices with high amylose content but differing in gel consistency. The taste panel will also evaluate the eating quality of cooked rice of promising lines on a regular basis.

Varietal differences in volume expansion during the cooking of rices of similar amylose content will be investigated. The effect of the exclusion of oxygen by the use of nitrogen atmosphere on the aging of rice will be studied to test hypothesis that oxidation is needed for changes in properties of starch and protein during aging.

Finally, we will continue to emphasize grain quality as a major breeding objective and attempt to satisfy the majority of the world's rice consumers. We hope to further refine and simplify our present tests for cooking and eating quality and possibly develop new, more sensitive tests which would further enhance the screening work for grain quality in the GEU Program.

DISEASE RESISTANCE

There are many diseases of rice; some of the major ones can cause heavy to complete losses. No reliable figures are available on the annual yield reduction due to diseases but a very conservative guess would be 15 percent. Varietal resistance is the only practical way to control diseases. Chemical control is often undependable, uneconomical and, in the case of small farmers, unavailable.

Aware of the complexity of disease resistance breeding, our approaches include:

1. Developing proper methods for screening the germplasm collections to identify the best sources of resistance, and as many as possible, in order to diversify the genetic base of our program.
2. Studying the variability of the causal agents and its relation to the stability of the resistance sources.
3. Incorporating resistance with other desirable traits by hybridization, screening progenies of crosses and, when necessary, testing the progenies at an international level.
4. Studying the genetics of resistance and investigating the possible use of multiline varieties.

This outline of our work will deal with the diseases in broad groups (fungi, viruses and bacteria) and finally discuss the development of varieties with multiple disease resistance.

FUNGAL DISEASES[1/]

Blast Pyricularia oryzae

Justification and objectives:

Specific figures on yield reduction due to blast are not available on worldwide basis but it is considered to be a major serious disease of rice. It is especially serious under upland conditions which accounts for 60 percent of the world's rice land. It is more serious in South America and Africa than in tropical Asia.

Our objective is to develop varieties with stable resistance to the blast fungus, as many "resistant" varieties developed in the past had only a very temporary value.

Summary of accomplishments:

We helped establish the International Blast Nursery (IBN) in 1963 which is coordinated by us and now grown at 60 locations in 30 countries. The test results of the last 12 years have identified several traditional varieties with a broad spectrum of resistance to the highly variable fungus.

We found that the blast fungus has not only different pathogenic races in different localities and seasons; it has another dimension of variability. Conidia from single lesions, from monoconidial cultures or even hyphal-tip cultures from a germinating cell of conidia consist of many races. It changes from generation to generation. It is very unstable and a race does not breed true.

[1/] Project Leaders - S. H. Ou, Plant Pathologist; H. Ikehashi, Plant Breeder; W. R. Coffman, Associate Plant Breeder and G. S. Khush, Plant Breeder

When the fungus was isolated from resistant varieties, and inoculated back on the original varieties, only a few lesions were produced. We found the fungus had changed into many races as it multiplied and that the varieties were resistant to most of the races. Thus, a stable type of resistance is maintained. We hope this type of resistance will not "breakdown" easily.

Two of the best performers in the International Blast Nursery were the varieties Tetep and Carreon. The latter proved to be a poor combiner but many improved lines have been recovered from Tetep and the resistance of some of these lines is still holding. They are presently being tested in the IBN and will be very useful in further breeding work.

Most of our varieties and elite breeding lines distributed have had acceptable levels of resistance to the fungus at the time of distribution. This is due to our intensive screening program in which we evaluate more than 50,000 lines per year.

Future plans (5 year projection)

We will continue the routine search for new sources of resistance with preliminary screening at Los Baños and final evaluation in the IBN. Routine screening of the breeding material will be continued in order to maintain an acceptable level of resistance in our material.

Cytogenetic investigations will be conducted to determine the genetic basis and/or mechanism for the extraordinary variability of the fungus. We shall cooperate with the Boyce Thompson Institute in investigating the use of toxins produced by the fungus for screening blast resistance.

Our efforts will center on developing and implementing a strategy to produce stable resistance to the fungus. We assume this resistance is multigenic. Our present plan is to take breeding lines derived from apparently stable sources and screen them in the IBN. We will use the IBN data to determine lines which collectively represent the complete spectrum of race resistance, and intermate them. We will screen the early generation material at 3 or 4 "hotspots" around the world, test the best lines thereby derived in the IBN and again intermate the best performers which collectively represent the complete spectrum of race resistance. We will repeat this cycle until we no longer detect performance gains in the IBN. After one or two cycels it will probably be possible to formulate a stable multiline. It may take several cycles to identify a stable uniform line.

Sheath Blight *Thanatephorus cucumeris*

Justification and objectives:

The heavy use of nitrogen and density of growth associated with modern varieties appears conducive to sheath blight. We view it as an extremely serious disease of the future unless steps are taken to curtail it through resistant varieties.

Our objective is to develop efficient screening methods, identify the best sources of resistance and incorporate them into modern varieties.

Summary of accomplishments:

Seedlings can easily be tested for resistance in an upland nursery but reactions do not correlate with adult plant reactions. The disease always occurs at the adult stage so the seedling test is not satisfactory. The adult stage testing also has drawbacks. Disease development is affected not only by the stage of growth of the plant but by weather conditions. Thus, repeated testing is necessary for comparative evaluation of materials.

We have tested about 10,000 lines and varieties per year since 1972. None were found highly resistant but distinct differences existed.

Fungus isolates differ in virulence and infection takes place when infectious mycelium forms from the running mycelium. Basidiospores were first found in our upland seedling test plots and were then observed in upland rice on farmers' fields. High nutrition of the fungus and host plant favor the development of the disease.

Yield loss experiments in the dry season showed a reduction of up to 25% of paddy in severely affected plots.

Future plans:

We will try to develop more efficient screening methods and attempt to identify higher levels of resistance through the continued screening of the germplasm collection and the breeding material. We will investigate factors affecting virulence of the fungus and explore basidiospore production and their use in inoculation.

Our breeding work will be geared to the progress in identifying satisfactory sources of resistance. At the least we will avoid a high degree of susceptibility.

Minor Fungal Diseases

There are too many minor fungal diseases of rice to deal with specifically but their collective importance is significant. We try to use common sense in our selection work and have thus avoided serious susceptibility to any of these organism although Cercospora leaf spot has occurred in significant proportions from time to time on some of our varieties and elite lines and several other such diseases can be of importance in certain regions. We plan to monitor the occurrence of these diseases and take appropriate action should they show signs of becoming serious.

VIRUS DISEASES[1]

Justification and objectives:

Six virus and virus-like diseases of rice occur in the tropics, four in Asia, one in South America and one in Kenya. Rice tungro disease often occurs suddenly, widely, and destructively. As recently as 1971, it resulted in a 30 percent loss in rice production (compared to the previous crop) in Central Luzon, Philippines. In 1973, several thousand hectares in Sulawesi, Indonesia were seriously damaged by the disease. Grassy stunt has become a major disease because of recent outbreaks of its vector, the brown planthopper, in the Philippines, Indonesia, and India. The other two diseases in Asia -- yellow dwarf and orange leaf -- are of minor importance because of long latent periods and the early death of infected plants, respectively. Hoja blanca occurs in South America and the Caribbean area and has caused serious losses in the past. In Kenya, the yellow mottle disease has been reported.

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[1] Project Leaders - K. C. Ling, Plant Pathologist and W. R. Coffman,
Associate Plant Breeder and G. S. Khush, Plant Breeder

The use of resistant varieties is one of the most effective, cheapest, and simplest ways to control the virus diseases. Our objective is, therefore, to combine virus resistance with other attributes essential to modern rice varieties.

Summary of accomplishments:

Rice tungro disease

A mass screening method, capable of inoculating 32 entries per day, was developed in 1965. The fundamental problem of the development of the method was maintaining the infectivity of the insect because the tungro virus does not persist in its vector. The testing capacity was further improved in 1972, capable of inoculating 64 entries per day, by using the insect to inoculate seedlings twice a day. The infectivity of the insect was maintained by providing a reacquisition feeding to the insect between inoculations. As present, about 16,000 entries are tested per year.

Based on percentage of infected seedlings, more than 50 rice varieties have been classified as resistant. Among these varieties, Pankhari 203, Habiganj DW8, T412, and Andi from Pokhara showed the lowest percentage of infection.

Although a rice variety resistant to the severe strain of tungro virus is generally also resistant to the other two mild strains in the Philippines, the resistance to the virus and the resistance to the insect vector are independent. In addition to the resistance to the insect vector due to the mechanism of antibiosis and the resistance to the virus due to the inhibition of multiplication of the virus and/or the inactivation of the virus by the substance or substances in the plant demonstrated in 1967, one reason for field resistance to tungro disease due to the insect's nonpreference was demonstrated in 1974. The vector moves more often on seedlings of nonpreference which results in a low percentage of infection due to a shorter visiting duraction per seedling.

Whenever possible, rice varieties and breeding lines have also been evaluated in the field by natural infection. In general, the mass screening test in the greenhouse seems to be more severe.

IRRI varieties and advanced breeding lines distributed to international cooperators have shown a steady improvement in resistance. IR8 and IR5 were susceptible. IR20, a derivate of TKM6, was the first moderately resistant variety. It does reasonably well in the field; sometimes having fairly severe symptoms at early stages of growth but tending to recover at later stages of growth. IR34, the latest variety, is highly resistant in both mass screening and field tests in the Philippines.

Grassy stunt disease

A mass screening method for testing varietal resistance to the grassy stunt causal agent was developed in 1968. The method is capable of inoculating 32 entries a day. At present, about 8,000 entries are inoculated in a year. The mass screening test correlates well with field reaction to the disease.

Thousands of rice varieties from the germplasm bank were screened for resistance to grassy stunt but all were susceptible. However, one selection from a species of wild rice, Oryza nivara was found to be resistant. This resistance was incorporated into an improved type through backcrossing and verified to be conditioned by a single dominant gene. All of our recent varieties (IR28, IR29, IR30, IR32, and IR34) and most of the improved breeding material carries this gene for resistance.

Hoja blanca

IRRI varieties such as IR8 and IR22 and some other IRRI dwarf materials that were introduced into the Caribbean area have been found resistant to the vector of hoja blanca, *Sogatodes orizicola*, and perhaps also to the virus. The varieties developed locally are now carrying the resistance and may be the reason that hoja blanca is not a problem at present.

Future plans:

We will continue to search for new sources of resistance to the major virus diseases and attempt to develop more efficient screening methods for application to the large volume of breeding material.

We will monitor the newly developed resistant varieties to determine the stability of their resistance. We will determine the existence of possible different strains of the viruses through the IRTP and, if they exist, take steps to develop the necessary spectrum of resistance.

BACTERIAL DISEASES[1]

Justification and objectives:

Bacterial blight (*Xanthomonas oryzae*) is found throughout Asia. Incidence and severity have increased during the last several years and

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[1] Project Leaders - T. W. Mew, Associate Plant Pathologist; W. R. Coffman, Associate Plant Breeder; H. E. Kauffman, Plant Pathologist and G. S. Khush, Plant Breeder
Rice Testing Program.

yield reductions of 30 to 70 percent are possible in severely affected fields. Bacterial leaf streak is also widespread but of much less, perhaps insignificant, economic importance. Our objective is to control the diseases through varietal resistance.

Summary of accomplishments:

About 7,800 varieties were screened during 1965 to 1968 for bacterial blight. Resistant entries were further tested with several strains. A number of them were found to have a broad spectrum of resistance. A very efficient clipping method for screening was developed in 1971. Some 10,000 more varieties were screened during 1972 to 1974. About 700 of them were found resistant to representative isolates of the Philippines.

Genetically at least three distinct types of resistance have been identified: dominant (TKM 6, Sigadis, Syntha, etc.); recessive (BJ1, DZ192, PI 231129, etc.), and recessive with intermediate level of resistance (Zenith, Malagkit Sungsong, Madhukar, etc.). All of our recent varieties are resistant. They carry the dominant type as do most of our improved breeding lines. However, we have several improved lines conditioned by the other types and we are working to expand the proportion of these types in our breeding material.

About 1,100 varieties were screened for bacterial streak resistance during 1966 to 1967. More than 50 percent were resistant or moderately resistant. Apparently, many varieties possess the resistance. The disease has been monitored in the breeding materials and other plantings but no special breeding work has been done.

Future plans:

We will continue to improve the inoculation method for bacterial blight to find if two or more mixed strains can be inoculated at the same time without interference. All new germ plasm bank entries (apprx. 10,000/year) will continually be tested each season in seed increase plots. Resistant varieties will be tested further against many distinct isolates to identify a broad spectrum of resistance. Newly identified resistant varieties will be studied for allelic relationships. Systematic screening of breeding material will continue in all generations.

Studies are planned on the nature of pathogenic variability - (a) variation originating from single lesions or single isolates, (b) relationship between virulence and aggressiveness, etc. We will study colony characteristics that may serve as markers for studies on variation; their relation to virulence. Spread and distribution of Isabela strain in the Philippines, and occurrence of possible new strains will be monitored.

We shall monitor disease incidence of released resistant varieties grown in different countries through the International Rice Testing Program.

For bacterial streak we plan to develop an artificial inoculation method for mass screening. Prior to that we will evaluate the field reaction of the germ plasm collection and breeding lines during the wet season. We will continue studies on pathogenic variation and factors affecting disease severity in the field.

MULTIPLE DISEASE RESISTANCE[1]

Justification and objectives:

All the diseases discussed above occur unpredictably and sometimes simultaneously in the rice field and it is necessary or desirable to have a variety resistant to all of them. Our objectives is to combine resistance to all important diseases in a single genotype.

Summary of accomplishments:

Our recent varieties and most of our advanced breeding lines each carry resistance to both major virus diseases (tungro and grassy stunt), the bacterial diseases (blight and streak) and to some extent, the fungal diseases of which blast and sheath blight are the most important.

Future plans:

As soon as dependable and stable resistance to the major fungal diseases is identified and or incorporated into an improved plant type, we will attempt to combine it with resistance to the other major diseases. We will try to simultaneously incorporate stable blast resistance into improved plant types while maintaining resistance to the other diseases. The same will be done with other fungal diseases as superior sources of resistance are identified. We will continuously guard against selecting abnormally susceptible types with respect to the minor fungal diseases.

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[1] Project Leaders - W.R. Coffman, Associate Plant Breeder;
S. H. Ou and K. C. Ling, Plant Pathologists;
T. W. Mew, Associate Plant Pathologist; and
H. E. Kauffman, Plant Pathologist

INSECT RESISTANCE[1]

Justification and objectives:

Insect pests are one of the major factors limiting rice production in most parts of the world. The warm temperature and high humidity that are typical of rice environment are also conducive for the multiplication of insect pests. Consequently a wide variety of insects infest the rice crop in large numbers. Of nearly 70 species of insects recorded as rice pests, 20 are of major significance and cause extensive losses. The pest problem appears to be particularly severe in field treated with higher rates of fertilizers and other improved agronomic practices which are commonly adopted for modern high yielding rice varieties and in areas where rice is grown throughout the year.

The extent of losses in rice yields due to insect pest ravages is not available from most of the developing countries, but is believed to be substantial. A total of 80 different experiments conducted at the International Rice Research Institute during 1962-75 showed that the yields of plots protected from insect damage averaged 5.8 t/ha while those unprotected plots averaged about 2.9 t/ha only. A series of experiments conducted in the farmers' fields in the Philippines (by IRRI and in cooperation with various national agencies) showed that plots protected with insecticides produced an average of 1.0 t/ha (or about 20-25%) more rice than plots receiving similar treatments but not protected from

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[1] Project Leaders - M. D. Pathak, Assistant Director; W. R. Coffman, Associate Plant Breeder; H. Ikehashi, Plant Breeder; B. O. Juliano, Chemist; and G. S. Khush, Plant Breeder

insect damage. Similar results on extents of yield losses have recently become available from many Asian countries. Thus, proper pest control appears to be a must for a sustained increase in rice production.

Of the various methods of insect control, the use of genetic resistance in rice varieties to insect infestations appears to be a very practical approach. This method offers the unique advantage of being a built-in control which is inexpensive, compatible with other methods of control and does not create undesirable side effects or environmental pollution problems.

Varietal resistance to insect pests is generally of a relative nature and there are only a very few cases of high resistance approaching immunity. Since insects have the ability to select their hosts, resistance to pests comprises insects liking or disliking a plant (non-preference) and the suitability of the selected plant as a host for the insect (antibiosis). Many resistant varieties possess both the non-preference and antibiosis type of resistance, and thus, varietal resistance tends to be more complex in nature and more stable than resistance to pathogens. Although the antibiosis type of resistance is generally more emphasized, non-preference is of a major significance particularly where even brief infestations cause severe damage. In addition, some host-plants, primarily because of their vigorous growth, are more tolerant to insect damage than others. Varietal resistance is generally more feasible against insects which have high host plant specificity than those which are of polyphagous nature.

The objectives of these studies are:

1. To identify sources of resistance to common insect pests in collections of Oryza sativa, O. glaberrima, and wherever appropriate in other species of Oryza.
2. To investigate the nature and cause of resistance.
3. To develop varieties resistant to these insects.
4. To investigate the existence and development of insect biotypes capable of surviving on resistant plants.
5. To study the genetics of resistance of plants to existing as well as new biotypes of the insect pests.
6. To incorporate in an improved plant type diverse sources of resistance to the same and other species of insect pests to enhance and broaden the existing levels of resistance.
7. To develop isogenic resistant lines.

Results obtained:

The use of varietal resistance in rice as a method of insect control is a comparatively recent approach. Although differences in varietal susceptibility to pest infestations have been recorded for almost the last 50 years, these were mostly based on observations on a comparatively smaller number of varieties and the selected varieties were rarely investigated for the consistency or the nature of their resistance. Also, efforts were not made to utilize host-plant resistance as a practical method of insect control.

At IRRI, studies on developing insect resistant rice varieties were undertaken since the beginning of its research programs in 1962. The results obtained are summarized in Table 1 and some of the highlights are discussed as follows:

Stem borers

On the whole, stem borers are probably the most serious pest of rice. They usually occur during every crop season and infest the plants from seedling to maturity. The stem borer damage frequently becomes evident as dead hearts and white heads.

Most of the earlier studies on varietal resistance to insect pests of rice were aimed primarily against the stem borer and several varieties were recorded as less susceptible than others. However, these results were mostly based on field observations of a small number of varieties and generally experiments to determine the consistency of resistance or to breed resistant varieties were not undertaken.

A more sustained approach to the use of varietal resistance as a method of stem borer control was initiated at IRRI in 1962. At that time the primary emphasis was on the striped borer. In these studies, a total of about 20,000 varieties have been field tested and selected several hundred varieties evaluated with controlled infestations in greenhouse and field experiments. From these, 30 varieties have been identified as moderately resistant to this species. The resistance to striped borers appears to be of non-preference and/or antibiosis nature. Several plant morphological and anatomical characters have been recorded to be correlated with borer resistance. On resistant varieties the borer larvae suffer high mortality, have slower rate of growth and their body size is smaller than those reared on susceptible varieties. Selected varieties have been used in a breeding program to combine stem borer resistance with improved plant type and other desirable characters. The varieties IR20, IR26, IR28, IR29, IR30, IR32 and IR34 were bred to be moderately resistant to the striped borer.

Studies have also been initiated to search and breed for resistance to yellow borer. The yellow borer is somewhat difficult to handle because of problems in its mass rearing and the extreme sensitivity of the larvae to mechanical disturbances. Nevertheless, about 5,000 selected varieties have been screened using techniques similar to those for striped borer and a few varieties have been identified as moderately resistant. For both the striped and the yellow borers efforts are now underway to combine sources of resistance from various parents to further increase the existing levels of resistance. Some notable success in this has already been achieved against the striped borer. The reactions of selected varieties from these experiments have also been evaluated against the white borer and the pink borer, the other two most common stem borer species. Most of this work has been done in cooperative experiments at Maligaya Rice Research and Training Center, Nueva Ecija, and Visayas Rice Experiment Station, Iloilo, Philippines. Selected lines have also been evaluated at Rice Research Stations in Sukhamandi and Maros, Indonesia.

Few of these varieties are moderately resistant to all the four stem borer species tested. Plant morphological and anatomical characters appear to be the major cause of resistance of these varieties.

Plants with narrower stem, shorter, hairy and narrower leaves, tightly wrapped leaf sheaths around the stem, shorter height, larger number of tillers, stems with thick sclerenchymatous tissues, larger percentage of silica content and closely placed vascular bundles are usually more resistant. On the other hand, insects reared on media containing extracts of resistant plants suffer the typical antibiosis effects of the resistant plants. Thus, both plant biophysical and biochemical factors affect varietal resistance but the latter appear more important.

The resistance to the striped borer appears to be of polygenic nature and diallele crossing of seven moderately resistant varieties have resulted in progenies more resistant than any of the parents used. So far, the variety TKM 6 has been used extensively in breeding for stem borer resistance.

There is a very definite effect of plant age on borer susceptibility. Many varieties, particularly ponlai types, resistant at vegetative stage of growth (dead heart) become susceptible at reproductive stage (white head) but the reverse reaction has not been observed.

When reared for four consecutive generations starting with the same number of insects, the striped borer population became 100 times larger on susceptible (Rexoro) than on resistant (Taitung 16) but 10 times larger than on moderately resistant (IR20) plants.

There are no indications of the occurrence of striped biotypes capable of survival on resistant plants.

Leafhoppers and planthoppers

Several species of leafhoppers and planthoppers damage the rice plant by feeding on them and by transmitting virus diseases. They have been serious problems in Japan, Korea and Taiwan and apparently the micro-climate in the fields of thickly growing improved rice varieties and generally the greater use of nitrogenous fertilizers on them are more conducive to the build up of leafhopper and planthopper populations.

Consequently, these appear to be a growing problem on modern rices in the tropics. The rice green leafhopper and the brown planthopper have in recent years afflicted serious losses to the rice crop in many tropical countries. The white-backed planthopper appears to be a major problem on upland rice.

Very little work was done on varietal resistance to leafhoppers and planthoppers before studies on these were initiated at IRRI in 1965. These studies have led to the identification of many varieties highly resistant to the common leafhopper and planthopper species (Table 1). The techniques for screening for leafhopper and planthopper resistance are simple and rapid. These supplemented with the economic status of the various leafhopper and planthopper pests have made breeding for resistance to these insects a popular project in many countries. Most of the IRRI's breeding lines as well as varieties developed after 1968 are resistant to the green leafhopper and brown planthopper. Also, several are resistant to white-backed planthopper and zigzag leafhopper. Many of these varieties are now being grown over vast areas.

Most of the varieties recorded as resistant to the leafhoppers and planthoppers appear to possess antibiosis type of resistance. The insects caged on resistant varieties suffer high mortality and the surviving insects are smaller in size and have slower rate of growth. Young adults caged on resistant varieties lay fewer eggs. Some of the varieties also possess a non-preference reaction for the oviposition by the insect.

Biophysical plant characters do not appear to be an important factor in the resistance of the rice plant to any of the leafhopper and planthopper species investigated. On these resistant varieties, the insects make more feeding punctures, their stylet sheaths reach the vascular bundle areas, still they do little feeding. In general, brown planthopper resistant varieties appear to either lack phagostimulants or to possess a feeding-deterrent(s) while the green leafhopper and the white-backed planthopper resistant varieties are either toxic to the insects or lack vital nutrients. In latter cases where some feeding takes place before the insects get killed, heavy infestations do occassionally damage the resistant plants but brown planthopper resistant varieties are rarely damaged even the greenhouse mass screening experiments.

Resistance to none of these insects have been observed to change with plant age, except for the variety ARC 5792, which is highly resistant to the white-backed planthopper but its panicles are as susceptible as those of susceptible plants.

Genetics of resistance to Nephotettix virescens and Nilaparvata lugens has been investigated in selected varieties. It is of monogenic nature. Four different pairs of dominant genes and one pair of recessive genes have been identified attributing resistance to the green leafhopper, while the resistance to the brown planthopper is attributed by two different pairs of dominant and two pairs of recessive genes.

Three different biotypes of the brown planthopper but no biotype of the green leafhopper capable of surviving on resistant plants have been identified. At present, studies on brown planthopper biotypes are being intensively followed as these could limit the success of resistant varieties. Varieties identified as resistant to the brown planthopper at IRRI have also been recorded as resistant in Japan, Korea, Taiwan, Thailand and Indonesia but many are not resistant in certain parts of India and Sri Lanka.

Rice whorl maggot

The rice whorl maggot is a major pest of rice during its vegetative stage of growth. The insect is very common and usually infests almost all fields through most of the tropical and subtropical Asia. The maggots feed on the unopen central whorl of the leaf and the symptoms become evident as small chewed up discolored areas on the inner margin of the central leaves. Heavy infestations cause marked stunting of the plant and probably a reduction in the number of tillers per hill.

About 20 thousand varieties and selections have been screened for their resistance to the whorl maggot but only a few moderately resistant lines have been recorded.

Several individual plants in the cross IR2070 ($IR20^2$/*Oryza nivara*// CR94-13) have exhibited good resistance to the whorl maggot. These are at present being pedigree tested to verify their true resistance. CR94 and IR20 are moderately resistant to the whorl maggot. A diallele system of crossing of selected resistant varieties was initiated in 1974 to increase the existing level of resistance to this insect. In the F_1 generation several lines exhibited greater resistance than any of their parents. Selected plants have been intercrossed. Resistance appears to be due to non-preference of the ovipositing fly for certain varieties and the antibiosis effects of the plant on the maggots. Maggots placed on resistant varieties usually suffer higher mortality and have slower rate of growth than those on susceptible varieties.

Rice leaf folder

The rice leaf folder has been a common but minor pest of rice in many areas. However, in recent years it has been often recorded heavily infesting fields planted with high yielding short-statured varieties.

One-thousand varieties were screened for their reaction to the leaf folder in field and greenhouse experiments but no variety was recorded even as moderately resistant. Although there are some differences in the susceptibility of various varieties, at best certain varieties could be called as moderately susceptible while others are susceptible.

Rice gall midge

Rice gall midge is a severe pest of rice in several parts of India, Sri Lanka, Thailand and Indonesia, but it has not been recorded from the Philippines. In recent years, excellent sources of resistance to this insect have been identified and high yielding resistant varieties have been released in India and in Thailand. We have been cooperating with the scientists in these countries to incorporate resistance to the gall midge in breeding materials. The resistance of IR32 to rice gall midge was the outcome of such cooperative experiments conducted by scientist in India.

Future plans:

Work will be continued on the aspects being presently investigated with emphasis on developing varieties resistant to additional insect pest species, increasing and diversifying sources of resistance presently available, and determining the occurrence of biotypes of different insect species capable of surviving on resistant plants. This work can be broadly classified as follows:

1. Sources of resistance

Continue screening of collections of rice and breeding materials against various insect pests with emphasis on evaluating collections from different geographical regions and of other species of Oryza. This may help in identifying lines with different nature and genes for resistance than of the presently available resistant varieties. An example is the resistance of many Oryza glaberrima varieties to the rice green leafhopper, N. virescens.

In appropriate cases different biotypes of the insect will be used for screening the rice collections and the breeding materials. For example, we have so far been testing only the varieties that have shown resistance to biotype 1 for their reactions to biotypes 2 and 3. However, it is quite likely that some of the varieties susceptible to biotype 1 may be resistant to the other biotypes.

Work on diallele system of crossing resistant varieties for increasing the level of resistance to the striped borer and rice whorl maggot will be continued.

While resistance to the striped as well as the yellow borer appears to be generally adequate against the dead heart stage, adequate resistance has not been recorded against the white head damage. Varieties showing resistance to the latter will be searched for. This will probably have to have a high level of non-preference reaction to the ovipositing moths because the hatching larvae often cause white heads with little feeding.

The work on yellow borer resistance will be further intensified as it is probably the most widely distributed borer species in South and Southeast Asia. We will need to develop a more efficient mass rearing technique for this insect and possibly a simpler method of screening for varietal resistance.

Investigations on other insect pests which are not common at IRRI will be emphasized in cooperative experiments with scientists working in areas of their occurrence.

In all these studies emphasis will be placed also on those varieties which possess moderate levels of resistance.

2. Genetics of resistance

Studies will be continued on the genetics of resistance to various insects with the objectives of identifying diverse sources of resistance and to further building up the existing levels of resistance.

3. Causes of resistance

Basic studies on various aspects of resistance (non-preference, antibiosis and tolerance) will be continued on selected varieties. Also, the role of plant morphological and anatomical characters in these will be investigated. While some studies on the biochemical nature of resistance will be continued, far more in-depth studies on this subject will be undertaken in collaboration with research institutes in the developed countries. Several organizations have shown interest in cooperating with us in these studies.

4. Insect biotypes

At present, biotypes of insects capable of surviving on resistant plants appear to be a crucial factor in the success of brown planthopper resistant varieties.

To determine the biotypes, studies along the following lines will be conducted:

a. Continuous rearing of field collected insects on different resistant varieties.

b. Evaluations of varieties known to possess different sources of resistance in the International insect nurseries.

6. Breeding for resistance

Efforts will be continued to breed varieties resistant to as many insects as possible. Emphasis will be laid on developing varieties with multigenic resistance which are expected to be more stable against the development of insect biotypes. Also, isogenic resistant lines will be developed and feasibility of multi-line varieties will be investigated.

7. International insect nurseries

International insect nurseries on selected insects and more informal collaborative projects on others will be continued to determine the reactions of varieties to pests which are not common at IRRI. As discussed above these will also help identify insect biotypes.

Table 1. Summary of work done at IRRI on varietal resistance to insect pests of rice. From 1962 to October 1975.

Insects	Year project started	No. of varieties recorded as Tested	 Resistant	 Moderately resistant	Genetics of resistance	No. of biotypes recorded	Resistant IRRI varieties[1]
Stem borers:							
striped borer *Chilo suppressalis*	1962	20,100	0	26	Polygenic	0	IR20 IR26 IR28 IR29 IR30 IR32 IR34
yellow borer *Tryporyza incertulas*	1967	5,000	0	15	-[2]	-	IR20
white borer *Tryporyza innotata*	1969	2,000	0	10	-	-	-
pink borer Sesamia inferens	1969	2,000	0	10	-	-	-
Leafhoppers and planthoppers:							
green leafhopper *Nephotettix virescens*	1966	11,200	79	194	Monogenic 5 genes	-	IR8 IR20 IR26 IR28 IR29 IR30 IR22 IR34
green leafhopper *Nephotettix nigropictus*	1972	232	15	45	-	-	none
zigzag leafhopper *Recilia dorsalis*	1972	1,500	5	5	-	-	IR26 IR28 IR29 IR30 IR32 IR34
brown planthopper *Nilaparvata lugens*	1965	17,400	142	105	Monogenic 4 genes	3	IR26 IR28 IR29 IR30 IR32 IR34
white-backed planthopper *Sogatella furcifera*	1970	6,600	11	44	-	0	IR28 IR29 IR30 IR34
whorl maggot *Hydrellia philippina*	1965	20,100	0	17	-	-	-
leaf folder *Cnaphalocrosis medinalis*	1972	1,000	0		-	-	-

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[1] Including moderately resistant varieties.

[2] Not investigated.

PROTEIN CONTENT[1]

Justification and objectives:

Rice protein is one of the most nutritious of all cereal proteins (about 4% lysine), but the protein content of milled rice is the lowest of all cereals (about 7% at 14% moisture). Screening a major portion of the cultivars in the germplasm bank revealed a variation of one half of one percentage point in lysine content. We have found that some cultivars show a consistent advantage of about two percentage points in protein content over presently cultivated varieties at comparative yield levels. Therefore, we have focused our research on the improvement of protein content while maintaining the nutritional quality and other essential traits of modern, improved rice varieties.

The utility of additional protein in rice is disputed but there is a lack of firm evidence on both sides of the question. We are presently providing high protein rice to be used in a feeding trial with young children. We expect the results of this trial to resolve the question. If high protein rice proves nutritionally superior, it should eventually be beneficial to untold millions of consumers throughout the rice growing world.

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[1] Project Leaders - W. R. Coffman, Associate Plant Breeder; B. O. Juliano, Chemist; S. K. De Datta, Agronomist; K. A. Gomez, Statistician.

Summary of accomplishments:

We have found that environment contributes a large portion of the total variability in protein content. From 964 experimental plots of IR8 grown under varying test conditions, brown rice protein content ranged from 5% to 12%. However, protein content of grain is influenced less by the environment than is grain yield. From the same 964 plots of IR8 grain yield ranged from 1.0 ton/hectare to 9.8 tons per hectare with a coefficient of variation of 13% for protein and 28% for yield.

"Protein (mg) per seed" has been found to be less affected by the environment than "percent protein" and may be a useful selection criterion, especially in early generations.

We have found that there is a quadratic relationship between grain yield and protein content. Both characters can be increased simultaneously only up to a point, beyond which an increase in protein content can be obtained only as a result of a decrease in grain yield. For IR8 grown in the dry season, this protein yield threshold was reached at 6.6 tons per hectare grain yield and 8.5% brown rice protein. For IR480-5-9-3 (a high protein line) this protein yield threshold was reached at 6.5 tons per hectare grain yield and 10.3% brown rice protein. These data clearly established the potential for improving the protein content of rice without sacrificing yield potential.

The IRRI world collection of rice varieties was screened for protein content starting in 1966 to identify genetically high protein varieties to be used in the breeding program. Out of 7,760 varieties screened, 6 varieties with over 14% protein in several trials were used as parents in crosses with IR8 made in 1967. These varieties mature early, with low dry matter production and are susceptible to several important diseases and insects. The best lines from these crosses, IR1100 to IR1105, had higher protein than IR8 but had only 2/3 of its grain yield potential. We have concluded that intensive evaluation of world collection materials is not a very promising approach to the identification of genetic sources of higher protein content.

IR480-5-9 was identified several years ago as having high protein content and is now used as high protein check in our trials. Except in Cuba and Fiji, it has not been released for commercial production because of its susceptibility to some major disease and insect pests. Crosses were made about three years ago to remedy that problem. Improved lines are now available with protein content and yield potential comparable to IR480-5-9, and carrying resistance to blast, bacterial blight, green leafhopper and brown planthopper. These lines lack resistance to the major virus diseases but many crosses have been made toward that objective. We now have advanced lines from these crosses under evaluation, which carry a complete spectrum of disease and insect resistance and are potentially higher in protein content.

In addition, we have identified through routine screening procedures two promising lines which have consistently been at least one percentage point higher in protein content as compared to the IR20 standard check variety at comparable levels of yield (IR8 and IR20 have similar protein contents). One of these lines, IR2031-724-2-3 carries a complete spectrum of resistance except that it is susceptible to the tungro virus. IR2153-338-3 is at least moderately resistant to all of the major diseases and insect pests in the Philippines.

We have utilized what may be loosely defined as long cycle recurrent selection in an attempt to concentrate or reinforce genetic factors for protein content. We are now evaluating 100 uniform lines derived from the first and second cycles of this scheme.

We have found that an increase in protein content of 2 percentage points does not adversely affect any aspect of grain quality. Cooperative feeding studies have been made using Streptococcus zymogenes, growing rats, and adult and 1.5 to 2 year old human subjects. Results have been mostly favorable but inconclusive.

Future plans:

Through cooperative feeding trials we expect to verify the usefulness of high protein rice in augmenting human nutrition.

Procedures will be developed to determine whether relative genetic ranking of the same lines for protein per seed would be consistent over seasons and over nitrogen levels. If this selection criterion proves effective it will be utilized extensively in identifying early generation high protein materials, and may alter procedures in the recurrent selection procedure.

The systematic hybridization, screening and evaluation work will be continued and the promising breeding lines will be distributed and tested in the International Rice Testing Program. The recurrent selection scheme now employed for reinforcing or concentrating factors for protein content will be evaluated for effectiveness and continued if results warrant.

Work will be continued on the isolation and characterization of the major protein fractions of the rice grain.

Previous results on nitrogen metabolism in low and high protein varieties will be verified using low and high protein sister lines.

New and promising high protein breeding lines will be carefully evaluated for all important characteristics before being distributed or recommended for possible commercial utilization.

DROUGHT RESISTANCE[1]

Justification and objectives:

The potential growth and yield of improved rice varieties is often limited by water supply in upland, rainfed lowland, deep water and even irrigated rice culture. An appraisal of the extent to which the world's rice crops are affected by inadequate water supply demonstrates the magnitude of the problem. Upland rice occupies 10 percent of the rice hectarage in South and Southeast Asia (8.1 million ha), nearly 80 percent of Latin America (3.3 million ha) and 75 percent of Africa (2.7 million ha). Rainfed lowland rice accounts for about 50 percent of the rice hectarage in tropical Asia (40 million ha). The hectarage of upland and rainfed lowland rice will increase as man cuts down forests and brings more marginal lands into crop production. Approximately another 10 percent is sown in dry soil and grown for several weeks before monsoon rains arrive providing flooded conditions. In the remainder of the world's rice (irrigated systems), water deficits are not commonly appreciated. However, irrigation systems often operate at low efficiencies or on inequitable schedules. IRRI's recent work on the constraints of rice production has cited inadequate water supply as a major factor even in irrigated areas. Thus we believe that as much as 90 percent of the world's rice growing area may suffer from various degrees of drought at some yield determining stage of crop growth and development. These statistics establish the potential for increasing and perhaps

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[1] Project Leaders - J. C. O'Toole, Associate Agronomist; T. T. Chang, Geneticist; S. K. De Datta, Agronomist; S. Yoshida, Plant Physiologist.

more importantly stabilizing rice yields over the immense cropping regions susceptible to this type of environmental stress. It is our conviction that success in this research effort will bring immeasurable benefit to the rice producing world, especially Asia's millions of subsistence rainfed rice farmers.

Since the 1969 decision to direct more of IRRI's research toward non-irrigated areas, the awareness of water deficits in the breeding and technological development programs has increased dramatically. The task of developing more drought resistant rice varieties is formidable indeed. The utilization of inherent differences in drought-resisting mechanisms is related to climatic, edaphic and cultural conditions which are location specific. Therefore IRRI must identify and incorporate mechanisms that will function over a broad spectrum of environments. Cognizant of these facts we have formulated five objectives which should maximize the resources in an interdisciplinary research approach.

1. To achieve a better understanding of the physiologic basis of drought escape, avoidance, tolerance, and recovery in relation to varietal differences in these component traits.
2. To devise and refine techniques to enable researchers to quickly identify the different components of drought resistance, each of which probably operates at a particular stage of plant growth.
3. To utilize the appropriate screening techniques in screening the elite breeding lines and accessions in the germ plasm bank for adaptiveness to different water regimes.
4. To develop a full spectrum of genetic materials to recombine as many drought-resisting components as feasible together with a higher but stable yielding potential.

5. To mobilize, coordinate and enhance the total inputs of national and international research centers in the development and evaluation of drought-resistant genetic lines for farmers' adoption. This will primarily be accomplished through the International Rice Testing Program and the Genetic Evaluation and Utilization Training Program. Appendix I illustrates how such a program will progress from evaluation of the germplasm available, to the eventual field testing of elite lines at many diverse locations.

Summary of accomplishments:

Morpho-agronomic studies

IRRI's initial research efforts were directed to the agronomic evaluation and growth analysis of diverse germ plasm under upland and lowland cultures in order to identify varietal characteristics and growth features that are associated with the complex problem of drought resistance.

A. Lowland experiments

Field studies were initiated during the 1969 dry season to assess the effects of drought at various physiological growth stages of the rice crop. The soil moisture tension was allowed to reach 50 centibars (cb) after which adequate moisture was provided to compensate for losses through evapotranspiration. Grain yields were reduced when stress occurred during the reproductive and ripening stages as well as during the early stages of vegetative growth. These data suggest that grain yield will be reduced unless adequate moisture is available at all growth stages of the crop.

Studies in the greenhouse demonstrated that grain yields of IR8 and IR5 were more sensitive to the intensity and duration of moisture stress than to the particular growth stage at which stress was applied, while tall variety H-4 was sensitive to moisture stress during the reproductive and ripening stages. These data indicated that moisture stress effects could be variety-specific and related to growth duration. Subsequent studies indicated that soil moisture tension as low as 15 cb was enough to reduce grain yield of rainfed lowland rice. Part of the reduction in grain yield is due to the loss of nitrogen under alternately dry and wet conditions.

B. Upland experiments

A group of 20 varieties, including both upland and lowland types, was intensively studied under different cultural and water regimes during 1970-1972. The traditional upland varieties were characterized by low tillering ability, tall plant stature, rather long and droopy leaves, plasticity in leaf rolling and unfolding during stress, long and well-exserted panicles, good grain filling under mild water stress, early maturity, and deep-and-thick roots. The lowland varieties generally have a higher rate of leaf and tiller production and greater plasticity in tillering and period of vegetative growth in response to varying degrees of water stress. Because of shallow and thin roots the growth and yield of lowland varieties are more readily affected by stress but they recover quickly upon watering. On the other hand, the upland varieties show slow recovery and generally have a low but stable yield potential.

Traditional varieties from rainfed lowland areas generally have moderate tillering ability, tall plant stature, long and narrow leaves, photoperiod sensitivity, moderately resistant to drought, and fast recovery after water stress is relieved. Such varieties are location-specific in harvest date, highly competitive with weeds, and poorly responsive to added nitrogen. Low and stable yield is again a unique feature of such traditional varieties.

Field experiments conducted during the 1973 dry season under 75 cb stress condition demonstrated that varieties and lines differ greatly in the reduction of plant height, tiller number and dry matter production, due to moisture stress during the vegetative and reproductive stages. The studies further indicate that the reduction in grain yield may be due to the direct effects of moisture stress or to moisture-stress-induced soil problems such as iron deficiency, or a combination of both.

Yield trials were conducted on a multi-date and -location basis. This has led to identifying a number of varieties and breeding lines tolerant to drought. The lowland variety IR5 was found to have good tolerance to drought, particularly if moisture stress occurs during the vegetative period. Subsequent field studies lead to identification of IR442-2-58, IR1529-430-3 and some others which have shown promise under upland rice culture.

Another approach was to plant rice in rainfed lowland fields at various toposequence to study water balance in relation to growth stages of rainfed rice. In these test sites, rain water flows from the highest to the lowest paddies and is finally lost as drainage. The difference between the highest to the lowest paddies was about 3 meters. Correlation studies between relative elevation of paddies and grain yields of different varieties clearly demonstrated the drought tolerance of IR442-2-58, an experimental line derived from a cross between a semidwarf and a floating variety. Subsequent studies clearly demonstrated that IR442-2-58 has the ability to adapt itself to varying levels of water from upland conditions to a water depth of about 1 meter.

Screening for drought resistance or tolerance

A mass screening program was developed during 1972-73 which made possible the testing of thousands of varieties and lines for field resistance to drought during the dry season. Plants are grown under a simulated upland culture and watered by gravitational irrigation. Since 1973 a total of 6,182 varieties and lines have been screened for water stress at three growth stages. About 150 entries were found to be resistant and another 1,500 entries moderately resistant. Drought-resistant varieties were identified from traditional upland varieties of West Africa, Brazil, Laos, Malaysia, Japan, and India. Drought-resistant entries again show their resistance when water stress occurs in wet season plantings.

Similarly 1,003 varieties and lines having one or more resistances to diseases and pests were screened during the 1975 dry season for field tolerance under a sprinkler irrigation system. Thirty-two varieties from South and Southeast Asia were identified to be tolerant to stresses at three growth stages. These varieties will be further evaluated at many locations abroad.

We have developed a greenhouse technique by which a constant soil moisture tension can be maintained at two levels continually. We found this setup to be useful in comparing relative drought tolerance of rice varieties and breeding lines at low but constant soil moisture tension at two growth stages.

Varietal differences in drought tolerance were also investigated in drums or pots of soil in the screen house. The technique developed in this study is now being used in an expanded greenhouse screening program.

Several experimental lines have been found to be tolerant at the vegetative stage and moderately tolerant to drought at the reproductive stage. Some examples of drought tolerant lines are as follows: IR1646-623-2, IR1529-430-2, IR442-2-58, IR1750-F5B-5 and several IR2035 lines. These and other promising varieties and lines are being evaluated through multi-location trials in the International Rice Testing Program (IRTP).

Studies on root system

During droughts, soil begins to dry at the surface and extends to lower soil horizons. Under such conditions, the growth and yield of rice depend on deep and proliferated roots that can effectively use water stored in the subsoil. Thus, deep root growth can be a major characteristic contributing to drought resistance under field conditions.

Early studies on root characteristics of rice varieties revealed that drought resistant upland varieties are characterized by deep and thick roots. On the other hand, typical lowland varieties have shallow root systems and are susceptible to drought in upland plantings.

Recently, we extensively studied varietal differences in root systems using a root box technique. A total of 221 varieties and selections have been so far examined. The findings are that no shallow-rooted varieties are drought resistant and no deep-rooted varieties are drought susceptible, thus indicating a close association between root system and drought resistance.

Deep root systems have another advantage in nitrogen absorption. Several experiments indicated that a deep-rooted variety has a greater ability to absorb soil nitrogen from deep soil horizons and to recover fertilizer nitrogen placed deep or moved downwards. This function of deep roots should be considered desirable for upland rice, particularly in coarse-textured soils where both drought and leaching of applied fertilizer nitrogen are likely to occur.

There has been a strong supposition that a tall plant height is related to a deep root system. A comparison of root systems of two nearly isogenic lines differing in plant height, however, demonstrated that root depth is not necessarily associated with plant height.

Boxes of different constant-watertable depths have been devised by use of an open syphon. Rating of rice varieties on drought resistance in these boxes generally agrees with their field resistance to drought. Analysis of growth in these boxes also revealed a greater sensitivity of rices to drought at anthesis than at pre-anthesis time.

Breeding for drought resistance

The major breeding objective for upland rice is to incorporate a higher yielding potential into a drought-resistant background without sacrificing the yield stability and other desired agronomic features of the traditional type. Meanwhile, the levels of resistance to major insects and diseases as well as tolerances to adverse factors of upland soils will be enhanced. Concurrently, by using appropriate drought-screening techniques a wide array of genetic lines can be developed so as to provide the necessary level of resistance and/or tolerance to suit rainfed lowland, partly irrigated, and deep-water cultures.

Crosses among diverse parents have been made to recombine the desired component traits. During 1974, 493 single crosses, 274 three-way crosses and 36 double crosses were made. And additional 182 crosses were made during the 1975 dry season.

Problems have arisen in successful genetic recombination in wide crosses. Difficulty was encountered in finding the desired progenies from traditional upland x semidwarf crosses that have intermediate features or other desired recombination. A genetic study involving three marker genes indicated aberrant segregation ratios in nearly all of the distant crosses. We are using the more promising lines from upland x semidwarf crosses made earlier as an intermediary in combining the desired features from the two ecologic groups.

We have identified several breeding lines that have adequate levels of field resistance to drought, a higher tillering capacity than their upland parents, and a higher yielding potential (2.0 - 3.5 mt/ha) than the traditional upland varieties (1.5 - 2.0 mt/ha). However, our lines lack resistance to sheath blight, the leafhoppers, and stem borers.

We have supplied F_2 bulks or early generation lines to cooperators in Brazil, Indonesia, Ivory Coast, Liberia, Thailand, and Nigeria for evaluation and selection under local conditions.

Future plans:

Efforts in the near future will be focussed on the unravelling of the different physiologic and morpho-histologic mechanisms that contribute to drought resistance and recovery under diverse environments. Collaborative research with academic institutions abroad will be sought to advance the scope of research on the basic aspects. The progress in research will be gauged by the scope in research as well as the magnitude of testing. Therefore, research on screening methodology will be of high priority as current methods lack quantitative precision, speed, and the capability to handle large numbers.

In order to arrive at a better understanding of various physiologic components related to drought resistance operating at different growth stages, critical studies using common tester varieties and comparing different techniques will be made. Greenhouse experiments and field tests shall be compared with each other so as to reaffirm the findings obtained under each set. When such basic information is available, breeding efforts can be directed to combine the essential components into genetic lines intended for use in different agro-climatic or cultural systems.

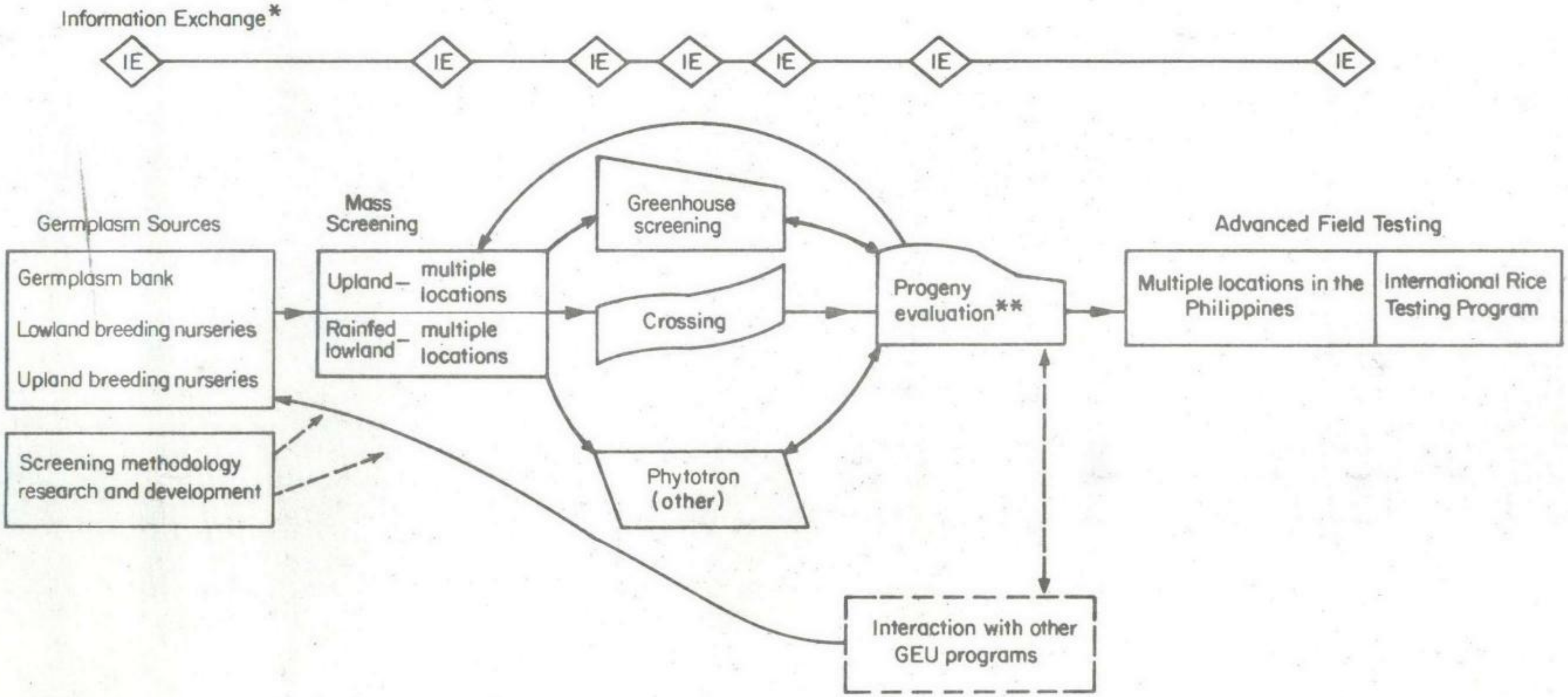
Stable germ plasm as well as hybrid progenies will be field screened at multi-location sites in the Philippines. The sites will represent different soil types and cultural systems. Increased personnel and expanded physical facilities are needed to implement the multi-site screening and evaluation. Field screening will be followed by specialized greenhouse tests that would ascertain the inclusion of the necessary drought-resisting mechanisms. Expansion of field screening facilities will allow tens of thousand of breeding lines to be evaluated each year.

Along with the expanded field listing, the search for deep and efficient root systems in diverse germ plasm will be intensified. Morphologic and structural features of the plant that contribute to drought resistance will be investigated.

Our initial interest in drought resistance was primarily directed toward the improvement of the upland rices. Future breeding efforts will be expanded to develop genetic lines that can produce yields that are higher than but equally stable as the traditional rainfed lowland varieties. The total effort is to develop a full range of genotypes that can adapt to drought conditions ranging from the rainfed upland to the partially irrigated culture.

Because much of the evaluation of hybrid progenies will be made outside the IRRI premises, attention will also be given to early-generation evaluation, the training of technicians, and development of adequate testing sites in collaborating countries.

Appendix I



* Progeny evaluation involves a logical progression of material through all drought resistance screening procedures to assure that a comprehensive report is available via the information exchange system.

ADVERSE SOIL TOLERANCE[1]

ADVERSE SOIL TOLERANCE

Justification and objectives:

By 1980 the world will need 30% more rice than it did in 1970. In overpopulated India and Bangladesh the increase in demand will be nearly 40%. This demand can be met by increasing the yield per ha or by extending the area under rice. Either way soil problems are major obstacles. There are more than 40 million hectares of current and potential rice soils in the tropics and subtropics on which one or more of the following problems occur: salinity, alkalinity, strong acidity, iron toxicity, zinc deficiency, and phosphorus deficiency.

We emphasized salt tolerance in the GEU program because salinity is the most extensive soil problem. Excess salt is the main obstacle to successful rice culture on about 10 million hectares of salt-affected soils in the Indo-Gangetic plain and on more than 20 million hectares of tropical coastal saline soils physiographically and climatically well suited to rice culture. Large irrigation and drainage works are required to reclaim saline soils in arid regions and massive dikes and huge pumps are needed to reclaim soils inundated by seawater during high tides. These capital-intensive measures are beyond the reach of most poor countries in the tropics.

Alkalinity is a major retarding factor on a total of several millions of hectares of irrigated soils in the arid parts of India, Pakistan, Iran and Egypt. The problem will spread as more arid soils are brought under irrigation and the existing ones age. Because sunshine is abundant and disease and pest damage is minimal, arid soils have a high potential

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[1] Project Leaders - F.N.Ponnamperuma, Soil Chemist and H. Ikehashi, Plant Breeder

productivity if alkalinity is corrected. Alkalinity can be remedied by applying gypsum, irrigating and leaching but these are costly measures.

Excess water-soluble iron limits rice yields on about 30 million hectares of strongly acid oxisols and acid sulfate soils. Iron toxicity can be corrected by liming the soil but lime is not readily available in the acid regions where the problem is widespread. Besides it is not economically feasible to lime acid sulfate soils.

Phosphorus deficiency limits the rice yields on millions of hectares of ultisols, oxisols, andosols, and vertisols. These soils are not only low in available phosphorus but they also fix large amounts of applied phosphate.

Next to nitrogen and phosphorus deficiencies, zinc deficiency is perhaps the most important nutritional factor limiting the grain yield of wetland rice. It occurs on alkaline soils, calcareous soils, wet soils, peat soils, and sandy soils. Millions of hectares of low-lying land on the humid tropics, well-supplied with water, may be brought under rice if improved varieties with resistance to zinc deficiency are developed.

Rice grown under upland conditions yields less than that grown in lowland soils. The growth-limiting factors that affect upland rice are iron deficiency on neutral and alkaline soils and manganese and aluminum toxicities on acid soils. Applying iron compounds to the soil or the plant is not effective in correcting iron deficiency. Besides the cost is prohibitive. Lime, a remedy for manganese and aluminum toxicities on acid soils, is not readily available in the acid regions where the problem occurs. Submerging the soil, which corrects these growth-limiting factors in upland soils, is often not feasible for upland rice areas.

Since improving adverse soils by chemical amendments or by water management is beyond the means of most developing countries, varietal tolerance to these conditions is one attractive alternative. There are undoubtedly varieties which may have, over the centuries, developed tolerance to these adverse soil conditions. Identification of such sources of tolerance and breeding of improved varieties with good plant type and with combined tolerance to soil problems, diseases and insects will increase yields in existing rice land with soil problems and will make possible the bringing of more land under rice.

The objectives of our research are:

1. To develop for each problem soil, a reliable method for mass screening of rice varieties and breeding lines;
2. To identify the sources of tolerance to injurious soils in the world collection of rice cultivars;
3. To screen promising breeding lines for their tolerance to adverse soils;
4. To breed improved varieties suited to adverse soils by using the germ plasm identified as sources of tolerance as parents; and
5. To conduct basic studies on the biochemical, physiological and genetic aspects of tolerance to soil problems.

Summary of accomplishments:

Close to 5000 varieties and breeding lines have been screened for tolerance to the following injurious soils: salinity, alkalinity, iron toxicity, zinc deficiency, phosphorus deficiency, iron deficiency, and manganese and aluminum toxicities.

We screened over a thousand varieties and breeding lines for tolerance to salinity in the greenhouse on a nearly neutral clay amended with 0.4% salt in the tests made during 1974 and 1975 using plant performance 4 weeks after transplanting of 2-week-old seedlings as criterion. 67 entries were rated better than Pokkali, a salt tolerant variety from India, being used as the check and 462 were found as good as Pokkali. Of the more than 500 strains found to be salt tolerant, 14 are elite breeding lines and varieties from IRRI, 91 are from Indonesia, 86 are varieties and selection from India, 57 are from Pakistan, Thailand, Sri Lanka, Bangladesh and Vietnam. The 14 entries from IRRI include IR5 and IR30.

A total of 50 selected entries are at present being evaluated for their salt tolerance at 20 different locations in an International Rice Salinity Tolerance Observational Nursery.

Of more than one thousand entries screened in the greenhouse for tolerance to alkalinity in a nearly neutral soil alkalized with 1.4% sodium carbonate, 109 were observed at 4 weeks after transplanting to be as tolerant to alkalinity as Pokkali, the tolerant check. Of these 52 varieties are from India.

We screened 230 varieties and lines on a lateritic clay that builds up more than 400 ppm iron in the soil solutions after submergence. Forty were found tolerant to iron toxicity and of these, six are promising lines from IRRI.

We screened 220 varieties and breeding lines for tolerance to phosphorus deficiency. Twenty-four varieties and breeding lines notably IR1514AE666,were found to utilize soil phosphorus more efficiently than others.

Among the 70 varieties and 2000 breeding lines screened in zinc-deficient areas, 31 varieties and 325 breeding lines were selected as tolerant. IR30 and IR34 are among the tolerant varieties.

We screened 144 varieties for tolerance to iron deficiency on aerobic neutral and calcareous soils and found 22 varieties to be suited to these soils. IR24 is one of these varieties.

Of the 128 varieties screened, 22 were found to yield well in spite of manganese and aluminum toxicities in an acid aerobic soil.

We distributed varieties and breeding lines with superior tolerance to soil problems to be evaluated in several rice growing countries.

An extensive number of crosses have been made starting 1974 to combine tolerance of the various adverse soils with the many characteristics essential to improved varieties. Although high-volume screening techniques are not yet available for many of these traits, we are making the proper crosses in anticipation of their development. Much of the GEU breeding material now carries tolerance to many of the adverse soils.

We have systematized our approach toward the development of improved materials tolerant to adverse soils. We have emphasized salt tolerance in the breeding work. During 1973, numerous crosses were made with Pokkali because it appeared to be the most tolerant cultivar to salinity and to several other adverse soils. Although Pokkali was proved to be a very poor combiner we were able to select some salt-tolerant progeny of satisfactory agronomic type by making numerous topcrosses and double crosses involving F_1 hybrids of Pokkali and other cultivars of desirable agronomic type. The F_3 lines were grown in salt-amended and alkali-amended plots during the 1975 dry season and 575 plant selections were made. The F_4 lines are now grown in the salt-amended and alkali-amended plots for further selection and evaluation.

Future plans:

Our research work in the expanded Germ Plasm Evaluation and Utilization Program will include:

1. refining and standardizing the methods for each problem for mass screening of plant materials.
2. screening of materials from the world collection, materials from problem soil areas and materials from the total GEU program for tolerance to adverse soils,
3. further evaluation of promising materials in countries where the problems occur,
4. developing improved varieties with tolerance to adverse soils through systematic hybridization, screening and evaluation; and
5. basic studies on the genetic, biochemical, and physiological aspects of tolerance to adverse soils.

In the initial stages, salinity, alkalinity, iron toxicity and zinc deficiency will receive priority. Later studies will emphasize tolerance to aerobic soils, reduction products, and other subsequent problems.

We have cut down the time involved for screening for salinity, alkalinity, and zinc deficiency from 4 months to 6 weeks but our screening capacity is still inadequate for testing the materials from the world collection and the rapidly growing number of lines in the breeding program. We will therefore investigate ways of further refining these techniques. With ease and speed as objectives we are investigating the use of culture solution for screening for tolerance to salinity, phosphorus deficiency, and iron toxicity.

Screening of varieties and breeding lines will be continued using the present techniques. Survey of literature, visits to problem soil areas and correspondence will be used as means of obtaining the names and seeds of indigenous varieties from problem soil areas.

Since our ratings are based on plant performance in the early stage, further evaluation and more rigorous testing of the identified sources of tolerance and advanced breeding lines will be conducted in problem soil areas in the Philippines and in other countries, through the International Rice Testing Program. In some cases, even very early segregating generation will be supplied to testing sites and the ratings will be used as aid in making the selections.

We shall hybridize promising sources of tolerance to adverse soils with selected improved lines with other essential varietal traits to produce improved materials with tolerance to soil problems. Tolerance to injurious soils will be included as criterion in the evaluation of advanced lines in the total breeding program.

To gain an understanding of the mechanisms of tolerance to adverse soils and to help us in finding ways of overcoming the problems, fundamental research on the biochemical, physiological and genetic aspects of tolerance to these stresses should complement our present efforts. For example if iron exclusion from the cytoplasm is involved in salt tolerance, the limit of survival may be set by the degree of osmotic adjustment the plant can achieve. Another aspect worth looking into is enzyme stimulation.

DEEP WATER AND FLOOD TOLERANCE[1]

Justification and objectives:

Farmers grow improved rice varieties extensively in the world's "shallow water" regions, where water depths range from 5 to about 50 centimeters. But the new rice technology has bypassed other areas, including the vast regions where water is not controlled and may become too deep during the monsoon season for the semidwarf varieties. Estimates of such areas range from 25 to 40 percent of the world's rice land. These include areas where water normally reaches from 200 to 600 centimeters forces farmers to grow special "floating" rice varieties. These varieties are broadcast on dry soil and are usually subjected to drought during early stages of growth and to deep water later on. They have developed a mechanism which enables them to survive deep water - their stems elongate as water rises. These floating varieties are harvested when the water has receded. About 10 percent of the rice land in Asia and Africa is planted to such floating rices.

A much greater area is planted to tall, non-floating varieties adapted to medium-deep water (50 to 200 centimeters) which are sometimes damaged or destroyed when the flood waters come. Very little fertilizer is presently used on these types since they tend to be unresponsive. Yields in these areas continue to remain stagnant. These marginal flood areas have not yet been affected by the green revolution.

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[1] Project Leaders: B. Jackson, Plant Breeder; B.S. Vergara, Plant Physiologist; W. R. Coffman, Associate Plant Breeder; S. K. De Datta, Agronomist; D. H. Ris Lambers, Associate Plant Breeder.

Crops are often completely submerged by unpredictable floods in vast rice areas. Submergence may last from 1 to 30 days at different growth stages. Work on flooding has been mostly on its prevention which is very expensive and not very effective. Increasing the tolerance of the rice plant to submergence has received very little attention although this would greatly reduce the annual losses resulting from floods.

Our objectives is to increase and stabilize grain yields in rice areas of medium deep (more than 50 cm) and deep (more than 200 cm) uncontrolled water. Preliminary objectives will relate to agronomic, physiological, and pest incidence investigations which will serve to refine the breeding objectives. We plan to emphasize the medium deep water areas and to combine flood tolerance, in the form of elongation ability and tolerance to submergence, with the other attributes essential to varieties suitable for such areas.

Major accomplishments:

We have found that semidwarf and intermediate-statured rices can be developed which adjust their heights to an increase in water depth. Prototype selections evaluated on farmers' fields at IRRI and at the Huntra Experiment Station in medium deep water (100 cm) exceeded their floating rice parent in yield by 40 percent and were decidedly superior to a popular traditional tall variety evaluated in the same trial. These prototype selections (T442 and IR442) are not suitable for commercial use because, among other things, they lack the appropriate sensitivity to photoperiod as well as disease and insect resistance.

Preliminary screening of the Germplasm Bank material has shown dramatic variation for tolerance to submergence. While most varieties die in 3 or 4 days, depending on water temperature and turbidity, others remain alive for 10-14 days.

These two major findings have led us to establish a cooperative program with the Thai Department of Agriculture to facilitate further research. Suitable rice growing areas for such work do not exist in the Philippines.

Future plans:

We plan a survey of the medium deep and deepwater area to more precisely identify the requirements of varieties for such areas. This will include information on prevalent diseases and insects, specific growth duration and photoperiod sensitivity requirements, prevalent soil types, cultural practices, frequency and duration of flooding and other factors that may affect varietal adaptability.

We will refine our present screening techniques for elongating ability and tolerance to submergence. We will place emphasis on the development of efficient screening techniques for other essential traits such as kneeing ability. This trait is essential in elongated plants when the water drops prior to harvest. We plan extensive agronomic and physiological investigations in collaboration with appropriate institute programs that will undoubtedly identify other essential traits and help to elaborate screening methods. For instance, drought tolerance at early stages of growth appears to be a definite requirement for many deepwater areas. We will continue to screen the Germplasm Bank for the best possible sources of all desirable attributes.

We will give major attention to refining the breeding operations for this aspect of our program. We have recognized that the specific photoperiod sensitivity requirements of varieties in deepwater areas presents a special problem. We will explore all possible breeding technique to minimize generation time without sacrificing the ability to select types with a specified sensitivity to photoperiod. When all presently know essential requirements of deepwater varieties are considered, the definition of efficient and effective selection pathways presents a very complex problem. A major effort will be required.

As new prototype breeding lines are identified we will place heavy emphasis on their evaluation so as to refine our breeding objectives and pinpoint further areas for investigations. To accomplish this and other objectives we expect to place immediate emphasis on training to augment the meager number of qualified personnel now available for deepwater rice research.

We expect that within the next five years new breeding lines and varieties will be in commercial production and begin to have an impact on those areas that cannot grow high yielding varieties. This will be accomplished by transferring photoperiod sensitivity and deep water tolerance from floating rice to disease and insect resistant semi-dwarf types. Furthermore, we are optimistic that tolerance to submergence after a period of up to 1 week can be successfully identified and transferred to high yielding types. We believe that some degree of elongation ability and as much submergence tolerance as possible would be desirable trait for nearly all improved varieties of the future. Very few lowland rice growing areas are immune from the threat of flood devastation.

TEMPERATURE TOLERANCE[1]

Justification and objectives:

Low temperature limits the adoption of high-yielding varieties in many rice growing areas such as India, Nepal, Bangladesh, Indonesia, and the Philippines. Although we do not have accurate figures, we believe there are at least seven million hectares of rice area in Southeast Asia where modern varieties cannot be cultivated because of low temperatures. In addition, low temperatures may reduce yields during the "off season" in the ever widening area where rice is cultivated year-round as irrigation becomes available.

Although much work has been done in Japan on the effect of low temperature on the rice plant, the emphasis has been on japonica rices which are already relatively resistant to low temperatures. The indica varieties adapted to the tropics have hardly been studied nor has any breeding work been done to develop lines resistant to low temperature. In addition, the temperature patterns of the tropics are quite different from temperate areas. In the latter, rice is always grown during the summer with low temperatures at the beginning and the end of the season. In the tropics or sub-tropics, rice may be grown in the winter. In areas such as Bangladesh, the temperature will be within safe limits at the beginning and end of the season but dip to low levels at mid-season. In the high elevation tropics temperature is continously marginal for rice cultivation and may dip precipitously during cloudy periods.

TEMPERATURE TOLERANCE

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[1] Project Leaders: B. S. Vergara, Plant Physiologist, S. Yoshida, Plant Physiologist and W. R. Coffman, Associate Plant Breeder

Also, in certain areas high temperatures limit rice yields. Unusually high percentages of sterility occur in lowland rice when air temperature at flowering time exceeds about 35°C. High temperature-induced sterility has been reported from Cambodia and Thailand for the dry season crop, and from Pakistan and Egypt for the regular season crop. This suggests that high temperature-induced sterility will become a serious problem when more rice is grown in the dry season and when rice is introduced into new areas where high temperatures prevail such as the Middle East and Tropical Africa.

Under rainfed and upland conditions, the rice plant is often subjected to water stress. When this occurs, leaf temperature rises and the plant may suffer from heat stress. Thus, tolerance to heat stress would be a desirable trait for rainfed and upland rice.

Basic studies on the effect of high temperature on rice are virtually nil. IRRI has the facilities to conduct such research and contribute to the rice improvement programs of the countries concerned.

Our ultimate objective is to combine tolerance to low or high temperatures with the other attributes characterizing modern rice varieties. Preliminary objectives which must receive immediate emphasis, especially in the case of high temperature, are understanding the effects of temperature stress at different stages of growth, and the perfection of screening techniques.

Summary of Accomplishment:

Low Temperature

Although some basic work on the response to high and low temperatures was conducted as early as 1962, no concerted efforts were made towards the breeding of varieties tolerant of low or high temperatures until 1968. No screening methods were then available for use in breeding work at IRRI. Initial studies were aimed at developing screening methods and understanding some of the growth responses of the rice plant to low temperature.

a. A satisfactory technique for identifying tolerance to cold water at the seedling stage has been developed but this reaction does not indicate the reaction of plants at later stages of growth. Low temperature affects the rice plant at all stages of growth.

b. Plant height. A comparison of the growth of a set of varieties grown in the phytotron and field conditions indicated that plant height was the easiest character to measure or visually observe as a criterion for low temperature tolerance. At low temperature, the varieties which were over 100 cm in height were more desirable. These same varieties are very tall when planted under Los Baños conditions (more than 140 cm). Lines planted in Los Baños which are suitable for low temperature areas should be at least 140 cm in height during the wet season. Plant height is one criterion that can be used in selecting low temperature resistant lines or varieties grown either at high or low temperatures.

Comparison of the growth duration of the rice varieties showed that growth duration is proportionally lengthened with lower temperatures. At Los Baños, the number of days from sowing to harvest is still the simplest method of screening varieties with suitable growth duration for cooler areas. Varieties or lines with growth durations of less than 110 days will be more stable in growth duration under various temperatures and will not have a long growth duration even when delayed by low temperature.

Several hundred crosses have been made at IRRI using parents recommended by cooperators in the outreach locations and other cultivars which we identified through the various tests for cold tolerance at different stages. Progeny have been screened in the Mountain Province, Philippines in cooperation with the Bureau of Plant Industry and distributed internationally as part of a cooperative network that we are attempting to establish among rice improvement programs representing the three different types of temperature regimes.

An International Cold Tolerance Nursery (IRCTN) has been established as part of the international testing program and distributed to Korea, Taiwan, Burma, Indonesia, U.S.A., Bangladesh, Nepal, Bhutan, India, Pakistan, Sri Lanka, Iran, Mozambique, Brazil, Argentina, and Liberia. Several lines are performing better than local checks according to preliminary observations. This testing will allow all areas in the world where low temperature poses a problem for rice cultivation to benefit from this program.

High Temperature

Studies on the response of rice varieties to high temperatures were started in 1974 using the IRRI phytotron. "High temperature" in our studies is a temperature regime of 35°C for 8 hours daytime and 27°C for 16 hours nighttime.

Visual symptoms observed under the high temperature at different growth stages were documented. The most dramatic varietal difference was observed in percentage of sterility, ranging from less than 10% for some upland varieties such as N22 and Dular to more than 95% for H4, Basmati-370 and BKN 6624-46-2. Subsequently, we have found that flowering is the most critical stage of growth for high temperature-induced sterility. Thus, high temperature-induced sterility differs in its mechanism from low temperature-induced sterility wherein the critical stage for cold temperature is about 11 days before flowering.

Duration of high temperature hours of daytime is another important factor inducing sterility. More than four hours of high temperature centering around noontime causes a high percentage of sterility. Examination of diurnal changes in air temperature of some rice growing areas suggests that daytime temperatures higher than 35°C are likely to persist for more than four hours in the hot months.

A simple screening technique for high temperature-induced sterility has been devised. Twenty seeds are sown in a circular pattern in 4-liter pots. This provides twenty uniformly grown main culms. The plants are subjected to 35°C/27°C temperature regime at flowering time. About 60 varieties and selections have been tested so far for high temperature-induced sterility. The varietal difference is quite apparent, ranging from less than 10% to more than 95% sterility.

Future Plans:

Low Temperature

We will continue to study cold resistance at different stages of growth with the two-fold objective of elaborating useful screening techniques and determining whether tolerance at one stage of growth might be related to tolerance at another stage.

We will complete the establishment of a network at locations throughout Asia representative of the three temperature patterns encountered in cool rice growing areas. Crosses will continue to be made at IRRI employing parents recommended by cooperators. Also, we will make extensive use of the materials identified which have the broadest possible tolerance in terms of growth stages. F2 seed will be distributed to all cooperating locations and seed of promising selections from each location will be returned to IRRI for further crossing and or distribution through the International Rice Cold Tolerance Nursery.

High Temperature

Using the recently perfected screening technique, we will continue to evaluate our advanced breeding lines and material from the Germplasm Bank for tolerance to high temperatures at flowering. We will complete a survey to determine the importance of heat induced sterility as a limiting factor in rice production. The degree of emphasis on this problem in our breeding work will be geared to the results of that survey.

INTERNATIONAL RICE TESTING PROGRAM[1]

Justification and objectives:

Although farmers have adopted the new semidwarf rice varieties on about 20 percent of the world's rice land - mostly the irrigated and rainfed regions where water control is relatively good - the new rices often don't grow well in other rice regions because of adverse conditions such as either too much or too little water, temperatures that are too cold, certain pests that cause crop damage, soils that adversely affect plant growth or consumer preferences for different grain types. It is now recognized that a wider range of rice varieties are needed to spread the new rice technology to more rice growing regions of the world.

To meet this need, it is apparent that cooperative research and testing must be expanded among rice scientists in rice producing countries in Asia and other parts of the world. Although many national rice improvement programs and IRRI's Genetic Evaluation and Utilization (GEU) Program are now generating many new breeding materials the germplasm base is still narrow and not widely tested. The effectiveness of all rice improvement programs can be enhanced by making available the world's best rice genetic material by providing a testing network under a wide range of agroclimatic and cultural conditions so all materials can be systematically evaluated.

INTERNATIONAL RICE
TESTING PROGRAM

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[1] Project Leader - H. E. Kauffman, Plant Pathologist

The objectives of the International Rice Testing Program (IRTP) are:

1. Disseminate germplasm and breeding lines between IRRI and national rice improvement programs.
2. Identify donor varieties and breeding lines with broad resistance to diseases, insects, and other stresses.
3. Identify elite breeding lines best adapted to each region.
4. Train national scientists in the operation of national GEU programs and provide a genetic transfer system for rice technology.

Summary of accomplishments:

The accomplishment of the Uniform Blast Nursery (started 1963) and subsequent bacterial blight nursery (started 1972) have contributed greatly to the development and widespread use of effective screening methods, of understanding pathogen variability and in identifying resistant varieties. Likewise, the International Yield Nursery (started 1972) helped demonstrate the yield stability of some semidwarf varieties and the International Rice Observational Nursery (started 1974) gave interested scientists access for the first time to a broad array of elite breeding lines.

The administration of the International Rice Testing Program was consolidated with the initiation of the UNDP contract in early 1975. A small working group of active rice scientists from eight countries planned the strategy for the IRTP at the ad hoc planning session in January. Participants from 26 countries met at the International Rice Research Conference in April and discussed and finalized the methodologies, the type of nurseries desired by each and the number of locations for testing (Appendix 1). Sets of all 12 types of nurseries were prepared by July and a total of 465 nurseries were dispatched to 46 countries around the world with the bulk of the nurseries going to Asia (Appendix 2). To foster good record keeping and quick data retrieval, special field books were designed for each nursery. Also, booklet on the standard evaluation system for rice was developed so that scientists who participate in the program would use the same experimental procedures and data recording systems.

Scientists, recognizing that the IRTP provides access to the world's best breeding material as well as a testing ground for their own breeding material have given strong support to the program. This is shown by the large demand for seed and the good management of the nurseries during the 1975 season. IRRI and national scientists have jointly participated in several regional monitoring tours to observe the nurseries and related research activities in various "hot spots" in the region.

Future plans:

The primary aim of the IRTP is to be responsive to the needs of the national rice improvement programs. Although we do not expect to greatly enlarge the number of nurseries or the number of cultivars in the nurseries, we do expect the composition of the materials to increase in diversity. The type of nurseries from year to year will depend upon the utilization of the germplasm by national programs and the methodologies they adopt. The International Rice Observational Nursery (IRON) is expected to provide most widely applicable information because of its diverse genetic material and the stresses to which it will be exposed while more specific information will be obtained from special nurseries.

We intend to selectively increase the locations where the yield nurseries (IRYN) will be grown in an effort to better measure the adaptability and stability of varieties and to attempt to define specific genotype/environment interactions.

Over the next few years we hope to progressively standardize all operations of the IRTP. We expect to gear our data management system to the use of the computer so we can be more punctual in our analysis of data and return of reports to cooperators.

We envision that the regional monitoring program will be expanded and that working groups in 4 or 5 problem areas (diseases, insects, upland rice, deep water, and cold tolerance) will play a large role in accelerating the evaluation and utilization of the rice germplasm through the IRTP network. Conferences for discussing nursery results and planning the next year's activities will be held at IRRI on alternate years with those in selected countries.

Appendix 1. Highlights of the IRTP 1975 program of action developed at the International Rice Research Conference, April 21-24, 1975.

I. Conference Highlights

The International Rice Research Conference held at IRRI April 21-24, 1975 provided a forum for scientists of various disciplines (agronomists, soil scientists, plant breeders, entomologists, pathologists, and economists) to jointly and individually discuss constraints which are limiting rice yeilds and production. The group looked at some of the reasons why the improved rices have not spread into larger areas of rice producing countries of the world and assessed the possibility of collectively exploiting the tremendous genetic potential in rice to overcome some of these constraints.

It was consensus that strong, independent national programs are the key component in generating the "genetic technology" needed to not only obtain high yields, but even more important, to put stability and genetic insurance against stresses, into the rices. This genetic technology can be most rapidly developed, however, through collective efforts of national programs and the international institutes so that a critical mass of knowledge, resources and germplasm is generated and made available to all participating countries. The International Rice Testing Program can serve as a mechanism to evaluate and transfer this technology to rice scientists around the world.

II. Standard Evaluation System (SES) for Rice

Discussions at the conference focused on standardizing the scoring system for rice experiments to enable rice scientists in all countries to talk the same language when referring to genetic traits of the rice plant. Separate committes for

1. agronomic, morphological and quality traits,
2. insect resistance traits,
3. disease resistance traits

revised the draft manuscript. The general scale is as follows:

			For stress		
Index value	Desirability		Expanded code (judgement)		Severity or incidence (factual)
Blank	No data or no information		Blank		
0	Immune reaction		0		
1	Trait expression is satisfactory (useful) from the plant breeding point of view and can be used as a donor parent or variety.	Good or High	VR	Equal to best resistant check	Less than 1%
2			R		
3			MR		1-5%
4	Trait expression is not as good as it should be but it may be acceptable under some circumstances (i.e. horizontal resistance to diseases).	Fair or Intermediate	HI	Between resistant & susceptible checks	5-25%
5			I		
6			LI		
7	Trait expression is unsatisfactory (not useful) in terms of being either acceptable commercially or for genetic improvement of the crop.	Poor or Low	MS		25-50%
8			S		
9			VS	Equal to most susceptible check	More than 50%

1/9 = Resistant/susceptible (segregation)

The larger group of discipline area scientists then discussed and made modifications in the system. After scientists use it for a year or two, additional modifications may be made as warranted by the experience of cooperators.

III. IRTP Nurseries (1975)

1. Yield nurseries

Lowland

IRYN-Early - elite breeding lines with less than 120 days maturity (15 entries)

IRYN-Medium - elite breeding lines with more than 120 days maturity (25-30 entries)

Upland

IURYN - elite breeding lines (25-30 entries)

2. Screening nurseries

2.1 Observational

International Rice Observational Nursery (IRON) - approximately 500 entries from all countries of improved plant type with all known sources of resistance and tolerance to adverse stresses.

International Upland Rice Observational Nursery (IURON) - elite upland breeding lines from various countries.

2.2 Disease nurseries

Blast (IRBN) - best donor parents from previous IRBN and national breeding lines.

Sheath blight (IRSHBN) - donors and entries with improved plant type.

Tungro (IRTN) - donors and entries with improved plant type.

2.3 Insect nurseries

Gall midge (IRGMN) - donors and improved plant type entries.

BPH (IRBPHN) - donors and improved plant type entries.

2.4 Other stresses

International Rice Salinity Tolerance Observational Nursery (IRSTON) - donors and improved plant type entries.

International Cold Tolerance Nursery (IRCTN) - donors and improved plant type entries.

Appendix 2. International Rice Testing Nurseries in progress - August 1975

Nursery	No. of Nursery	No. of Countries
International Rice Yield Nursery (IRYN) Early maturity	49	20
International Rice Yield Nursery (IRYN) Medium maturity	38	15
International Upland Rice Yield Nursery (IURYN)	33	16
International Rice Observation Nursery (IRON)	83	32
International Upland Rice Observation Nursery (IURON)	51	18
International Rice Blast Nursery (IRBN)	47	26
International Rice Sheath Blight Nursery (IRSHBN)	19	11
International Rice Tungro Nursery (IRTN)	18	7
International Rice Brown Planthopper Nursery (IRBPHN)	20	11
International Rice Gall Midge Nursery (IRGMN)	20	8
International Rice Salinity Tolerance Observation Nursery (IRSTON)	17	12
International Rice Cold Tolerance Nursery (IRCTN)	34	18

INTEGRATION INTO AN INTERNATIONAL GEU PROGRAM[1]

Justification and objectives:

The development of improved varieties probably has a greater immediate potential to raise yields on farmer's fields throughout the rice growing world than does any other scientific endeavor. To realize this potential we must:

1. Collect and conserve the germ plasm.
2. Systematically evaluate the genetic potential of the collected material and develop superior genotypes.
3. Systematically distribute the improved germ plasm for evaluation and utilization and monitor performance.
4. Train a cadre of enthusiastic, dedicated scientists who will work at the national and provincial levels to utilize this improved germ plasm, and modify it as needed to make it of practical use to farmers.

Summary of past accomplishments:

We have collected much of the most valuable rice germ plasm. We have used it to develop improved varieties and lines with a yield potential that has not been exceeded in the tropics. We have incorporated disease and insect resistance and tolerance to certain other adverse factors into this material.

INTEGRATION INTO AN INTERNATIONAL GEU PROGRAM

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[1] Project Leaders - W. R. Coffman, Associate Plant Breeder;
M. D. Pathak, Assistant Director; and
H. E. Kauffman, Plant Pathologist

We have reorganized our program to emphasize practical objectives rather than scientific disciplines. We have expanded it to accomodate the most pressing of the increasingly obvious needs of the world's rice farmers. We now accomplish 3000 crosses per year which exceeds the total output in the Institute's first 10 years of existence. Emphasis has been placed on multiple crossing which accelerates the combining of many favorable traits. We now work over 500 combinations per year in F2 and over 50,000 lines per year in the F3-F6 generations. We believe that this high volume systematic approach and the utilization of multi-disciplinary expertise in the screening and evaluation procedures is the only way to make steady and effective gains in the exploitation of the genetic potential in rice.

We have recognized that the success of such an approach depends heavily on proper coordination of the multi-disciplinary inputs. We have organized teams, composed of appropirate problem area specialists and plant breeders to be responsible for each major breeding objective. The GEU Operations (GO) Committee functions to integrate their activities at the operational level.

Our operational activities center around the Hybridization Block which is formulated each season by the various GEU teams and contains a general group of our elite lines plus the best improved lines for each problem area. This is planted at six dates to assure a steady supply of plants for crossing. At the same time, the teams compose the Observational Nursery which contains the best, newly identified sources of the various desirable traits. Plants from these two nurseries are used for most of the crossing work although plants may be taken from any GEU nursery for crossing.

We have perfected a vacuum emasculation system which greatly facilitates our crossing work. We can produce 200 hybrid seed per man hour. This allows us to make extensive use of multiple crosses (three way and double crosses).

We begin screening the multiple crosses in the F1 generation. The F2 and subsequent generations are divided by crosses into High Input(HIP) and Low Input (LIP) nurseries. These two groups are further sub-divided for the degree of insect protection applied. A final division may be made wherein the materials are grown in adverse soils, or subjected to drought, or flood or adverse temperatures. F3-F7 lines growing in the field may be concurrently screened in our testing facilities for grain quality, disease resistance, insect resistance, protein content or submergence tolerance. Promising lines enter advanced evaluation trials, including the International Rice Testing Program, at any stage past the F3 generation.

We first began distributing improved lines to national programs in 1965 and from that date until December 31, 1973 we had distributed approximately 90,000 seed packets of improved lines and IRRI varieties. During 1974-75, we distributed more than 100,000 such packets mostly through the International Rice Testing Program. This program also facilitates the interchange of improved material among national programs (more than 25,000 national varieties and breeding lines in 1974-75) and is organized to rapidly provide performance information to all cooperators.

We consider that practical, skills-oriented training is essential for the scientists and technicians who modify the improved germplasm at the local level and actually put adapted, improved varieties into the hands of the farmer. This past year we conducted the first GEU Training Program for that purpose.

Future Plans:

We will continue to emphasize germplasm collection as necessary to complete the work. We will make every effort to secure a satisfactory facility in which to safely store the collection and from which it can be efficiently evaluated and utilized.

We do not anticipate further expansion in the volume of our program. Rather we will place emphasis on effective performance evaluation of our material in the International Rice Testing Program and refine and redirect our efforts as results indicate. We will give major attention to the operational aspects of our program. We still face some problems in utilizing the expertise of problem area specialists in the day-to-day operations of the program. Some of our screening facilities need further orientation toward the needs of the breeding work, in terms of volume and turn-around time.

We plan to give major attention to our data handling requirements. Present procedures are not adequate to cope with the volume of breeding material that must be evaluated nor are they geared to the needs of a multidisciplinary program wherein several scientists have a simultaneous need for current, comprehensive data on the breeding materials. We expect to make extensive use of the computer to remedy this problem.

We have recently secured a training officer for GEU who will give major attention to this aspect of the program. However, the training will continue to be done as an integral part of the operational program with the trainees learning by actually participating in, and taking responsibility for, the various operations.

We have been concerned that Los Baños may not be very representative of the rice growing tropics and subtropics and that this may result in the production of poorly adapted breeding material for other locations. Differences in soils, and disease and insect biotypes, are of major concern. Preliminary data from the IRTP have given some weight to this hypothesis. Once we have firm data on the matter, we may need to shift a major portion of our early generation screening work to one or more representative locations.

Our ultimate objective is to develop an international GEU network. This network would consist of strong national programs cooperating with IRRI to develop the many diverse varieties needed for the world's rice farmers. This network will provide national programs the resources (germplasm, screening facilities, training, manpower, etc.) on which they can draw on to supplement and strengthen their rice improvement programs.

We feel that teams of interdisciplinary scientists from national programs and IRRI can take the lead in accelerating the utilization of the genetic potential of the rice plant to overcome many yield limiting constraints. Our experience with the scientists who have participated in the monitoring of the international nurseries has clearly shown the value of soliciting the active participation of leading scientists of various countries in such an endeavor. Not only does it allow national and IRRI scientists to broaden their vision but it encourages the direct involvement of all disciplinary scientists in the total GEU program.

Finally, we aim to maintain the GEU Program of IRRI as a creative force in rice improvement. We recognize that progress creates a plethora of second generation problem and that we face the ever present danger of being placed in a reactive position. Even now the requirements of relatively prosperous farmers in productive, irrigated areas place heavy demands on our program while the demands of a still vast number of farmers who have generally remained unaffected by our work, beg silently for attention. We must avoid this situation by emphasizing the need for strong national and local rice improvement programs and by cooperating with them in every possible way.

CONTROL AND MANAGEMENT OF RICE PESTS

DISEASES

Aside from the GEU program we have made only limited efforts on studying other aspects of rice disease such as the mechanism of resistance, epidemiology, chemical control, etc. A post-doctorate fellow worked on the biochemical aspect of blast resistance and found that resistance or susceptibility is mainly due to the balance between two counteracting forces on the polyphenols of the host variety and the fungus; more oxidation by enzymes resulting resistance and more reduction, susceptibility. On the two bacterial diseases, the bacterial blight organism produces three more enzymes than the bacterial leaf streak organism. We studied a little on physiology of the sheath blight organism. Both were done as student thesis problems. We have tried culturing the kernel smut and tested inoculation method as a request of Pakistan. We tried to develop selective medium for X. oryzae, and a few other minor studies. Recently, we started the epidemiology of tungro and blast diseases. We have also spent some time in chemical control of blast and sheath blight. Some ecological studies on bacterial blight will be initiated.

Areas of our major research efforts are discussed as follows:

EPIDEMIOLOGY OF RICE BLAST[1]

Justification and objectives:

While blast epidemic occurs in lowland fields when weather is favorable, it is much more often and severe in upland rice. Epidemiological factors may have caused this difference.

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[1] Project Leader - S. H. Ou, Plant Pathologist

In controlling blast, there are many good chemical compounds available. The more difficult problem is when to apply the chemicals to be most effective. Epidemiology may provide the information -- forecasting disease outbreak.

Epidemiological studies also provide possible alternative strategy for disease control.

Summary of accomplishments:

A few preliminary experiments were started in 1973. We found spores were released at night with the presence of dew. At least 10 hours of leaf wetness (dew) are necessary in order to have appreciable number of infection. Temperature at low twenties (in centigrade) are more favorable for infection. A few spores survived until next night if infection did not take place in the previous night (those spore released in early morning hours). Spores begin to produce at night when dew begins.

Upland rice field has longer duration of dew than lowland. Plants grown on dry soil contain more protein and sugar and more susceptible to blast than lowland rice. It seems that both chemical constituents of plants growing in upland conditions and microclimate (particularly dew) are affecting the blast development on upland rice. However, preliminary experiment showed that when flooded (lowland) pots were kept in upland rice field, there were as many lesions as that of upland rice, indicating microclimate may be more important than the lowland conditions. As these experiments are preliminary in nature, confirmations and other experiments will be made when more and better equipment become available.

Future plans:

We intend to study the major climatic parameters of the tropics - temperature, relative humidity, dew period, rain, etc., and their relationship to the disease processes of blast - spore germination, infection, colonization, spore production and release, survival, etc., in phytotron and greenhouse to find out more important factors influencing blast disease. We also intend to monitor the weather conditions and disease development in upland and lowland rice fields to compare with phytotron results. A simple computer simulation may be developed when all or most of the data are available. May be we can forecast disease outbreak by simply measuring one or two major weather parameters.

CHEMICAL CONTROL OF BLAST AND SHEATH BLIGHT[1/]

Justification and objectives:

The rice varieties in present day use are either moderately resistant or susceptible to blast and sheath blight. Outbreaks of these diseases often occur. Chemical control offers a temporary or emergency measure to meet these situations.

We are more interested in systemic fungicides or those with good tenacity since tropical monsoon rains wash the non-systemic compounds off the plants.

In blast, our objective is to prevent or reduce the most destructive phase of the disease, the "neck" blast. To protect the plant throughout the season is economically not practical in the tropics. Sheath blight

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[1/] Project Leader - S. H. Ou, Plant Pathologist occurs also in the late stage of rice growth. We are hoping to find chemicals which would be effective in controlling both diseases, with one chemical and one operation, when they occur together as they often do.

Summary of accomplishments:

We have conducted several experiments since 1969 on the chemical control of blast and sheath blight. Beginning with Benlate, many other systemics have been tried: Topsin M (also sister compounds NF-35, NF-48), Kitazin, Hinosan, etc., and also several experimental compounds: Homai, Hoe 22843, Hoe 22845, Hoe 22985, Hoe 17411, MKS 103, F1, etc.

Three types of experiments for each of these compounds were made:

1. Seed treatment to see if they protect from blast at seedling stage.
2. Soil treatment to see how effective are they as systemics.
3. Spraying tests in small plots for leaf blast control.

Selected fungicides from these experiments were tested in farmers' fields, both as soil treatment and as sprays, for the control of neck blast. Many of the test compounds acted as systemic fungicides for blast. Also, several of them were efficient against the sheath blight, but additional tests are needed to confirm the effectively against the sheath blight.

Summarizing the results, we think seed treatment for controlling blast in nursery bed is practical in areas where seedling blast is a problem. Soil treatment with systemics is much too expensive to be of practical value. The most useful information is that when a field has been already infested with leaf blast, to protect from neck blast, two sprays, one just before panicle emergence and another one 7 to 10 days later, are very effective. The 12 experiments in farmers' fields showed an increase of one ton of paddy per hectare (approximately, if no blast, 5 tons/ha; blast with sprays, 4 tons/ha; blast without spray, 3 tons/ha).

Future plans:

We shall continue to test some new and standard chemicals with emphasis on sheath blight control.

EPIDEMIOLOGY OF RICE TUNGRO DISEASE[1]

Justification and objectives:

Rice tungro disease, including similar diseases such as leaf yellowing in India, penyakit habang in Indonesia, penyakit merah in Malaysia, and yellow-orange leaf in Thailand, is prevalent in rice growing countries in South and Southeast Asia. Major outbreaks of the disease in Bangladesh, India, Indonesia, Malaysia, Philippines, and Thailand have been recorded in recent years. The disease reduces the rice production, for instance, about 30 percent (or 460,000 tons) reduction of 1971-1972 rice production in Central Luzon, Philippines was mainly due to the outbreak of the tungro disease.

The outbreaks of the tungro disease have been irregular or sporadic, severe in one year, very little in the next year. This suggests that the outbreaks are influenced and controlled by environmental and biological factors. To identify these factors, the study of epidemiology of this disease is essential and it was started in 1972.

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[1] Project Leader - K. C. Ling, Plant Pathologist

The objectives of epidemiological studies are to find an economically feasible way to control the disease through formulating methods to forecast the disease, predicting yield losses, and developing recommendations for control measures based on epidemiological results.

Summary of accomplishments:

Tungro disease in Luzon

The statistical approaches to investigating the epidemiology of the rice tungro disease in Luzon include collecting, collating, and analysis observations about the incidence of the disease and information of existing factors related to the disease in 37 farmer's fields in five provinces in Luzon at bi-weekly intervals.

The results obtained seem to indicate that rainfall in dry season (March to early June) is a key factor affecting the incidence of tungro disease on the wet season rice crop (July-November). The rainfall in dry season determines the growth of weeds as well as the regenerated growth of rice stubbles that are essential for the propagation of insect vector and perpetuation of the virus source. In fact, it was very dry in dry season of 1973, resulting in practically no tungro disease on the wet season rice crop in the area in 1973. Hence, no rainfall in the dry season can serve as a criterion for the 'Negativprognose' (negative prediction) for the outbreak of tungro disease in Central Luzon.

Typhoon and heavy rain during the period from September to early November could be two major factors affecting the incidence of the tungro disease of the second rice crop. In general, the population of insect vectors reaches the highest level during the period. The typhoon and heavy rain may not elimiate completely the insect vectors, but would greatly reduce the population of insect vectors in the rice field that decreases the spread of the disease.

Experimental epidemiology

Since the cage method for studying experimental epidemiology of rice tungro disease was developed in 1972, the effects of number of insect vectors (N) per cage of 300 test seedlings, duration in days (D) of insect's confinement with the seedlings, and amount of virus source in percentage (V) on the incidence of tungro disease in terms of percentage of infected seedlings (Y) have been determined. Their relationships can be expressed as follows:

$$\hat{Y} = 100(1 + aN + bN^2),$$
$$\hat{Y} = 100(1 - e^{-0.1368D}), \text{ and}$$
$$\hat{Y} = cV + d\sqrt{V},$$

where a and b varied according to the mortality of the insects during the test period, $e = 2.718$, and c and d varied according to the growth stage of the insect. The adult insect appears to be about three times more efficient in spreading the tungro disease than the nymphal insect. Nevertheless, the extreme low population of insect vectors in an area can serve as a criterion for 'Negativprognose' for the outbreak of tungro disease in the area. Similarly, absence of diseased plants in an area can also serve as a criterion for the 'Negativprognose' if there is no incoming virus source from viruliferous insects.

Based on calculation of obtained results, an infective adult insect can theoretically infect at maximum 288 seedlings in a day but practically only about 40 seedlings. A diseased plant at a distance of longer than 250 m can no longer be a direct virus source excluding the passive movement of the insect.

The temperature range of Los Baños does not affect the transmission of tungro virus drastically by the insect vector. However, the retention period can be prolonged at low temperature (13°C). Because the retention period of tungro virus by Nephotettix virescens can be longer than 3 weeks at low temperature, the term 'nonpersistent' becomes not appropriate for describing the virus-vector interaction. Therefore, a new term 'transitory' has been proposed recently for leafhopper-borne viruses that have the following features of virus-vector interaction:

1. The virus does not persist in its leafhopper vector.
2. The retention period can be longer than a week particularly at a low temperature.
3. There is no demonstrable latent period in the insect vector.
4. The infectivity is lost due to molting -- transstadial blockage.
5. The insect can become reinfective after reacquisition feeding on a diseased plant.

Light trap of insect vectors at the IRRI farm

Trapping insect vectors of tungro and grassy stunt by light at the IRRI farm every Tuesday has been conducted since August 1972. Due to absence of severe outbreak of tungro disease in IRRI farm, no conclusion has been drawn for the correlation between tungro incidence and vector population. For grassy stunt, however, the difference between outbreak in 1973 and no outbreak in 1974 was mainly due to the difference of population of its vector, brown planthopper (8,900 per collection in 1973 versus 1,200 in 1974) rather than the difference of percentage of infective insects (3.4% in 1973 versus 2.2% in 1974).

Future plans:

1. Continuing the studies of tungro disease in Luzon and light trap of insect vectors at the IRRI farm.
2. Determining the requirements for an outbreak of tungro disease in a seedbed.
3. Examining the effect of combined factors (e.g., number of insect vectors, amount of virus source, duration of insect's confinement, susceptibility of rice variety, etc.) on the incidence of tungro disease by the cage method.
4. Investigating tungro spreading pattern.
5. Searching the role of rice stubbles in tungro incidence.

ECOLOGICAL STUDIES OF BACTERIAL LEAF BLIGHT[1]

Justification and objectives:

Little is known on the disease establishment and spread in the field. There are different symptoms, such as "pale yellow" and "kresek" on rice plants. Yet the factors associated to these symptom types are not clear. Similarly, little information is available concerning the population fluctuation, survival and effect of bacteriophage on blight pathogen. Such information is useful in formulating possible alternative control measures of the disease.

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[1] Project Leader - T. Mew, Associate Plant Pathologist.

The objectives of this study are to find adequate techniques for detecting X. oryzae on plants, soil and water and use this to study factors affecting the development of the organism and the disease.

Summary of accomplishments:

A low population of the bacterium is present in irrigation water at IRRI but blight symptoms are not observed until the population is high. Based on bacteriophage plague counts, the bacterial population fluctuates greatly during the growing season, high counts of plague following rains in the irrigation water. By using bacteriophage to indicate bacterial population, however, was found inadequate because phage population does not always correlates to bacterial population.

The bacterial pathogen is not capable to survive well in dead tissues. In an infected leaf, the bacterium cannot be isolated from older portion of the lesion, or recovered from infected dead tissues. Xanthomonas oryzae dies rapidly in high temperatures (30-35°C).

Future plants:

We will continue to search for a selective medium for X. oryzae, to provide a reliable technique for studying various ecological problems, and seed-transmission of the bacterium.

We also plan to find out factors affecting the relative survival ability of isolates distinct in virulence and pathogenicity.

The factors associated with "kresek", "pale yellow" and blight symptom development will be carried out in the phytotron and in the greenhouse.

The establishment of initial infection and spread of the bacterial leaf blight in the field are also planned to study.

INSECTS

Justification and objectives:

Insects are one of the major factors preventing rice yields from reaching their potential. Much of the world's rice is produced in a warm, humid climate which provides an extremely favorable habitat for the survival and multiplication of insects.

There are approximately 70 insect species for which rice serves as a host plant. Of these about 20 occur regularly and are considered to be of economic importance while others occur sporadically and occasionally develop populations of economic significance. Together they attack the plant from seedlingto maturity and feed on all portions of the rice plant. Certain species also transmit virus diseases. It is difficult to determine exact losses due to insect attack but a 20-30 percent figure has often been suggested. Results of a study conducted in Laguna Province, Philippines by IRRI scientists indicated that insects and diseases reduced farmers' yields by an average of 1.2 t/ha and are the major factors for reduction in rice yields. A study conducted in several Asian countries indicated that most farmers consider insects as one of the constraints to higher yields (Barker, personal communication).

In addition to favorable climate, the common practice of multi-cropping rice also favors insect attack. Here we can take the IRRI farm as an example wherein 80 separate experiments conducted over several years, plots with insect control produced yields of 5.8 t/ha compared to 2.9 t/ha in the untreated plots. Similar increases in yield due to insect control have been reported from various south and southeast Asian countries. Unfortunately, insect attack is most severe in countries where the farmers can least afford the cost of chemical control.

The major beneficiary to improved pest control is the producer who obtains a greater economic gain from his investment. However, the consumer generally benefits due to greater availability and hence lower price for milled rice. Effective, economical pest control can contribute to more stable yields and income.

The objective of the program of control and management of rice insect pests is to develop and test economically sound rice insect pest management practices and packages of practices which optimize rice yields in the tropics without producing concomitant damage to the environment.

This overall objective is to be achieved through a number of subobjectives as follows:

1. to develop and compare specific rice insect control methods including chemical control (insecticides), host resistance, biological control and cultural control.
2. to study the complementarity of the various insect control methods with the aim of selecting the combination or combinations which provide effective and economical insect management and which produce no serious environmental contamination.
3. to investigate insect-plant relationships with the view of determining the economic tolerance limits of insect densities.
4. to study the behavior of rice insects, their parasites and predators as affected by the environmental conditions to gain insight into the best use of individual insect management mechanisms.

5. to train and increase the capability of rice researchers at various levels of responsibility in the recognition of pests and pest damage, in pest biology, control methods and research techniques.
6. to influence, stimulate and encourage rice researchers in national programs to develop and implement effective insect management research programs.
7. to disseminate information on rice pests and their management and assist in the exchange of this information among rice scientists in national programs.

Insecticidal Control[1]

Justification and objectives:

Although very significant progress has been made in the development of alternative means of control, insecticides are still our main line of defense against insect attack. We recognize the continued need for insecticides and on the other hand are concerned with the many problems involved in their use. They are expensive and will continue to be more so due to the pressure for greater specificity and the stringent requirements they must meet before release. This is illustrated by the fact that the average cost of developing an insecticide has risen from US$3.4 million in 1967 to about 8 million today. Most insecticides are often toxic to the applicator and to natural control organisms, and

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[1] Project Leader - E.A. Heinrichs, Entomologist

continued use can result in insect resistance. Taking these factors into consideration the objective of our insecticide program is to search for chemicals and application methods that:

1. Are effective in controlling the target pest
2. Are effective in low dosages
3. Have sufficient residual activites to minimize the number of applications.
4. Are relatively safe to the applicator.
5. Do not adversely affect predators and parasites of the target pest.
6. Do not contaminate the environment or leave residues in the grain and straw.
7. Are economical to apply.

As such insecticides are found they are incorporated into an integrated program of control where they are used only when economic injury levels warrant.

Summary of accomplishments:

We have a screening program in which our objective is to determine the activity of every new compound that the manufacturer feels may be promising against rice insects. Several hundred compounds have been screened against primarily the striped stem borer, green leafhopper and brown planthopper. Insecticides are first screened in the laboratory and greenhouse to determine their activity as a contact poison and residual activity when used as foliar sprays and as a paddy water application. The most promising have been further screened under field conditions and a number of the most effective are widely used today.

Early work was primarily on foliar sprays. However due to frequent rains in the tropics, residual activity was short. Due to their feeding habits, stem borer and brown planthopper control was inadequate and due to overlapping generations of many pests, timing was difficult and numerous applications were necessary. Thus research was conducted to find alternative methods to foliar application of insecticides. These methods consisted of seed treatment prior to sowing, treatment of the seedbead with granular insecticides, treatment of seedlings prior to transplanting and applying granular insecticides to the soil and water of paddy fields.

Granular application to the paddy water proved to be more effective than foliar sprays. The method provided wide spectrum control, was relatively safe to predators and application was simple. However, broadcast applications were required every 20 days. In order to decrease cost, root zone application was tested. Insecticide was first placed into paper straws that were inserted into the root zone at transplanting. Later gelatin capsules were used. It was found that this method was more efficient and long lasting than paddy water application. One application is sufficient for season long control whereas the paddy water application method required repeated applications. The longer residual activity was apparently due to the fact that the chemical is readily available to the roots and is protected from decomposition due to heat and light and is not subject to being washed out of fields by overflowing water. It was demonstrated that when chlordimeform was placed in the root zone it was taken up by the plant in greater quantities than when it was broadcast on the soil surface or broadcast and incorporated in the topsoil. Analysis of plant tissues by electron-capture gas liquid chromatography indicated that at 10 days after treatment, insecticide levels were 8-10 times higher in the root zone application than in any of the other application methods. Even at 70 days after treatment, concentration of the insecticide in the root zone treatment was twice that of the other treatments. Similar results were also obtined with carbofuran. Thus, one application for the root zone provided season long control whereas the standard paddy water application required applications at 20-day intervals and 4 times as much insecticide.

Current Research:

Screening of insecticides to determine their contact toxicity and residual activity as sprays and their activity as a paddy water application is continually being conducted. About 50 compounds have been screened thus far in 1975. New compounds are also being screened to determine their suitability as a root zone application.

Foliar Sprays:

Despite the many problems involved in the use of foliar sprays, the method remains the most commonly used. We are currently searching for effective chemicals which have low mammalian toxicity, are safe to non-target organisms and pose no residue problem.

A new group of compounds, the synthetic pyrethrins or "pyrethroids" meet some of the above-mentioned requirements. Initial screening has indicated that certain of the "pyrethroids" are extremely active against the green leafhopper and brown planthopper. We are now conducting tests to observe their activity under field conditions.

Chitin inhibitors are urea based compounds which are still in the experimental stage. They inactiviate the precursor to chitin and thus disturb the molting process. They have extremely low mammalian toxicity, are ecologically compatible and are effective against certain insect species at dosages as low as 5 g active ingredient/ha. Chitin inhibitors hold promise for the control of lepidopterous defoliators and possibly stem borers.

The bacterial agent Bacillus thuringiensis Berliner has provided promising results in tests against the leaf folder and the stem borer. This is an ecologically safe insecticide specific for Lepidoptera.

New formulations of commonly used chemicals may provide more effective control. We are experimenting with the use of oil based ULV formulations of carbaryl which have shown longer residual activity and are more resistant to being washed off the plants by rain.

Root Coat Treatment:

Dipping roots of seedlings in a solution containing insecticide prior to transplanting provides short term protection from seedling insects. Previous research has indicated that the addition of a sticker such as methyl cellulose to the solution somewhat increased the residual activity of the insecticide. We are now testing the use of gelatin as a sticker which provides a good root coat treatment which is not washed off by the water when the seedling is transplanted. Non-phytotoxic rates have been determined and we are now field testing the concept.

Soil Application:

We are continuing the screening of compounds and formulations suitable for broadcast or root zone application. However, carbofuran continues to be the most effective chemical. It is an expensive insecticide. To cut cost, we are determining the minimum dosage necessary for adequate control.

The entomology department is cooperating closely with engineering and agronomy in the development of the root zone technique. IRRI engineers have developed an applicator that we are currently field testing in the application of fertilizer + insecticide combinations. Through the use of gas chromatography, we are determining the relationships between carbofuran uptake and location of fertilizer placement. Agronomy is conducting analyses to determine the amount of N uptake in relation to method of carbofuran placement.

Many of the newly released varieties are resistant to some of the major pests but not to others such the whorl maggot, leaf folder and other pests considered to be of minor importance. These minor pests, however can be considered potentially serious and may already be so in certain locations. Thus, we feel that occasionally some insecticide applications may be necessary on these varieties under certain conditions. In this respect we are currently studying the uptake of granular insecticides by these varieties to determine whether or not they differ in this respect and thus to more accurately determine dosages upon which to base control recommendations.

Collaborative Research:

Insecticidal controls which prove to be effective at IRRI are tested under varying conditions at several locations in the Philippines. These trials are conducted at and with the cooperation of the Bureau of Plant Industry Experiment Stations. The Entomology Department has also collaborated with other entomologists on an international basis in developing the root zone technique. Insecticides in capsule form were distributed to several countries and evaluated for their effectiveness in controlling various insect pests in their countries.

Future plans:

The objective of our insecticide program is to conduct and encourage basic and applied research that will provide information that can be utilized in an integrated program of control (pest management concept). Our goal is to:

1. Determine the effective minimum rates necessary to control the pest.
2. Search for selective chemicals which control only the target pest.
3. Determine the effectiveness and residual activity of new formulations of currently used chemicals such as slow release granules, oil based ULV sprays and combinations of larvicides and ovicides.

We will continue searching for new compounds, formulations and application techniques that are compatible in an integrated program. Development of the pest management concept of insect control in rice lags behind some crops such as cotton, soybeans and fruits. This is unfortunate as rice is beseiged by pests from seedling to maturity. Insect attack is especially severe in the humid tropics where the farmer can least afford the cost of applying insecticides. We believe that the solution to the problem of insect control in rice lies in the use of resistant varieties combined with the selective use of insecticides. With these thoughts in mind we now propose our program of continued and new research.

Screening Program:

We will continue to screen compounds in the laboratory and greenhouse against the stem borer, green leafhopper and brown planthopper. We will enlarge our program to include additional insects such as the rice bug, leaf folder and the white-backed planthopper.

Timing and Techniques of Application:

Studies concerning the application of insecticides will be conducted to find simpler, less laborious and more economical means of control. Studies will determine proper timing of treatment at a stage where the pests are most susceptible and predator survival is maximum.

The root coat concept of seedling treatment will be further refined. Studies will be conducted on ULV application with an attempt to increase effectiveness through better distribution of the chemical and greater residual activity.

Procedure and equipment for the root zone method of application need further development and testing. Continued cooperative work with the engineers is necessary to find the most suitable application equipment.

Gas chromatographic analysis of plant residue and bioassay will be conducted to determine effectiveness of the different application methods, chemicals and formulations. Water, soil and grain will be analyzed when appropriate to determine level of contamination.

Entomology will cooperate with soil microbiology in a study of the degradation of insecticides applied in the root zone. The response of insecticide degrading microorganisms will be determined where insecticides are regularly applied as a broadcast and root zone treatment.

Upland Rice:

Increased emphasis will be given upland rice through cooperative research with cropping systems. Since certain control technology used in lowland rice is not suitable to upland conditions, new technology will be developed. Emphasis will be on control of rice bug, brown planthopper, green leafhopper, white-backed planthopper, lepidopterous defoliators and stem borers.

Adaptive Trials:

The most promising control technology as based on field trials at IRRI will be further tested under varying climatic and soil conditions throughout the Philippines. Also, where certain pests are not in sufficient abundance at IRRI, field experiments will be conducted in the Bureau of Plant Industry (BPI) Experiment and in farmers' fields where the Rice Production and Training Research (RPTR) experiments are located. High priority is development and testing of the root zone applicator to determine ease of application and effectiveness under varying conditions.

ECOLOGY AND BEHAVIOR[1/]

Effective control of pests in the long run requires a knowledge of their ecology, especially population dynamics, and their behavior. This knowledge provides insight into trends in pest problems, and the impact of changing cultural practices on insect populations. It also provides insight into the best use of individual control methods. For example, information on sampling techniques and population dynamics is necessary to make accurate decisions as to if and when insecticidal control is economically justifiable. Ecological studies produce feedback on the value of pest control practices, and assist in establishing research priorities. A knowledge of the ecology of natural enemies is fundamental to effective biological control research.

The primary objective of ecological research at IRRI is to support the work on pest control technology.

Summary of accomplishments:

We have monitored changes in pest densities throughout cropping periods in 50 crops over the last 4 years. In a given field, generations do not overlap greatly in the case of the brown planthopper, green leafhoppers (Nephotettix virescens), and even rice stem borers. There are three generations for the hoppers, and about two for the borers. The times of peak density can easily be monitored and sometimes predicted to insure proper timing of insecticidal application. In light traps these insects are recorded throughout the year.

[1/] Project Leader - V.A. Dyck, Associate Entomologist

Many environmental factors influence pest density. In the case of the brown planthopper, the insects survive best on 70 to 90-day-old plants when using IR22. Application of nitrogenous fertilizer increases pest density. Good control of irrigation water, and high-tillering varieties or close spacing have the same effect. Dispersal into a newly planted field occurs soon after transplanting, and insects fly out again primarily in the third generation. These facts influence the timing of control activities.

Fluctuations in insect abundance from season to season and year to year reveal that some pests are becoming more important. This is especially true of planthoppers and leafhoppers in several countries. The causes of the recent increase in hopper problems appear to be related to increased intensive rice cropping, such as the use of more fertilizer, high-tillering varieties, increased irrigation facilities and double cropping.

We have monitored the pest densities and fluctuations in upland as well as lowland fields. In upland rice in the Philippines pests such as mole crickets and seedling maggots were found in the early growth stages, and stem borers, rice bugs and leaf folders in the late growth stages.

Ecology and Behavior of Natural Enemies:

The egg, larval and pupal parasitism of stem borers fluctuates within a crop period and from year to year, but no definite pattern has been discovered so far. Predators such as Cyrtorhinus lividipennis fluctuate in density asynchronously with prey populations of planthoppers.

There may be some manipulation possible to improve the biological control value of these natural enemies.

Pest Sampling:

Reliable sampling techniques are necessary to evaluate control effects, and to determine if field densities require insecticide treatment.

We measured the distribution pattern of brown planthoppers with respect to plants in the field. The distribution, especially of the nymphs, is nonrandom, and apparently is influenced by the tiller number of the hills. This means that many hills must be sampled to get a good estimation of the pest density. However whorl maggot damaged tillers appear to be rather randomly distributed in the field.

Insect Behavior - Pheromones:

The occurrence of sex pheromone in striped borer female moths was recorded and behavioral responses of the moths intensively investigated.

In cooperation with the Tropical Products Institute (TPI) in London, the pheromone has been identified chemically and synthesized. Field testing confirmed that the pheromone is attrative to male moths for several weeks. The pheromone is slowly released through the walls of polyethylene vials. These chemicals could be used to monitor moth flights and then to time pesticide treatments correctly.

Future plans:

To give insight into the long-term trends in pest problems and possible future changes, we plan to investigate the causes of population increases and decreases over time. This will be done by the correlation of available insect population data with data on environmental factors, especially climate (macro and micro) and agricultural practices. Emphasis will be given to the brown planthopper and green leafhoppers. A collaborative project on the brown planthopper with scientists in India has already been started.

At the same time field research will be conducted on detailed population processes to determine the factors that greatly influence changes in pest abundance. Techniques such as life table analyses will be attempted. Climatic influences will be assessed in the phytotron.

A preliminary study on the population dynamics of the rice whorl maggot and the rice leaf folder will be done to indicate why these pests are increasing in importance. Factors involving agronomic practices will be investigated first.

Sampling techniques for whorl maggot damage, leaf folder damage, rice bugs, green leafhoppers, stem borers and natural enemies of pests will be developed following observations on field distribution patterns.

We plan to utilize the sex pheromones as a method of monitoring field populations. However, work is also anticipated on the "confusion" technique which attempts to achieve pest control by confusing the male stem borer moths with synthetically modified pheromone which causes poor mating behavior. In collaboration with TPI, we hope to identify pheromones in the yellow stem borer and leaf folder.

BIOLOGICAL CONTROL[1]

Natural enemies of pests play a bigger role in pest mortality than is usually recognized. The number of predators and parasites in rice fields, especially predators, is often surprisingly high. There is little evidence on the actual pest control value of natural enemies, but it is very probable that they are worth conserving, and possibly could be manipulated to exert specific control on pests.

The primary objective of the biological control research is to determine the role of naturally occurring beneficial organisms and conserving them. The second is to augment or manipulate the indigenous parasites and predators, especially the latter. This will be done within the context of a pest management strategy as a whole.

Summary of accomplishments:

The moderate climate, year-round cultivation of rice and occurrence of insect pests should favor biological control agents. IRRI has been very interested in this approach. A feasibility study undertaken in 1964 suggested that greater emphasis on exotic parasites be laid.

A survey of stem borer parasites on Luzon Island in the Philippines showed that, even though there were several species present which sometimes parasitised many borers, the overall contribution of these parasites to borer control appeared to be almost negligible. On the other hand there are reports that in some countries and in some cases, a high percentage of borers is parasitised in the field. Six species of

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[1] Project Leader - V.A. Dyck, Associate Entomologist

parasites from other countries were imported but only one was successfully reared in the laboratory and released in the field. Evidently this tachinid species, Sturmiopsis inferens, did not become established in the Philippines. Other parasites are being considered for importation and release if more ecological information about them can be obtained. Studies on the potential of endemic parasites are continuing.

Egg parasitism of the yellow stem borer is often greater than 80 percent at IRRI. Since pesticides do not appear to affect this percentage, parasites may be the most important factor controlling borer here.

Natural enemies of leafhoppers and planthoppers have been observed feeding on the pests and killing large numbers of them. Two species of fungi attack the pests, mainly during the cooler months of the wet season. Several predators prey upon them in the field such as a mirid bug, Cyrtorhinus lividipennis, coccinellid beetles, and spiders. The predatory activity of these insects has been demonstrated in an insectary.

The mirid bug can reduce a population of the green leafhopper by 40% if the prey and predator generations are synchronized. A spider, Lycosa pseudoannulata, is the best indigenous predator found so far for brown planthopper. In greenhouse experiments one spider can kill an average of 16 nymphal prey per day, continuously for 2 weeks. Their contribution to the control of the green leafhopper and the brown planthopper in the field is being investigated.

The bacterium Bacillus thuringiensis is toxic to young stem borer and leaf folder larvae, and could be used commercially, at least for stem borers. The manipulation of indigenous fungi attacking planthoppers may not be practical.

Future plans:

Conservation of natural enemies will be studied in relation to selective insecticides and crop cultural practices that destroy the beneficial effects of predators will be evaluated. Natural enemies of hoppers and borers such as spiders will be investigated first. We need data concerning the magnitude of parasitism of hoppers.

Some fundamental studies must be done as a prerequisite to attempts of manipulation, such as the potential for mass rearing of the natural enemy (and also the pest), food preferences, population growth rates and capacity to control pests. Indigenous enemies of borers and hoppers are a priority. Actual manipulation will be attempted using cultural techniques, mass release and field attractants.

The importation (from other countries) and release of parasites of stem borers will be reconsidered, including the nematode DD-136 from India. A large program of introduction, rearing and release would require quarantine facilities not presently available at IRRI.

The microbial pesticide, Bacillus thuringiensis, will be field tested for the control of stem borers and leaf folders. Insect viruses will be investigated for applicability to lepidopterous rice pests.

PLANT DAMAGE AND ECONOMIC THRESHOLDS[1/]

Most insects cause visible plant damage, but the yield loss due to the damage is generally not known. Therefore insecticide treatment may be applied without knowing what the potential yield loss is. This could

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[1/] Project Leader - V.A. Dyck, Associate Entomologist result in either an overuse of insecticide, or inadequate control because of too little chemical. If the damage or insect density is correlated with yield loss, a threshold of damage or density can be estimated by considering the value of the loss and the cost of protecting against that loss. This enables growers to treat their crops only when it is economic to do so. Of course a system of monitoring such insect damage and density levels must be established beforehand.

The objective is to establish insect-plant relationships with a view to determining the tolerable limits of insect damage or density. This knowledge supplements research on control methods, especially chemical control, providing an economic basis for making decisions on pest control in the field.

Summary of accomplishments:

Numerous experiments in the greenhouse and field on damage due to the brown planthopper have shown a maximum density per generation of about 25 insects per hill is tolerable unless the crop has been transplanted for less than 30 days. This threshold is now part of the official rice pest control recommendations in the Philippines and Taiwan. Preliminary work on green leafhoppers indicated that the usual field densities in the Philippines are not likely to cause a significant yield loss. Plants are most susceptible to these hoppers at the early growth stage and in the booting to flowering period.

Several greenhouse trials using caged rice bugs indicated a field economic threshold of no more than 5 to 10 bugs per square meter during the flowering and grain development phases. These figures are now used in the Philippine recommendations. A preliminary trial with leaf folders suggested that, at 70 days after transplanting, significant yield loss occurs even with a few damaged leaves per hill. Previously calculated thresholds for stem borer damage are now being verified in carefully controlled greenhouse and field experiments.

Both field and greenhouse tests at IRRI showed that whorl maggots usually cause a significant yield loss, often more than 10 percent. In this case the only solution appears to be to apply a prophylactic insecticide treatment right after transplanting since we have not found a useful economic threshold.

Future plans:

Refinements are needed in the thresholds for rice bugs, green leafhoppers, and stem borer and leaf folder damage. We will establish the relationship between whorl maggot density and plant damage, and between plant damage and yield loss. We expect to complete research projects in this program within 2 years.

INTEGRATION OF DIFFERENT METHODS OF CONTROL[1]

In spite of the serious yield losses inflicted on the rice crop in tropical Asia by insect pests, most of it is either left unprotected from pest damage or receives only partial protection. It is doubtful if farmers, because of their educational and economic limitations, would adopt sophisticated or intensive pest control practices in the near

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[1] E. A. Heinrichs, Entomologist and V. A. Dyck, Associate Entomologist

future. What is needed at present is a simple combination of different methods of control which, even though not highly efficient, should be inexpensive and relatively non-hazardous. Pesticides would only be used as needed. Thus we have to resort to integrated pest control almost as a necessity. Some efforts made along this line are discussed below.

Summary of accomplishments:

It has been established that up to 10% dead hearts caused by stem borers within the maximum tillering stage of the crop growth (generally about six to seven weeks after transplanting) do not cause significant yield losses provided the crop is later protected from the borers. Further studies have also demonstrated that during the monsoon crop such early borer infestations seldom occur but they are common on the dry season crop. The early insecticidal treatments for borer control on the monsoon crop are generally unnecessary, but their need can be determined on this as well as the dry season crop by periodic assessment of dead heart damage. Similarly, the new available information on threshold of damage by brown planthopper, rice leaf folder and rice bug will be useful.

This procedure not only results in savings on pesticides but should also encourage the biological agents during the pesticide-free period. The method of applying insecticide to the paddy water has the advantage of being effective against the borer larvae feeding within the stem but eliminates the contact toxicity hazard to the parasites and predators. The use of insecticides as a root-coat before transplanting the seedling or their placement in the root zone of the rice plants, should also prove relatively safe for the parasites and predators. These treatments would be particularly important where early treatment of the crop is essential to protect it from virus infection or from such seedling pests as the rice gall midge, and whorl maggot.

Control of pests by cultural practices integrates well with other methods. Traditional practices such as stubble management that are believed to contribute to pest population reduction, should be evaluated carefully. A systematic roguing of virus infected plants is expected to minimize the source of virus inoculum.

At present the integration of insecticidal control with varietal resistance offers the best possibility for the control of rice pests. The number and frequency of insecticidal treatments required for the control of a pest will largely depend upon the level of resistance the host variety possesses for it. For example, the new IRRI varieties which are moderately resistant to the striped borer may ordinarily need one treatment to protect them from white head damage, while susceptible varieties will need two or more treatments to protect them from dead hearts as well as white heads. In the case of varieties highly resistant to the rice green leafhoppers and brown planthopper (IR26, IR28, IR29, IR30, IR32 and IR34), insecticidal treatments may not be required against these insects at all, but may only be needed against the insects to which these varieties are not resistant. Also, it has been observed that varieties resistant to a vector but susceptible or moderately resistant to the virus it transmits need fewer insecticidal treatments than the varieties that are susceptible to both the vector and the virus. The lesser number of insecticidal treatments means lower costs and is less of a menace to the natural enemies of the insect pests.

Research is currently in progress to determine economic thresholds of other common pests and to develop various criteria for pesticide application. Based on field sampling and light trap counts, it may be possible to use insecticides more effectively and efficiently if they are applied at an ecologically appropriate time, for example, when the population is mainly composed of juveniles and when the pest density is considered to be above the economic threshold.

Future plans:

Prototype systems or pest control packages will be developed as based on research on individual control methods. This prototype can be tested at several locations in cooperation with other countries. The systems tested will be changed as new research findings are included. The system will be based on the following:

1. Use of varieties with resistance to some insects and diseases.
2. Use of economic thresholds; if possible insecticides will be applied only when pest population levels reach the economic threshold.
3. Use of pest-selective insecticides when available.
4. Use of low dosages of insecticides, or selective insecticides, which are effective in controlling the pests but are safe to predators and parasites.
5. Use of biological agents to control pests.

It is hoped that our experiences in the Philippines will be useful to other countries as rice researchers develop systems appropriate to each different environment.

WEEDS[1/]

Justification and objectives:

The new technology of the so-called "green revolution" is frequently referred to as a seed-fertilizer technology. Little emphasis was initially given to the complementary management practices, such as weed control and fertilizer management, that must accompany the new varieties if their yield potentials are to be achieved. The current fertilizer shortage has, however, drawn attention to the fact that weed control measures must be improved to effectively use existing fertilizer supplies and increase rice production.

In the Asian tropics, most transplanted rice farms are weeded by hand or with rotary weeders. Often, the weeding job is not very thorough because weeding is tedious, time-consuming, and, in some cases, expensive. Under the existing conditions of high weed density, relatively low cost of labor and some chemicals, weeding rice fields is important and not how it is achieved.

Weed control for broadcast rice is more critical and more difficult than for transplanted rice. Laborers cannot move through the fields to weed by hand without destroying some rice plants. However, the problems of weed control under direct seeding depend on how rice is direct seeded. For example, one method of direct seeding is broadcasting the seed directly into a wet or puddled field as in Sri Lanka, northeast India, and in parts of Bangladesh and the Philippines. Under this system of

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[1/] Project Leaders - S. K. De Datta, Agronomist and K. Moody, Associate Agronomist.

direct seeding, weed problems are often minimized by indirect methods of weed control such as puddling and flooding. On the other hand, by broadcasting ungerminated seeds into a non-puddled field, as in Central Plain of Thailand, the degree of weed growth often determines the success or failure of rice stand establishment.

At the present time, nearly all the rice grown in rainfed bunded areas in the Philippines is transplanted. Very little rice is direct-seeded. However, with the limited success of direct-seeding and the introduction of multiple cropping, the area planted to direct-seeded rice will largely depend on the successful development of weed control technology. It is quite likely that this rice will need to be seeded in dry soil rather than in wet soil because of lack of sufficient water to puddle the soil. Little research has been conducted on weed control for direct-seeded rainfed, bunded rice on dry soil. Herbicides that are effective in direct-seeded lowland rice on puddled soil or in upland rice sometimes give poor weed control or are phytotoxic to the rice when applied to direct-seeded rainfed, bunded rice. The latter tends to happen if waterlogging occurs soon after application of pre-emergence herbicides.

About 15 percent of the world's rice area is planted to upland rice. In Africa and Latin America, it is the major system of growing rice. In Asia, it is not the major but an important system. The usual low yield of upland rice has been attributed to inadequate and irregular moisture supply, heavy infestation of weeds, lack of suitable varieties, nutritional imbalance, and inadequate cultural practices. No improved variety is yet available that could effectively replace the traditional varieties which have low but stable yields. But even with the traditional varieties, weeds alone may reduce grain yields by as much as 80 or even 100 percent.

The objectives of our research are:

1. To examine the weed control problem in Asia in a socio-economic as well as an agronomic, context.
2. To evaluate weed control practices in rice production.
3. To develop weed control technology as an alternative existing practices for transplanted, direct-seeded rainfed (on dry or wet soil), upland and deep water rice.
4. To develop and evaluate integrated weed control practices to minimize the need for too much chemicals.
5. To evaluate the profitability of alternative weed control measures.

Summary of accomplishments:

In transplanted, direct-seeded or in upland rice, we have attempted to develop weed control measures which can be divided into direct and indirect methods. Among the indirect methods of weed control, we can list choice of variety and cropping pattern, puddling and flooding of paddy fields, and land preparation. In areas where rice is grown alone or in combination with other crops, there are advantages to maintaining a crop canopy and shading out the weeds. Alternatively, relying on heavy or repeated doses of chemicals can shift the composition of the weed population toward more noxious species that are not easily controlled. The importance of thorough land preparation in reducing the weed population has been demonstrated in several experiments.

Our research has been primarily on the direct method of weed control which include hand weeding, mechanical weeding and chemical weed control. Most of Asia is characterized by ample labor relative to land and low wage rates (less than US$1/day). Therefore, chemical weeding had to be competitive to low wage rates for hand weeding.

One of the greatest breakthroughs in weed control research in rice was the identification of low-cost herbicides for transplanted tropical rice. The fact that some of these 2,4-D-type herbicides are not patented helped in maintaining lower prices. The concept of using herbicides for pre-emergence -- rather than post-emergence -- weed control subsequently helped in identifying selective herbicides for transplanted tropical rice.

The effectiveness of 2,4-D, however, varies considerably between locations due to differences in water control, to the composition of the weed population, and to the other factors.

In the recent past, several selective herbicides have been identified for transplanted rice. They are butachlor, benthiocarb, and C-288 which provide better weed control under less favorable moisture conditions that exist in most rainfed and some irrigated rice areas. However, such selective herbicides are more expensive than straight 2,4-D or MCPA. Therefore, in the Philippines, 2,4-D is the principal herbicide used because of its low cost.

Generally, herbicide use is closely associated with farm size. For example, more farmers are using herbicides who have more than 1 hectare than those who have less than 1 hectare of land. Studies conducted by IRRI Economists demonstrate that labor use has actually gone up in areas where herbicides are used in rice.

For direct-seeded flooded rice, the herbicides butachlor and benthiocarb, available commercially in several Asian countries, give excellent weed control without injury to the rice crop. Among the new herbicides, C-288 and MON 0358 showed excellent selectivity and broad spectrum activity in the tropics. As the cost of labor goes up, the direct-seeded flooded rice culture would become an acceptable alternative with the availability of less expensive and selective herbicides and better water control.

In both transplanted and direct-seeded flooded rice, the use of granular herbicides has immensely reduced the problem of selectivity in controlling weeds and minimized toxicity to the crop. Of the herbicides that are somewhat effective in minimizing weed infestations in direct-seeded rainfed, bunded rice, butachlor has been widely used in the program areas in the Philippines.

For upland rice, the following herbicides looked promising: butachlor, oxadiazon, penoxalin, dinitramine, MON 0358, and the combination herbicide C-288. These herbicides were effective when used at the rate of 2 kg/ha active ingredient or less and sprayed before weeds emerged.

We recognize that we have achieved limited success in developing good control of weeds in rainfed rice. Nevertheless, some herbicides now on the markets in Asia, when properly used, minimize weed competition in direct-seeded upland and rainfed-bunded rice.

<u>Future plans</u>:

Adequate weed control in rice fields growing modern cultivars and with high fertilizer inputs is important. Chemical weed control provides one alternative to hand weeding, but cannot be used to the exclusion of all other methods. Many species of weeds infest rice fields in Asia and elsewhere and those that are propagated by underground rhizomes and tubers are difficult to control entirely with chemicals. It is true that some progress has been made to control some perennial weeds in rice by using chemicals. For the difficult job of weed control in rice, we plan to evaluate and develop suitable integrated weed control practices such as suitable varietal types, the shifting of land and water management systems, and adoption of cultural practices such as thorough land preparation, dry fallowing during the off-seasons, and suitable practices for fertilizer and water management.

Such integrated weed management practices do not exclude the use of herbicides, but may minimize the dosage requirements thereby minimizing the cost of weed control in rice.

Weed control research in South and Southeast Asia was conducted using few chemicals on the market. The initial screening of a large number of herbicides at IRRI and elsewhere and subsequent screening of the best eight to 10 in a number of Asian and African countries has helped stimulate weed control research in rice. Efforts will be continued to develop suitable weed control practices for rainfed rice -- transplanted, direct-seeded, and for deep water rice and to develop suitable weed control practices including the identification of suitable chemicals that will control all weeds in all crops in intensive cropping systems program.

For direct-seeded rainfed, bunded rice joint studies will be made between the Agronomists and the Crop Production Specialists to develop suitable stand establishment techniques by controlling weeds and conserving moisture by different land preparation methods. For direct-seeded rainfed, bunded rice, herbicides will be screened on different soil types. Future studies will include studies on rice varieties tolerant to herbicide damage on different soil types. Finally, the effect of various factors (e.g. date of planting, plant type and density of planting, time of fertilizer application etc.) on crop growth, yield and weed control will be studied on various soil and climatic conditions.

Our greatest challenges are to develop suitable weed control techniques for small rice farmers in rainfed areas to maximize efficiency of their limited resources such as fertilizers and insecticides. All of these studies will be developed and evaluated by working closely with the IRRI Economists.

IRRIGATION WATER MANAGEMENT[1]

Justification and objectives:

It has become widely accepted in recent years that the successful application of high yielding rice technology requires rather careful control of water. Research at the experimental and farm levels in many countries has shown that the achievement of high yields, and farmer adoption of high yield practices, are both strongly associated with adequacy and reliability of water supply. Water shortages are the chief reason for the differences between actual farm yields and potential or experimental yields (Herdt and Wickham, 1975).[2] The purpose of IRRI's water management program is to increase crop production through a better understanding and management of irrigation systems.

Unreliability and inadequacy generally characterize the supply of water to rice lands in South and Southeast Asia. There are many reasons for this, e.g. extremely uneven rainfall throughout the year, lack of water storage in irrigation systems, and the large number of small farms, but three recent developments have stimulated a reconsideration of the importance of careful water use despite these problems. The first is the growing awareness that food, and specifically rice, is becoming an expensive national commodity - especially when it is in deficit. The

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[1] Project Leader - T. Wickham, Associate Agricultural Engineer.

[2] Herdt, R. and T. Wickham. Exploring the gap between potential and actual rice yields in the Philippines. Food Research Institute Studies, Stanford Univ., Vol. XIV, No. 2, 1975.

opening up to new lands to grow more rice is increasingly difficult, and in the Philippines it has been an insignificant source of output growth since the late 1950's. This means that higher yields and more double cropping are the chief means to increase current production (Anden,1974)[3].

The second development was almost a by-product of earlier plant breeding advances, in which the growth duration of new varieties was substantially reduced. Until recently a shorter cropping season was not fully appreciated, but for the first time it has made double cropping a viable possibility for many farmers in areas of supplemental and unreliable irrigation.

The third important change stimulating current interest in water management is the advent of irrigation systems with storage reservoirs. Except for relatively minor tanks in South Asia, major storage systems in the region were begun only in the 1960's. Many times more expensive than the traditional wet season supplemental diversion systems, they have usually required external planning and financing. Although storage systems have not yet demonstrated significantly better water management than diversion systems, the assurance of water supply regardless of wide fluctuations in riverflow is a strong incentive for the more careful and productive use of water.

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[3] Anden, T. Data Series on Rice Statistics, Philippines, IRRI, Agri. Econs. Dept., 1974.

These are among the reasons that governments and irrigation agencies throughout the region have taken a greater interest in their water resources. This interest is reflected in two ways: the rapid expansion of irrigated area through new system construction, and the intensification or better management of existing capacity. To some extent the two approaches are conflicting because the strain to finance new systems -- which have resulted in doubling all previous irrigated area in the Philippines in slightly over a decade -- has not permitted adequate support for the improved management of existing systems.

The focus of IRRI's water management program is the second alternative above, improved system management. To the extent we are interested in new system construction, it is in the development of management practices which others might want to incorporate directly in new system design and construction. We view improved management essentially as more intensive management and control of water deliveries within a system, and farm decision making to make use of the water management improvements.

Although a substantial body of opinion has developed recently supporting better water management, and even specific practices, it is remarkable how little verification has gone into the recommendations. Consulting engineers and institutional lendors, usually together, prescribe "modern" management based on rules of thumb or on experience from very different hydrologic, agricultural and social environments from those of the humid tropics. Even typical pilot projects established in irrigated areas cannot supply reliable comparative data, for they are invariably biased heavily towards "success": they are usually located in the most favorable portion of an irrigation system, they are guaranteed more than enough water, and their levels of funding cannot realistically be expected of entire systems. Furthermore, the typical pilot project adopts only one management model, and thus cannot provide a basis for evaluating among alternative models. In short, the basis of today's decisions regarding irrigation design and operation can best be described as personal or institutional preferences for what is perceived as the most "modern" system, with essentially no comparative data available to support these preferences, and involving hundreds of millions of dollars per system.

The broad objective of the IRRI program is to demonstrate in existing systems feasible ways to increase agricultural production through systems' operation. Economic feasibility requires that the alternatives be replicable on a broad scale in existing and new systems. Engineering feasibility means that the physical requirements of the alternatives can be found or provided in typical systems. Management feasibility refers to levels of operational sophistication consistent with reasonable numbers of locally trained irrigation personnel.

The specific objectives of the program are:

1. To evaluate the performance of alternative irrigation practices;
2. To demonstrate through pilot systems one or more packages of water management practices which would reflect significantly better use of water for crop production;
3. To study the effects of engineering, agronomic, economic and organizational factors and their combinations on the productive use of water;

4. To develop and use practical techniques for measuring critical parameters such as volume flow of water, and water adequacy and yield measures over wide areas;
5. To communicate to irrigation agencies and international financing institutions information which could be used in planning, operating and evaluating more productive irrigation systems; and
6. To provide practical on-the-job training for irrigation agency personnel, and for a limited number of M.S. or Ph. D. graduate students at their research stage.

The first stage of our program consists of field evaluation of current practices. This involves field monitoring of water flows, drought incidence, yields and system-farmer participation in order to identify constraints and efficiencies. The second stage is to try out and evaluate in cooperation with systems personnel and farmers selected improvement packages.

Strong complementarities exist between the water management program and the rest of IRRI. As the principal constraint to high yields and adoption, water is one of the most important factors in the institute's constraints network. The highly refined crop response to water studies carried out by Agronomy and Plant Physiology Departments stand to gain from the application of their findings in the field. The institute's work in plant breeding, cropping systems and meteorology are all closely linked with water management. But perhaps the most compelling reason for IRRI's involvement in the field stem from its independence from prescribed national or international policies of the moment. The fact that most universities and national research programs in Asia are not so well insulated from their government's operational policies is probably the most important reason why they have not begun research questioning these basic assumptions and policies.

In 1973 the Philippine government programmed an expenditure of ₱350 million for construction and development of national irrigation systems, an amount equal to that spent for nitrogen fertilizer by all rice farmers in the country. The research base to determine how the investment should be made was then and still is almost entirely missing, in sharp contrast to the case of nitrogen use. IRRI's opportunity in contributing to this research need stems from its institutional independence, its capacity to integrate economic, agricultural, and engineering disciplines into single research projects, and its ability to work with national irrigation agencies in actual measurement and control activities.

Summary of accomplishments:

Research to date has been carried out jointly with the Philippine National Irrigation Administration (NIA). Within IRRI it has been a part of the Agricultural Economics Department program since 1968.

Our approach is to investigate different forms of water management and estimate their relative costs and benefits. The first step was to develop a methodology for measuring irrigation benefits which are composed of yield benefits and those of a wider irrigation area. Having specified these relationships, we then modified management practices in 2 systems and evaluated the results.

Three types of yield benefits have been studied: physiological yield response to water, timing of crop growth, and induced management effects. Physiological yield response studies were undertaken experimentally in which we found a sharp decrease in yield and yield per unit of water for uniform daily applications less than about 6 or 7 mm/day. The breaking point varied by season according to evaporative demand, but essentially no additional yield could be produced through water applications in excess of that point.

Subsequent yield response studies used prolonged periods of withholding all water applications instead of limited daily rates of supply in order to better represent field incidence of drought. Thirty days of drought early in crop growth resulted in about 2 t/ha yield loss compared with continuously flooded rice, but 30 days of drought beginning just before reproductive growth resulted in over twice as much yield loss.

Our first field project involving yield response to stress was conducted in eleven conventionally irrigated sites averaging about 25 ha. each. About 50% of the variation in dry season yields could be explained by nitrogen and our measure of drought, stress-days. Drought in the later stages of growth was again much more serious than early drought in reducing yield.

The second yield effect of irrigation is in permitting land preparation to be completed sooner, so that the wet season crop coincides better with the period of maximum rainfall. Up to 6 weeks advantage was found for irrigated areas in Central Luzon, which on the average means about 1 t/ha additional yield under rainfed conditions.

A third yield effect is that due to farmers' willingness to use more inputs, chiefly nitrogen, when their water supply is better. A comparison between a common sample of farmers in the 1974 and 1975 dry seasons showed that farmers used 25% more N per ha, at over double the cost, in 1975 compared with 1974. Although other factors could have contributed to these findings, the volume of irrigation water supplied to the area sampled was critically short in 1974, but approximately twice as great in 1975.

The next step in our methodology is to relate the above yield benefits to rates of water supply. Using water use values from the field study, we verified a daily iterative model using rainfall, irrigation and evaporative demand as inputs, to predict water use efficiencies and yields (Fig. 1). At expected rainfall levels, actual yields in irrigated areas were found to be about 1/4 t/ha lower than they would be in the wet season if water were sufficient; in the dry season they are about 1/2 t/ha lower. The yield increase over rainfed was about 3/4 t/ha under wet season irrigation. Water use efficiencies were about 38% in the wet season, and 68% in the dry season when water was often in short supply.

In analyzing where in the system inefficiencies occur, we examined the data further by location and found that yield and stress day differences were insignificant between locations close to a supply canal and those far from it, indicating that the overland or paddy-to-paddy movement of water across fields was reasonably efficient. However, there existed serious problems of distribution along canals, with areas near the beginning of canals having high yields, low stress days and low water use efficiencies (excessive drainage), with the opposite the case at the far end of the canal. From this we conclude that first priority in Philippine systems should be given to providing a better distribution of water along the whole length of supply canals rather than the development of a tertiary farm ditch layout, which is the point of emphasis in most new systems.

A sociological study superimposed on the same sample found that those farmers who were least adequately served with water were among the most cooperative with neighboring farmers and systems personnel, and were most willing to pay the irrigation fee. It is apparent that the generously served farmers took their water for granted, while the disadvantaged farmers recognized its worth.

At this stage our methodology was well developed enough to justify projects involving actual changes in system management. The new management practices were based on the earlier results showing over-irrigation along the beginning of canals, and under-irrigation towards their ends. The first project was conducted jointly with the NIA on a 5,000 ha portion of a Central Luzon diversion system. All the project area was irrigated from a single canal, Lateral C, and its sublaterals. After a season of simply monitoring flows, we trained the system personnel to provide water in proportion to the area planted. This required gate control at the head of the lateral so that about one third of the system's water entered the pilot project. A relative share criterion was used rather than a minimum in order to avoid robbing the rest of the system for the benefit of the project. Then, within the lateral we established measuring points at the quarter points, and set up a schedule designed to provide more nearly equal water delivery among the 4 sections (Fig. 2).

The schedule required 1-1/2 days per week during which each of the first 2 sections had priority in water use, and 2 days per week for each of the last 2 sections. Obstruction, or checking, of canal flows to increase water elevation and therefore field turnout as well was permitted only during the scheduled period for each section.

The system's regular personnel carried out this management program, but they were assisted by 4 technical assistants who were seconded by the National Irrigation Administration to the project. They were trained briefly at IRRI, and then assigned to each of the 4 sections in the project. New sets of technical assistants were used each season to maximize the training opportunities for NIA staff. A flexible staff of between 1 and 3 IRRI research assistants provided overall guidance and technical support to the project.

The aims and methodology of the project were carefully explained to farmers in village meetings throughout the project area. In particular we stressed that the first sections would receive less water, but that they would still be adequately supplied; and that checking was permitted only during the scheduled times.

After one season of unprecedented night patrols, we were satisfied that almost all checking was restricted to proper times, and that compliance could be maintained with much less effort. This had a favorable impact on water distribution, for enough water could then flow to the lower canal sections.

A comparison of the area irrigated, the volume of water supplied, yields, and farmer use of nitrogen fertilizer was made between the 1974 dry season before the project was fully implemented and the 1975 dry season (Table 1). All factors showed more equitable water use among the 4 sections in 1975, but the effect was caused partly by more water availability in that season due to an increase in the system's source of supply.

We also studied the spatial and sequencial distribution of drought, measured in stress days, within each section and related it to a) physical and b) hydrologic factors (Fig. 3). The number of on-farm tertiary canals did not significantly affect drought incidence as we expected, except for those areas with coarse soil texture. Distance along the lateral and sublateral canals, and overland distance from them were all significantly related to more stress days. Of the hydrologic factors, the excess of rainfall plus irrigation less evaporative demand was significantly and inversely related to stress days. The amount of water required to keep drought incidence at a low level increased by at least 4 times following major dry spells because of soil cracks which drain away much of the water.

A second field project involving modified management was conducted at 3 locations to test our earlier finding that farm-to-farm water movement is reasonably efficient. The project was organized to supply limiting but equal rates of water supply to a 50 ha. block irrigated by 24 hour rotation (5 ten ha. units fed by farm ditches), and an adjacent 50 ha. block irrigated in the usual continuous way without farm ditches. No significant differences were found in yield, yield per unit of water, or water use efficiency, despite the extra cost of the rotational model. We conclude that the rotational model has often been recommended because its performance has not been carefully compared with conventionally irrigated areas receiving an equal water supply.

Future plans:

In the immediate future we will:

1. establish a Philippine pilot project testing simultaneously several water management practices, and
2. organize together with The Agricultural Development Council a regional workshop of research and operations in water management.

Our hypothesis for the pilot project is that with proper management, systems with only modest physical improvements can produce benefits approaching those of the most detailed design, but at much less cost. The project will test 3 packages of practices, which can be viewed as 3 intensity levels of management, from complete land consolidation to only modestly improved conventional systems. All 3 alternatives will be subject to the constraints of the same system to ensure comparability in evaluating relative costs and benefits.

The workshop tentatively scheduled for May 1976 is an outgrowth of an informal network of research and operations workers in water management in South and Southeast Asia. At present this network is completing a bibliography of water management items with socio-economic content, and is circulating resumes of research in progress, some of which will be presented fully in next year's workshop. The A/D/C Inter-regional Program and one A/D/C Associate are jointly sponsoring these activities with us.

Longer range plans include:

1. the testing of our methodology in a location outside the Philippines,
2. the continuation of design work in water management instrumentation, and
3. the development of a more comprehensive understanding of water use based on data already collected.

The testing of our methodology outside the Philippines is important since numerous management practices are location specific. Thailand is a logical choice for such a project due to the different traditions of canal maintenance and operation there, and the newness of double cropping in many irrigation projects. As in our earlier work in the Philippines, initial research should start with monitoring how the systems currently perform, in order to learn what the inefficiencies and strong points are.

Projects involving different management practice packages would then be carried out and evaluated in an attempt to determine a more efficient model.

Perhaps the biggest constraint to better system management, and to better research, is the difficulty in measuring key variables. We will continue to develop new instrumentation, particularly means of measuring water flows in canals and small ditches. Meteorological research will concentrate on probable levels of rainfall, evaporative demand, solar energey, river flow, and their combined effects on production.

Data already collected from the Lateral C project can now be used to verify a model integrating the physiologic effects, timing effects, and induced management effects as they relate to yield. The model would also relate yield to area irrigated, water use efficiencies, and labor use associated with planting schedules.

The development of human resources is the most important part of improved system management. This will be incorporated in all our projects, not primarily through formal training sessions, although this may be included, but through using system's personnel jointly with our own in actually implementing improved management practices.

Table 1. Comparison of area planted, yield, and nitrogen use in 4 consecutive sections of Lateral C, Peñaranda River Irrigation System, before and after pilot project, 1974 and 1975 dry seasons.

Section	Year	Area planted (ha)	Yield (t/ha)	Water supplied (mm/wk)	Nitrogen	
					(kg/ha)	(₱/ha)
1	1974	1185	2.6	104	48	146
	1975	1110	3.0	157	58	457
2	1974	1055	2.4	84	33	133
	1975	1115	3.0	131	47	379
3	1974	1237	2.2	52	41	103
	1975	1699	2.6	186	44	296
4	1974	402	2.1	63	46	96
	1975	871	2.3	132	62	320
Total	1974	3878	2.4	78	41	126
	1975	4796	2.7	157	52	379

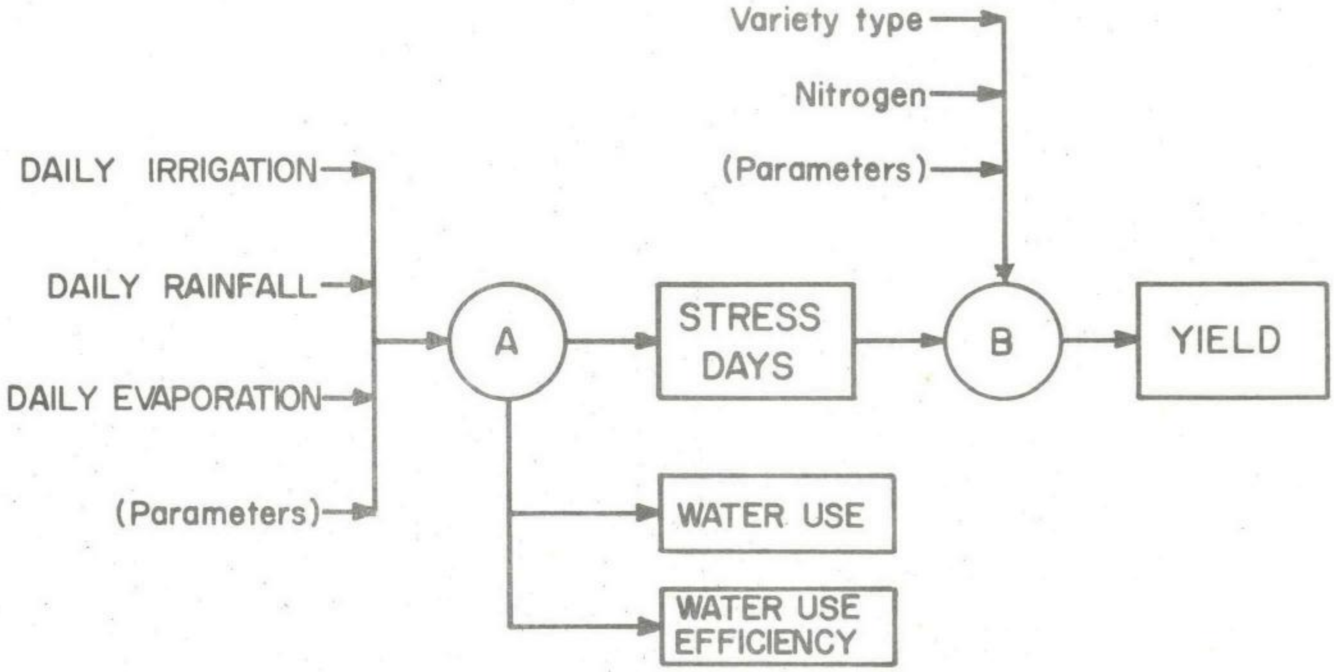

Fig. I. Flow diagram for yield and water use predictions.

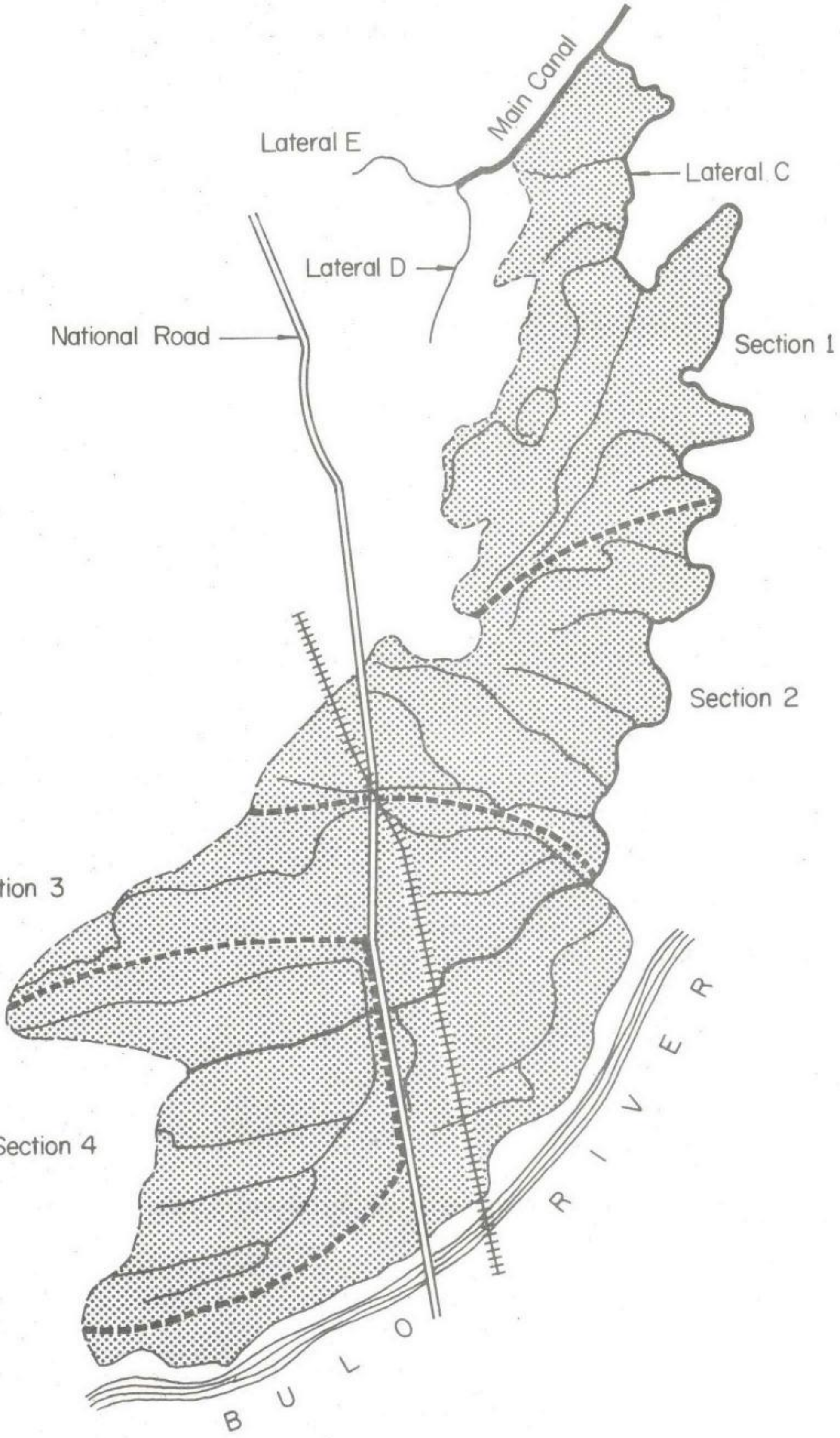

Fig. 2. Map showing the sites of observation paddies for assessing water adequacy at the service area of Lateral C, Peñaranda River Irrigation System.

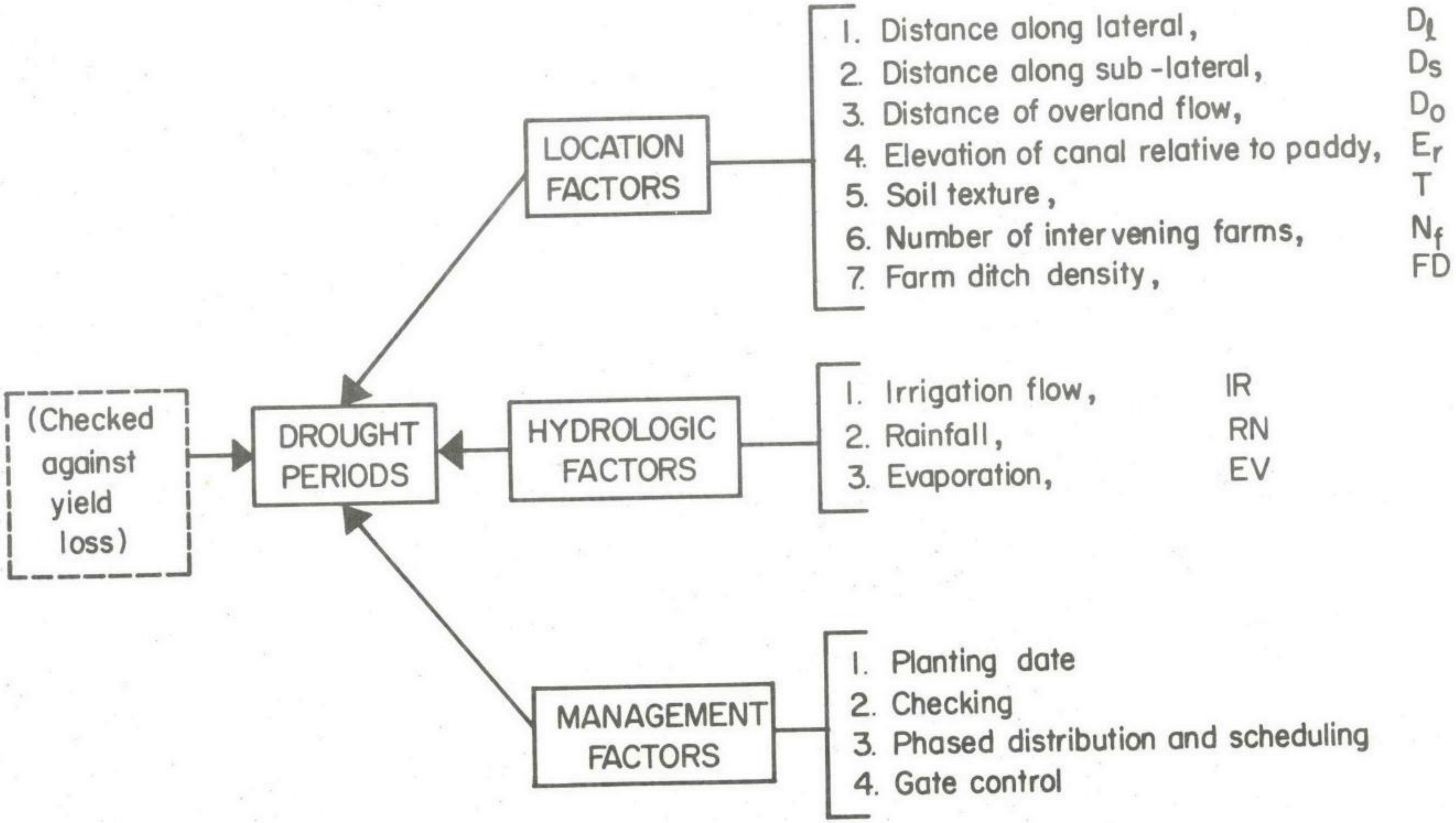

Fig. 3. Factors affecting the severity and distribution of drought periods in canal irrigated areas.

SOIL AND CROP MANAGEMENT

SOIL FERTILITY MANAGEMENT[1]

Justification and objectives:

With the recent concern over fertilizer shortage and high prices, studies are being focused in increasing fertilizer efficiency in all crops. In the course of a two-year period (1972-1974), the retail prices of N, P, and K fertilizers in most countries have increased several folds. As a matter of fact, average (for some countries) fertilizer prices have increased from 138 to 336 percent when comparison was made between 1972 and 1974.

These inflationary prices have created interest in field research to identify methods to maximize yields at low rates of fertilizer. For rice studies on fertilizer efficiency are of great importance because rice is the primary source of food for about half of the world's population and because of the great diversity of conditions in which rice is grown. Under these diverse systems of rice culture, management of fertilizer, particularly nitrogen fertilizer, becomes critical in order to maximize rice yields using low rates of fertilizer.

Since rice is grown on all major soil groups in South and Southeast Asia and over a wide range of soil pH, from 3 to 10, stable high yields cannot be obtained if nutritional deficiencies are not alleviated by proper fertilizer management practices.

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[1] Project Leaders - S. K. De Datta, Agronomist; F. N. Ponnamperuma, Soil Chemist; and I. Watanabe, Soil Microbiologist

In certain regions of Indonesia, Burma, Malaysia, and Sri Lanka, use of phosphorus is essential to obtain high rice yields. In India, phosphorus deficiency is widespread.

The decision as to whether to use complete fertilizer or single-element fertilizers such as urea or ammonium sulfate to obtain high grain yield depends primarily on the soil type. In view of fertilizer shortages, there is a move to reduce the doses of phosphorus and potassium and, in some cases, eliminate them altogether from recommendations for various crops in India. These recommendations should be evaluated in relevant context.

The primary objective of rice research at IRRI is to develop rice varieties and technology to raise the production at farm level. These objectives cannot be realized without any fertilizer application. On the other hand, these objectives do provide a challenge to rice scientists at IRRI to develop technology which will not require high level of fertilizer. To meet these challenges, IRRI scientists must develop a strong international cooperative program to generate a suitable technology for the small Asian farmers in cooperation with some key rice soil scientists of South and Southeast Asia.

In addition to increasing the supply of fertilizer, it is necessary to make more efficient use of fertilizer produced.

The specific objectives of our studies are to increase efficiency in rice through:

1. Evaluation and subsequent modifications of economical time-released nitrogen fertilizer.
2. Development and evaluation of fertilizers less subject to volatilization.

3. More nearly optimal timing, method and rate of application.
4. Improved land and water management, whether from rainfall or irrigation to control leaching and denitrification.

Summary of accomplishments:

Contrary to popular belief, the high-yielding tropical varieties developed at IRRI and elsewhere do not depend entirely upon fertilizers. These modern varieties generally yield more than the traditional tall tropical rices even when no fertilizers are applied.

A great deal of attention has been devoted to evaluate the relative merits of various fertilizers for flooded rice. The yield response of rice to different sources of nitrogen is affected by soil condition and management practices particularly time and method of application.

In recent years, several new products have been developed and tested that are released only slowly in available form. In 13 out of 17 experiments conducted by IRRI, slow-release fertilizers such as sulfur-coated urea (SCU) gave higher yields than the conventional fertilizers.

In some Asian countries, straw is available in large quantities as a source of organic matter and nutrients. Research conducted by IRRI Soil Chemists demonstrated the benefits of applying straw (straight or compost) as a source of plant nutrients.

A procedure is developed which enables one to make the choice of P sources on the basis of both agronomic effectiveness and economic considerations. As a result of these studies, rock phosphates are recommended as an alternative to superphosphate in some acid soils in South and Southeast Asia.

In field trials at IRRI, a single application of fertilizer nitrogen just before panicle initiation gave the highest efficiency of nitrogen, in terms of kilograms of rice yield per kilogram of nitrogen applied. There were some distinct varietal differences in the fertilizer responses however, primarily due to differences in growth duration.

Applying nitrogen in split doses improves considerably the efficiency of conventional fertilizer nitrogen use. In 16 out of 24 experiments conducted during 1967-1974, split application gave higher yields over basal application.

Deep-placed fertilizer is apparently less subject to volatilization and microbial oxidation. The loss of nitrogen is commonly more serious in rainfed lowland conditions than in irrigated rice field. The results were striking when the "mudball" technique was used in recent experiments. At half or one-third the recommended rate of nitrogen application, the mudball technique gave higher yields than with other methods of fertilizer application.

Experiments conducted at IRRI during the 1975 dry season confirmed the superiority of deep placement method over that of other methods of application.

In addition to the mudball technique, deep placement of urea by using capsule or as briquet (developed by TVA, U.S.A.) was also tested in these experiments. Urea briquets when placed at 10 to 12 cm soil depth gave comparable yields achieved as the mudball technique or using split application.

Recent experiments at IRRI during the 1974 dry and wet seasons and the 1975 dry season demonstrate that it is entirely feasible to apply insecticides and fertilizers together if a suitable placement technique can be developed which will considerably minimize the use of both fertilizer nitrogen and insecticides.

We have monitored changes in the capacities of rice soil to supply N, P, and K over a sustained period of intensive cropping. Results from the past seven years indicate that in areas where one crop per year is grown with an adequate supply of N, the response for P and/or K may be marginal. Response may become marked however under intensive rice cultivation involving more than one crop per year. These findings have led to recommendations of complete fertilizer in some areas where only N fertilizers were recommended earlier.

Data from IRRI Agronomy and Agricultural Economics Departments demonstrated that management practices such as land preparation and insect and weed control greatly affect fertilizer nitrogen efficiency in lowland and upland rice.

Future plans:

High prices of fertilizers add to the problems of all rice farmers particularly those of low income. This has led to some major shifts in our research programs. While in the past the emphasis was primarily to maximize grain yield at high level of fertilizer application, we are now paying a greater attention to practices which will give higher fertilizer efficiency in rice at low rate of application. This means we are willing to get somewhat less than the maximum yield possible with modern varieties but to obtain stable yields at low level of fertilizer application. Therefore, we plan to expandour research to increase the efficiency of fertilizer by evaluating varietal differences in and cultural practices for fertilizer efficiency in rice. Some basic concepts will be developed and tested at IRRI and in the Philippines. But soil fertility in the Philippines is greater than in most rice soils of South and Southeast Asia. We are developing cooperative and collaborative research with rice scientists of South and Southeast Asia to generate and evaluate technology which would increase efficiency of fertilizers at low rate of application. Studies by IRRI Economists clearly indicate that many farmers have used some fertilizers when they grew improved varieties. However, with present high prices, farmers are reluctant to put high dosage of fertilizer. Our efforts will be to develop fertilizer management practices which would maximize farmers' limited resources. These studies will be carried out on different soils and climatic conditions. We plan to expand our research in the future to increase the efficiency of both fertilizers and insecticides so that farmers can get higher yields from lower rates of chemical inputs.

We plan to evaluate various low-cost phosphate sources such as rock phosphates on various acid soils. We plan to evaluate also the interrelationships between P application and N mineralization rate and evaluate economic benefits from trade-off between P and N application and N mineralization.

We plan to pay greater attention to indirect methods of increasing fertilizer efficiency in rice than in the past. These indirect methods include integrated management practices such as good land preparation, adequate insect and weed control which would minimize fertilizer losses in flooded and upland rice. Soil puddling and water management also help water and nitrogen economy of rainfed rice.

We plan to screen rice varieties which shade out some weeds, thereby, increase fertilizer efficiency. We plan to screen varieties for high seedling vigor and with intermediate stature which would perform well under less favorable growing conditions such as poor water supply, poor soil fertility, heavy weed growth etc.

Cooperative and collaborative research work will be carried out to complement information generated by IRRI Agronomists and Agricultural Economists to develop relevant technology for the most rice farmers in South and Southeast Asia.

ROLE OF SOIL MICROORGANISMS IN RICE CULTURE[1]

Justification and objectives:

Microorganisms densely populate soil and play an indispensable role in maintaining soil fertility. Microorganisms add to the supply of available plant nutrients in the soil in two ways: (1) they effect various chemical changes that release nutrients previously unavailable to plants and (2) they degrade, as well as help detoxify, man-made compounds in the soil thereby contributing to the fertility of the soil.

The research of the soil microbiology department at IRRI has, since its inception in 1963, focused on these two aspects of microbial activities in rice soils.

Maximum plant use of soil nutrients - the role of microorganisms in paddy soil.

Nitrogen is considered the most important nutrient required by rice because the plant requires more of this nutrient than any of the other essential nutrients for growth and yield. Among the three major fertilizer components of nitrogen, phosphorus, and potassium, nitrogen consumption is greatest particularly in the rice-growing nations of Southeast Asia. Actually, nitrogen is perhaps the most limiting plant nutrient for rice production. Without adequate supplies of nitrogen available to the plant, high grain yields are impossible. Ways to improve the efficient use of nitrogen fertilizer have been and continue to be explored.

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[1] Project Leader - I. Watanabe, Soil Microbiologist.

Soil nitrogen remains a valuable source of nitrogen that has not yet been exploited to its maximum potential. Research data have shown that about 50 kg N/ha is absorbed by rice grain and straw per one crop. (Table 1). This can constitute about 67 percent of the nitrogen in rice grain and straw at harvest time. In order to maintain the fertility level of a soil, an amount of nitrogen equal to that removed by a crop should be returned to the soil. This can be via fertilizer nitrogen application and (or) the activity of soil microorganisms. Our object is to investigate the role of this latter factor along the following lines:

1. Nitrogen fixation

The energy crisis, which affected the worldwide supply of nitrogen fertilizer and increased the cost of this farm chemical, has fostered studies of the efficient use of biologically fixed nitrogen for food production. At present, chemical nitrogen fertilizers are produced principally through the Harbor-Bosch reaction, wherein 18,5000 Kcal energy is needed to process ammonia to obtain 1 kg of nitrogen. On the other hand, the energy requirement for the biological fixation of nitrogen by a purified enzyme system is 85 Kcal/mol NH_4 = 6,000 Kcal/kg N.

The most efficient system for the biological fixation of nitrogen is root nodules of legume plants. About 4.1 g of carbohydrate carbon is transferred from the aerial part of a legume (pea) to the root nodule to yield 1 g of fixed nitrogen. The energy efficiency is calculated to be 16,000 Kcal/kg N. The efficiency of other biological systems that fix nitrogen is summarized in table 2.

Globally, 40 x 10^6 metric tons of nitrogen is fixed through industrial production of nitrogen fertilizers, while 50-70 x 10 tons of nitrogen is fixed through biological systems. These data point out the importance of biological fixation of nitrogen, particularly in the field of food production.

2. Mineralization of soil organic nitrogen

At present, there is a dearth of experimental data to support the notion that the nitrogen which is fixed in paddy fields is directly available to the growing rice plant. Therefore, nitrogen taken up by the rice plant from non-fertilizer sources is considered to originate from irrigation water, rain water, and the mineralization of soil organic nitrogen.

The mineralization of soil organic nitrogen is affected by a number of factors. Wetting of dry soil may be a key factor controlling the nitrogen fertility of rice soils.

Flooding and wetting of paddy soils after a prolonged dry period during the dry season may accelerate the mineralization of soil organic nitrogen, and, consequently, a considerable amount of mineral nitrogen may be accumulated during the initial period of rice growth (fig. 1).

Proper management and efficient utilization of the mineralized nitrogen can contribute to the agronomic management of rice crops to achieve favorable grain yields. The dynamics of the mineralization of soil organic nitrogen is rapidly becoming a priority area of investigation for soil microbiologists.

3. Balance sheet study of nitrogen in rice growing countries in Asia

The limitations of the world resources for nitrogen dictate the need to develop efficient systems through which resources can be recycled. A fundamental knowledge of the balance of plant nutrients is essential in the development of an effective management program for soil fertility maintenance and improvement in tropical areas. This is critical in view of the increasing impact of higher crop production and efforts to increase the yields of food crops.

Basic studies on nitrogen balance and the nitrogen cycle are sparce, especially in Southeast Asia. For this purpose, systematic surveys and studies in collaborative effort among various rice-producing countries are critically needed. The worldwide interest in the mineral recycling system in agriculture is reflected in the May 1976 international conference in Amsterdam, Netherlands, on mineral recycling in the agricultural ecosystem.

4. Nitrogen economy in rainfed rice fields

In the Philippines, 60 percent of the rice under cultivation is not irrigated and rainfall is the primary source of water. The soil water conditions are unstable in these rainfed areas. Severe water stress during the growing season is a major constraint to rice yields in rainfed areas. This lack of water control produces a drying-and-wetting cycle in the soil. This cycle can accelerate the loss of nitrogen from the soil because the drying of the soil enhances nitrification, and the following wetting may effect loss of nitrogen from the soil by denitrification.

A fundamental knowledge of the soil nitrogen economy under conditions of uncontrolled soil drying and wetting might provide insights into ways to improve present agronomic management practices to promote improve rice yields in rainfed areas.

5. Degradation of pesticides and soil microorganisms

Increased acreage for the cultivation of high-yielding rice varieties promotes a wide use of pesticides, even with the pest and disease resistant varieties. The necessity of controlling and minimizing the pollution of the environment by pesticides is gaining worldwide recognition in both the developing and developed nations. The intensive activities of the soil microbial populations make soil a powerful buffer medium for reducing environmental pollution. More studies are needed to clarify the effect of soil microorganisms on the degradation of pesticides and their residues in soil.

Recent findings regarding the unique nature of anaerobic degradation of pesticides suggest that a knowledge of the microbial degradation of pesticides in paddy soil could assist in the development of practices to control persistent pesticides in these rice soils.

<u>Summary of accomplishments</u>:

Nitrogen fixation:

From the time it was established, the department of soil microbiology at IRRI has been studying the biological fixation of nitrogen. A major focus has been on the fixation of nitrogen by algae present in paddy soils. A relatively simple and sensitive method for detecting and measuring the nitrogen-fixing activities of rice and the soil environment in which rice grow -- the acetylene-reduction method -- has been developed through the departmental research program. Use of this technique revealed that nitrogen was fixed in the root zone (rhizophere) of rice, as evidenced by two major findings.

1. The acetylene-reduction activity (ARA) of excised roots of rice was high, especially when the rice was grown under lowland conditions. Maximum ARA was found to occur around the heading stage of rice development. The ARA of these excised rice roots was similar to that reported for the roots of tropical grasses.
2. The nitrogen-fixing activity of paddy soil was much higher in planted areas than that of unplanted areas.

Such findings encouraged IRRI soil microbiologists to investigate further the fixation of nitrogen in the rhizosphere of lowland rice. Fixation of nitrogen by Azolla (water fern) has been given peripheral attention.

Mineralization of soil organic nitrogen and its relation to nitrogen balance of rice-growing regions:

Using ^{15}N-labeled nitrogen fertilizers, the efficiency of fertilizer nitrogen and the availability of soil nitrogen has been studied at IRRI since 1972.

In 1974, studies of the mineralization of soil organic nitrogen showed that 75 kg N/ha was absorbed by the aerial portions of the rice plant during the dry season. During the early stages of rice growth and development, mineralization of soil organic nitrogen was found to be slow especially in the dry season. These findings did not support the commonly accepted notion that the rate of mineralization of soil nitrogen in the tropics is rapid during the early stages of rice growth.

The pattern of the mineralization of nitrogen in paddy soil incubated in the laboratory was similar to the pattern of nitrogen uptake by rice in the field. Rapid immobilization of mineral nitrogen into the organic fraction in the soil was found to be pronounced. A complete balance sheet study for nitrogen has to be carried out.

Nitrogen economy in rainfed rice fields:

Until around 1972, most investigations of the department's research program for nitrogen balance and transformations dealt primarily with soils from irrigated rice-growing areas. From 1972 to the present, more attention has been given to studying nitrogen transformations in upland rice soils. Recovery of fertilizer nitrogen was found to be higher in upland soils, while the availability of soil nitrogen was higher under submerged conditions.

Degradation of pesticides by soil microorganisms:

Departmental studies of the persistence and degradation of pesticides revealed that most of the organic chlorine pesticides are highly persistent in upland soils, but were less persistant under lowland conditions.

The anaerobic microorganisms which degrade BHC were isolated and the degradation of this insecticide by these microbial populations was studied.

The decomposition of organic phosphorus insecticides, such as diazinon, has been studied to determine how repeated applications of diazinon to flooding water enriched the populations of microorganisms which decompose this compound, thereby reducing the effectiveness of such pesticides. Soil microorganisms that degraded diazinon were isolated and the process by which the compound was degraded was investigated.

Some surveys on problems of pesticide residues in paddy soils were carried out in 1972 by the department.

Problem soils:

The microbiological profile of problem soils, such as acid sulfate soil, zinc-deficient soil, and highly reduced soils, were carried out by the department on a short-term ad hoc basis.

Future plans:

1. Nitrogen fixation

(a) Fixation of nitrogen in the rhizosphere of rice

The recently developed *in situ* assay methods for estimating the rate of nitrogen fixation in paddy fields will be applied in the field in the Philippines through 1977 and in other rice-growing countries in Asia. The significance of the fixation of nitrogen in the rice rhizosphere will be examined with these *in situ* assays. Workers in West Africa have reported that the fixation of nitrogen in the rhizosphere of some rice varieties was equal to that of legumes, suggesting that the *in situ* assays in regions near the equator might offer some promising leads in the search for rices with a high capacity for rhizospheric nitrogen fixation.

If rice cultivars with a nitrogen-fixing activity of the root zone similar to that of legumes could be identified in some region(s) of South Asia, perhaps the genes responsible for this characteristic could be incorporated into the IRRI GEU program. This prospect will be investigated within two years.

(b) Fixation of nitrogen by the water fern *Azolla*

Azolla, the nitrogen-fixing water ferns, have been used in the culture of rice in some Asian countries such as North Vietnam. *Azolla* is easier to grow than are nitrogen-fixing blue-green algae. *Azolla* can fix 1 kg N/ha daily. If fundamental studies to ascertain the best cultural conditions for *Azolla* for inoculum preparation, methods of inoculation, and the effect of Azolla on rice growth and on soil nitrogen fertility are successful, experiments are planned for growing and inoculating *Azolla* in paddy field in the Philippines and other parts of Southeast Asia.

2. Balance sheet study on nitrogen in rice soils

An annual nitrogen balance sheet analysis could be conducted in coordination with the long-term fertilizer trials at IRRI. Until recently little attention was given to the actual uptake of nutrients by rice plants. A centralized laboratory for chemical analysis could accomplish analyses of plant nutrients in both rice plants and soil.

A periodic check of the content of plant nutrients (particularly nitrogen) in irrigation water and rain water should be made systematically.

Recent progress in the technology of large-scale production of heavy nitrogen now provides heavy nitrogen at a cost lower than that of a few years ago. The relatively low cost of nitrogen compounds without ^{15}N will permit the widescale use of such compounds in field studies at IRRI during the next few years. Fertilizers free of ^{15}N will be applied in some field trials at IRRI.

3. Nitrogen economy of rainfed and upland rice fields

The dynamics of soil nitrogen under non-controlled water conditions will be studied. The seasonal change in the distribution of mineral nitrogen within the soil profile will be monitored for at least 2 years in both well-drained and poorly drained fields.

Preliminary trials at IRRI revealed that leaching losses of fertilizer nitrogen in upland soils was not too marked even during periods of heavy rain during the wet season. Additional studies on leaching losses of fertilizer nitrogen will be carried out under different conditions.

The release of soil nitrogen under dry season conditions will be studied to better understand the balance of soil nitrogen and plant uptake of soil nitrogen during the subsequent rainy season.

4. Continuous cropping studies in rainfed and upland rice-growing areas

Continuous cropping experiments on some upland crops, including upland rice, are presently under way. Mung bean and upland rice were found to be severely retarded after continuous (third) cropping. These trials will be continued for several more years. An investigation in cooperation with the multiple cropping system programs is needed to identify the cause(s) of "soil sickness".

5. Pesticide residue problems

Deep placement of insecticides in the form of a mudball or a coated capsule was shown to achieve effective control of rice insects. Relative to these findings, the decomposition of insecticides in rice soils will be studied to identify any differences that may exist in the effect of broadcasting and band-placement on the persistence and (or) degradation of these compounds in rice soils.

Since continuous pesticide application is known to promote the growth of microorganisms in the soil that degrate these chemicals, the integrated effect of repeated applications of pesticides will be investigated, using some carbamate pesticides.

The effect of pesticides, especially herbicides, on nitrogen fixation in rice soils will be examined.

Consideration is being given to expanding the present pesticide research program at IRRI beyond the present "application-response" studies to more in-depth investigations.

Systematic studies on soil residues of pesticides will be required in the foreseeable future even in developing nations. Man's increasing concern for the quality of his environment has brought about the establishment of standards for pesticide residues and environmental contamination levels. New systems of residue research must be investigated soon to meet these man-made constraints to food production.

It is obvious that the present staff in the departments of soil microbiology and entomology at IRRI cannot adequately handle the extensive studies needed to examine the problems of pesticide residues and their amelioration.

Table 1. Amount of soil nitrogen available for plant uptake by lowland rice in Asia.

Locale of research center	Country	Soil Nitrogen (kg/ha)	Method
Saitama	Japan	67	Isotope
Saitama	"	51-50	"
Hokuriku	"	70-74	"
Nagamo	"	78-108	"
Gifu	"	75	"
Bangkhen	Thailand	37	No N plot
Bangkhen	"	52	Isotope
Los Baños	Philippines	76	No N plot (wet season 1973)
Los Baños	"	68	No N plot (dry season 1974)
Los Baños	"	97-113	Isotope
Los Baños	"	86	No N plot (dry season 1973)
Mura	Indonesia	47	"
Pusakanagena	"	65	"
Ngale	"	49	"
Modjosari	"	47	"
Gentent	"	49	"

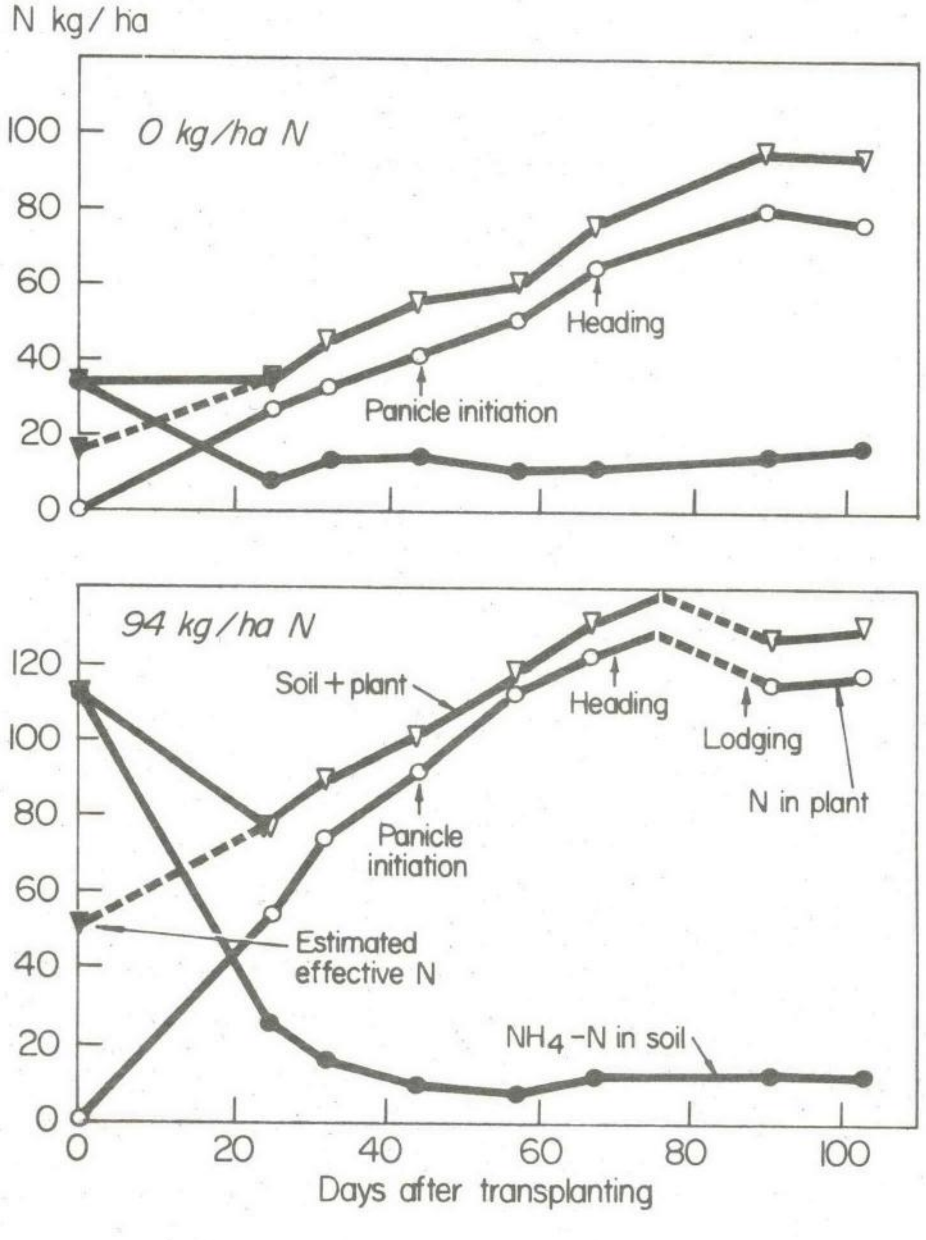

Fig. 1. Amount of nitrogen taken up by IR20 rice plants and remaining in soil at various stages of growth. Wet season, 1973.

Table 2. Efficiency and potential of various nitrogen-fixing systems in rice culture.

System	Nitrogen fixed annually (kg/ha)	Efficiency	Potential	Problems
Photosynthetic free-living (blue-green algae)	10-45 2 kg N/ha daily	Energy supplied by sunglight, but the rice canopy decreases the efficiency of algal use of sunlight.	Algal blooming after flooding is well recognized. Much data are available.	Inoculation experiments have not yet produced consistent results. Practical methods for growing soil inoculants need investigation.
Heterotrophic nitrogen fixation in the root zone of rice	While high values have been reported in West Africa, generally the activity is only 10% of that of nodule activity.	20-40 mg N/ 1 g glucose consumed	The role of rhizospheric nitrogen fixation in paddies is under study.	The annual fixation of nitrogen in the rhizosphere of tropical grasses is reported to be about 90 kg N/ha. However, this needs verification.
Algal symbiosis in aquatic plants (<u>Azolla</u>/water fern)	62-125 1 kg N fixed/ha daily	Higher than algal activity	Used as green manure in North Vietnam.	Studies on the practical application are needed.
Symbiotic nitrogen (nodule activity)	As high as 650	The most efficient of these four systems described. 100 mg N fixed/ 1 g glucose consumed.	Its greatest importance occurs under upland conditions.	No legumes can be grown in lowland rice paddy fields. Green manure crops, such as <u>Sesbania</u>, are being replaced by grain legumes for efficient use of the land.

SOIL CHARACTERIZATION[1]

Justification and objectives:

An understanding of the nature and properties of problem soils is essential in identifying the growth- and yield-limiting factors. Successful studies will lead to greater production in these problem soil areas. Flooding or moistening a soil sets in motion a series of chemical and physicochemical changes. These changes influence the rate and magnitude of nutrient release or removal and the generation of substances that can harm the rice plant. Thus, chemical kinetics holds the key to the understanding of flooded rice soils and has a profound influence on the growth and yield of rice. Therefore, we used chemical kinetics and soil and plant analyses as the diagnostic tools in identifying the growth-limiting factors in problem rice soils.

Such studies will have two important benefits:

1. It will help in conserving and improving soil fertility, thereby, increase fertilizer efficiency in rice.
2. It will lead to a greater understanding of problem soils which will lead to better procedure and selection criteria in screening rices for resistance or tolerance to problem soils.

The specific objectives of our studies are:

1. To examine methods of conserving and increasing the natural supply of the major nutrient elements and increase fertilizer efficiency by improving land and water management.

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[1] Project Leader - F. N. Ponnamperuma, Soil Chemist.

2. To evaluate and ameliorate problem soils by having a clear understanding of the nature and peculiar properties of these soils when flooded.
3. To have greater understanding of acid sulfate soils and their possible amelioration.
4. To identify the chemical factors retarding the growth of rice in cold acid soils.
5. To evaluate the long-term effects of straw and water management practices on the chemical properties of and nutrient balance in rice soils and on the growth and yield of rice.

<u>Summary of accomplishments</u>:

Phosphorus deficiency is perhaps the most important limiting nutritional factor on highly weathered acid tropical soils and acid sulfate soils. This chemical kinetics of the soil solution of an acid soil showed that phosphorus was deficient throughout the growing season, and plant analyses indicated very low levels of phosphorus. Addition of 50 ppm phosphorus however alleviated this problem.

Zinc deficiency has been associated with soils of high pH but we have found that it may occur in flooded soils with air-dry pH as low as 4.8 if kept continuously flooded and that it may retard the growth of rice on many soils where moisture regime favors the accumulation of organic matter.

In a study of 15 soils, the kinetics of water-soluble zinc was found to be influenced by pH, the organic matter content and the level of phosphorus of the soils. The decrease in water-soluble zinc was most rapid in the neutral and calcareous soils and least in the strongly acid soils. Except for 2 acid sulfate soils, soils high in organic matter tended to have low zinc concentrations after 2 weeks of flooding. Soils with a high content of available and water-soluble phosphorus had low concentrations of water-soluble zinc. This is confirmed by thermodynamics. Ammonium fertilizers may depress the concentration further.

Chemical analyses of the plants and soils revealed that zinc deficiency was associated with high magnesium content. An equilibration study showed that magnesium carbonate adsorbs water-soluble zinc, making it unavailable to rice.

Application of 10 ppm zinc on a zinc deficient soil increased the yield. High yields were obtained on a large scale where the only treatment was dipping the seedlings in a 2 percent suspension of zinc oxide before transplanting. On continuously wet soils, drying was as good a remedy for zinc deficiency as applying zinc compounds.

Because of high fertilizer prices, we focused our attention on ways to conserve and increase the natural supply of plant nutrients. A long-term study on an acid, a neutral, and a calcareous soil, revealed that flood fallowing between crops conserved and increased the nitrogen content of the soil and that some of the accumulated nitrogen was used by the rice crop. Midseason soil drying followed by flooding increases the availability of the stored nitrogen to the rice plants.

If rice is the only crop and where water control is possible, keeping the fields flooded between the crops and allowing it to dry in midseason and then reflooding, is worth practicing at this time of nitrogen scarcity.

Rice straw contains 0.6% nitrogen, 0.1% phosphorus, 3% potassium and 8% silicon, in addition to several other plant nutrients. The common practice of burning the straw in the threshing sites means a loss of valuable plant nutrients. We studied the long term effects of straw on the nutrient balance in soils and the growth of rice in the tropics since no data on these were available. Our results showed that leaving straw in the fields lead to a substantial increase of 60 kg/ha N, 6.6 kg/ha P and 250 kg/ha K over five seasons. This means that the soil received not only the nitrogen in the straw but additional nitrogen, presumably by bacterial fixation.

We found in another long-term experiment that straw, regardless of the method of application, increased the phosphorus and potassium contents of the soil and this benefit was most pronounced during the dry season.

Iron deficiency is likely to arise when soil is dried and is rendered aerobic. This could be corrected by the acidifying effect of ammonium sulfate or the chelating effect of compost. At the end of the fifth season, ammonium sulfate had depressed the pH, while compost had increased the content of organic matter, nitrogen, phosphorus and potassium.

There is little information on the response of the rice plant to water or chemical stress when puddled soils dry.

The plants in puddled soils subjected to water stress suffered much less than those in granulated soils subjected to water stress. The redox potential of the puddled soil was below 0.2 V for the entire season and soil moisture tensions exceeding 50 cb lasted only for 8 days compared with 40 days for the nonpuddled.

Puddling decreased the duration of water stress, produced a favorable chemical environment, and increased the yield of rice relative to the nonpuddled water-stressed treatments.

Chemical kinetics of a nearly neutral saline soil indicated high electrolyte content, sufficient concentrations of potassium, calcium, magnesium, iron and manganese throughout the growing season. Apparently, salt displaces cations from soil colloids into the soil solution. Plant analyses showed adequate levels of cations except potassium. The growth-limiting factors appeared to be excess electrolyte and incipient potassium deficiency.

Saline soils vary widely in salt content, composition of salts, pH, organic matter content and content of available plant nutrients. Thus, the effect of excess salt on the growth of rice are often confounded with those of other soil properties. To study the direct effect of excess electrolyte, we made three soils of varying pH (4.8, 6.8 and 7.5) saline by adding common salt. We found that at comparable electrical conductances, salt injury was least in the calcareous soil and worst in the acid soil, due to iron toxicity.

We attempted to quantify the effects of salinity on the chemical kinetics by amending a vertisol with increasing amounts of sodium chloride. We found that as salinity increased, the levels of NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, and Mn^{2+} in the soil solution rose markedly apparently increasing the immediate supply of these nutrients to rice. However, the activity ratio of K^+, decreased with increase in salinity in spite of the increase of K^+ concentration.

Alkali soils limit yield or prevent rice from being grown in many arid regions recently brought into production by irrigation in India, Pakistan, Iran, Egypt and other countries. The chemical kinetics of an alkali clay loam (pH 8.7, O.M. 2.2%) suggested that excess sodium, excess reducing substances, and low calcium and magnesium limit growth. The straw at harvest contained adequate amounts of iron, manganese, zinc, low concentrations of calcium and potassium and a very high content of sodium.

To ascertain whether the observed effects of this natural alkali soil were due to the presence of Na_2CO_3 or to some other peculiarity of this soil, we studied the kinetics of a neutral clay soil treated with Na_2CO_3 to raise its aerobic pH to 8.5. Addition of Na_2CO_3 made the pH and concentrations of sodium, calcium, magnesium, potassium, iron and manganese comparable to those in the natural alkali soil. Plant symptoms and plant analyses were similar to those on the natural alkali soil.

The limiting factors in the alkali soil were excess sodium, and calcium and potassium deficiencies. Excess reducing substances may have been another retarding factor.

The kinetics of acid sulfate soils showed that the retarding factor varied with the soil. Results demonstrate that leaching alone (with fertilizers) may be sufficient to make some acid sulfate soils productive; other soils may need liming. A combination of leaching, liming, and application of MnO_2 may, however, be the best amendment.

We found that soil is an important factor retarding the growth of rice at low temperatures. Low-temperature injury to rice was more severe in acid soils than in neutral soils. We identified the chemical factors retarding the growth of rice in cold acid soils to be high partial pressure of CO_2, excess water-soluble iron and organic acids. Internal drainage, midseason soil drying, liming or continuous submergence help minimize the harmful effects of low temperature in these soils.

The yield of rice on aerobic soils rarely exceeds 60 percent of the yield on the same soil rendered anaerobic by submergence. We identified the growth-limiting factors by chemical kinetics and plant analysis as iron deficiency in the neutral and the calcareous soils, and in the acid soils, manganese and aluminum toxicities.

The simplest remedy for iron deficiency was soil submergence. Liming prevented manganese and aluminum toxicities.

Future investigations:

We plan to identify, characterize, map and evaluate the productivity of problem lowland rice soils, both current and potential in Asia, Africa and Latin America. The project envisages establishing soil and plant criteria for identifying injurious soils and will involve travel to the problem soil areas, review of soil areas, review of soil survey reports and research and extension publications, field inspections and consultations with local research and extension workers.

Work on identification of growth-limiting factors in problem soils and their amelioration will be continued. Soil problems usually occur as combinations of toxicities, deficiencies and varying water and climatic conditions. Hence, recommendations for amelioration and management of specific problem soils will have to be worked out for each set of environmental conditions. We will investigate the growth-limiting factors on peat soils.

Deficiencies or excesses of minor elements constitute some of the main obstacles to bringing marginal land under rice. Understanding the behavior of minor elements in paddy soils will be valuable in the management of these soils. While literature abounds with methods for the analyses of elements like boron, molybdenum, copper and zinc the adaptability of these methods for soil solutions where these elements may be present in minute quantities together with a variety of substances that interfere with the accuracy of the analysis have to be looked into.

Long-term experiments designed for the purpose of evaluating the effects of current cultural practices on the chemistry of submerged rice soils and the growth of rice will be of great importance. Such studies will consider the short-term results and the long-term implications.

ENVIRONMENT AND ITS INFLUENCE[1]

Justification and objectives:

Rice is now being grown in widely different locations and hence under a variety of climatic environment. While the Genetic Evaluation and Utilization (GEU) program is directed toward improving rice varieties adapted to specific environments, research in this program focus on the influence of specific environments on rice yield and on a better understanding of both macro- and micro-environment.

Potential rice production is primarily determined by variety and environment as they interact with each other. Rice yield in farmers' fields is further modified by level of cultural practices.

To be able to identify the limiting factors to crop growth, and thereby suggest the means for raising rice yields, it is imperative to study the effects of individual climatic factors on crop growth. Information obtained from such studies not only suggests directions for improvements in agronomic practices and plant breeding but helps determine maximum productivity of rice production at different localities and the feasibility of rice production in new areas. Evaluation of maximum productivity as determined by climate is useful as it indicates how much yield increase will be possible under a given location, thereby quantifying a gap between current cultural practices and the present technology. Feasilibity assessment of rice cultivation for a given location is important as rice cultivation is being extended into new areas such as Middle East, Africa and South America.

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[1] Project Leader - S. Yoshida, Plant Physiologist

Summary of accomplishments:

In the past few years, we have studied effects of CO_2, light, temperature and water on growth and yield of rice. Under irrigated condition, cultural practices such as plant density and nitrogen application would be the major factors determining yield in the wet season at Los Baños provided diseases, insects, and weeds are adequately controlled. This can be shown by yield-leaf area index (LAI) curve in which grain yield increases with increasing LAI. At LAI of about 6, grain yield reaches a plateau of about 6 t/ha. Difference in grain yield between wet and dry seasons can be accounted for by sunlight and temperature. It is shown that a combination of high sunlight and relatively low temperature favors high yields through increasing spikelet number per square meter at Los Baños. This indicates that planting time should be chosen so that rice crop is exposed to high sunlight and relatively low temperature during reproductive stage, to produce high yields.

For further increase in yield, CO_2 supply becomes the limiting factor. This was demonstrated by CO_2 enrichment experiments in the field. Thus, the yield limiting factor varies with level of rice yield to be attained.

Throughout the experiments, we have reached the conclusion that spikelet number per square meter (size of sink) is the major yield limiting factor at the current yield level at many locations in Southeast Asia.

In the past, effect of sunlight on ripening, and hence yield, has been emphasized by many scientists. We feel this is a kind of overemphasis. Our shading experiment in the field has shown that sunlight during reproductive stage is even more critical to rice yield than during ripening at Los Baños. The same experiment also showed that a yield of 4 t/ha can be obtained with a 200 cal cm^{-2} day^{-1} during reproductive stage. Available data on solar radiation at different rice growing areas reveal that 200 cal cm^{-2} day^{-1} on monthly mean basis would be a minimum amount of solar radiation. Thus, it is unlikely that incident solar radiation limits rice yield in farmers' fields in most of tropical countries where a national average yield is about 2 t/ha.

Under upland conditions, water stress often limits crop growth and yield. With a crop photosynthesis model it is shown that under a certain degree of water stress, gross photosynthesis is higher under a low solar radiation than under a high solar radiation. This suggests that a partially shaded environment such as under coconut trees would favor rice growth under water stress. This is also supported by a field experiment that under rainfed condition at Los Baños, a shaded crop produced a higher yield than a non-shaded crop.

Current year's research is being focused on influence of temperature on growth duration, spikelet number, fertilization, and ripening. For these studies, the IRRI phytotron is being extensively used.

In heatsum or temperature summation, a base temperature (a low limit for growth) has been frequently suggested. We have found, however, there is a maximum effective temperature at about 24°C above which temperature has only a slight influence on number of days from seeding to flowering or duration of ripening. This explains well why growth duration of photoperiod insensitive varieties remains about the same regardless of planting time in the tropics where average monthly temperature varies from 25 to 30°C. Below 24°C, temperature has a profound influence on growth duration. For instance, one degree drop in temperature extends the growth duration of IR26 by 12 days.

At anthesis time, temperature has the most dramatic effect on fertilization. It is the time when the rice plant requires the relatively narrow range of optimum temperature.

Temperature during ripening does not have so great influence on grain weight as previously thought, but it affects duration of ripening and grain quality.

In the past, low night temperature was thought to be important for better ripening. However, our studies indicate that daily mean temperature is the most meaningful parameter within the temperature range from 16 to 32°C. Relatively high night temperatures could be compensated for by relatively low day temperatures. Also, we have found that a difference of 18°C or more between day and night temperatures adversely affects ripening. This suggests that under certain continent-type climate the daily mean temperature may be within the optimum range but large day-night temperature difference may not be adequate for rice growing.

Future plans:

In the future, we shall proceed with three directions. First, we shall continue our study on influence of environment on rice productivity. We would focus our efforts on influence of environment on spikelet number production and ripening as they determine rice yield under most conditions. In particular, we shall study interactions between temperature, solar radiation, and nitrogen for spikelet number formation. We would then proceed to build a productivity model by which we can assess climatic productivity of a particular location when relevant weather records and nitrogen input are given. Once the model is built, we shall carry on-site investigation to see the applicability of the model to estimate rice yields in the fields.

Second, we plan to make a survey into the weather characteristics of the major rice producing areas of the world and the physical parameters of the distinct environments in which rice is produced. We feel compiling accurate information on the rice growing environment with respect to types of rice culture and weather characteristics is one of the prerequisites in determining priority problems in rice research.

Third, we shall study the microclimate and macroclimate in a variety of rice environments with special reference to epidemiology of diseases and insects.

CONSTRAINTS TO INCREASED RICE PRODUCTION[1]

Justification and objectives:

The first director of the International Rice Research Institute, recently wrote that, "on retiring from IRRI in 1972, the only real disappointment I felt was that somehow we did not understand sufficiently why the Asian rice farmer who has adopted the new varieties was not doing better. Somehow, I felt that rice scientists who had obtained yields of 5 to 10 metric tons per hectare on the IRRI farm still could not explain why so many Filipino farmers (for example) obtained on the average less than one metric ton per hectare increase in yield after shifting from the traditional to the high yielding varieties."[2]

The objectives of research on constraints to increased rice production are twofold:

1. to develop and apply procedures for identifying the physical and socio-economic factors that influence the adoption and efficient use of technological and institutional innovations designed to increase rice production.
2. to define and, where practical, test alternative measures for alleviating constraints to increased rice production.

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[1] **Project Leaders - R. Barker, R. W. Herdt, Agricultural Economists; S. K. De Datta, Agronomist and K. A. Gomez, Statistician.**

[2] **Robert F. Chandler, Jr., "Case History of IRRI's Research Management During the Period 1960 to 1972." Asian Vegetable Research and Development Center, Shanhua, Taiwan, 1975.**

Summary of accomplishments:

The current focus of our research is on the first of these two objectives. More specifically, we are developing and testing a methodology for identifying and explaining the "gap" between the yields obtained in the experiment station and those obtained by farmers. Providing a better understanding of this gap should assist our own scientists and administrators and research and extension administrators in national programs in establishing research priorities. Recognizing the limitations of our own resources, we hope that this methodology can be successfully extended and used by research workers elsewhere tackling problem of this nature.

A recently completed study, Changes in Rice Farming in Selected Areas of Asia, involving more than 30 social scientists throughout South and Southeast Asia, also provided valuable information on factors that impeded the introduction of modern rice technology. The results of this study showed that yields were directly connected with input use and the level of input use was more closely associated with physical environment than with socio-economic factors with the exception of price which is clearly related to input use. However, participants in the project concluded that social scientists alone relying principally on survey methodology could not hope to clearly identify and explain the yield gap.

In April 1974, 25 biological and social scientists held a workshop at IRRI to develop the basic objectives and methodology of our current research effort. The International Rice Agro-Economic Network was subsequently organized and has involved participants to date from six Asian countries.

The Methodology

Figure 1 shows a way of conceptualizing the difference between actual farmer yield and a maximum possible yields. The first component, environmental effects, arises because of environmental differences between the experiment station and the average rice farm. Most farmers cannot obtain irrigation water throughout the year and so they cannot always take advantage of the high level of dry season solar radiation. Most experiment stations are located on a soil that is almost ideal for rice production while many rice farmers are less fortunate. Very high cost inputs such as rat fences and bird boys are used to protect experimental plots, but these are out of the question for farmers. The technology that gives high yields on experiment stations may not give nearly as high yields in the less favorable environments that make up a large proportion of the rice-growing area of Asia. We are working to measure the size of these environmental effects and, in other research programs of the Institute, to develop rice technology better suited to adverse environments.

The second difference identified in Figure 1 is the yield gap between the maximum yield in farmer's environments and the yield farmers are actually getting. By definition, this gap exists because farmers use inputs or practices that result in lower yeilds than are possible in _their_ environments. Yields would be higher on farmer's fields if they would use the highest yielding variety, apply maximum yield levels of fertilizer and insecticides, correct existing soil problems, and use the best cultural practices. The most critical factors differ from one region to another, but before any remedies can be taken (e.g., recommending a package of improved practices) the biological nature of the gap must be understood.

Once the magnitude and nature of the yield gap is established, then one must identify the socio-economic factors that explain why farmers are not using the practices and inputs necessary to obtain maximum yields. The reasons may include economic profitability based on calculations of costs and returns, lack of knowledge of how to use the technology, lack of credit, poorly operating irrigation systems, or such factors as non-availability of inputs or traditional beliefs. The importance of these factors will differ from area to area, but understanding them will help in designing programs to provide the missing bio-physical components to overcome the yield gap.

In order to identify what biological or physical inputs or cultural practices account for the yield gap, an experimental design has been developed for implementation on farmers' fields. The design consists of two components:

1. a factorial combination of several production factors each at two levels: the farmers' level and the "recommended level" or level expected to give maximum yield.
2. a series of combination of inputs (i.e. management packages) of increasing intensity.

The factorial component was initially developed and tested in farmers' fields by the Statistics Department. At each sample farm site the maximum potential yield, the yield corresponding to the farmers' input level, and the yield corresponding to the inclusion or withdrawal of one or more selected components of the technology (e.g. fertilizer, insecticide, etc.) are measured through plot experiments. The relative contribution of each of the selected factors to the difference between the potential yield and the farmers' yield can then be assessed.

The Agronomy Department has, over the years, conducted a number of "management package" experiments. It is possible to determine the effect on yield of each incremental increase in the level of the input package although it is not possible to identify the contribution of individual components of the package to the yield increase.

Assuming that a yield gap between the farmers' level and the recommended level does exist, economic and statistical analysis of the factorial and management package experiments will give some indication as to whether it is profitable to apply a higher level of inputs, which inputs show the highest profit margin and the degree of variability from farm to farm in the pay off. If, in fact, the higher level of inputs is profitable, why don't farmers apply this level? Farm surveys have been designed to answer some of these questions relating to farmer behavior by providing information on input availability, the farmers' knowledge, and the farmers' attitude.

Results

In presenting the results, we refer principally to experiments conducted in two locations in the Philippines, Laguna and Nueva Ecija Provinces. Similar experiments have been conducted on farmers' fields at sites in the Bicol Region of the Philippines, in Thailand, and in Central Java, Indonesia. Farm surveys are also underway in each of these locations but have not yet been analyzed. Work is currently being initiated in West Java, Bangladesh, Sri Lanka, and Taiwan.

What is the magnitude of the gap between the yield of rice at the farm level and at the high level of inputs (the level expected to maximize yield)? The yield gap was noticeably larger in Laguna than in Nueva Ecija (Table 1). As a result of severe typhoon damage, farm level yields were very low (1.8 t/ha) in Nueva Ecija during the wet season. The yield gain resulting from a high level of inputs averaged only 0.5 t/ha ranging from -0.9 to 1.6 t/ha. Yields in 3 out of 10 farms were lower at the high compared to the farm input level. The yield gain from the farm to the high level of inputs was 1.0 t/ha in Nueva Ecija during the dry season, but 2 t/ha in Laguna during the wet season and 2.6 t/ha during the dry season.

The contribution of the inputs to the yield gap differed by location and season. For example, in Laguna added fertilizer accounted for more than 50 percent of the yield increase in both seasons. In Nueva Ecija during the wet season typhoons caused severe lodging and applying fertilizer at the high level did not increase yields. Insect control contributed 60 percent to the yield gap probably because of the brown plant hopper attack. The common variety used by farmers in this season was IR20, which was not resistant to the brown planthopper.. The contribution of inputs to the yield gap in Laguna was very similar for the wet and the dry season.

There was also considerable difference as one compares the contribution of inputs to the yield gap from one farm to another. For example, the addition of fertilizer in Laguna during the 1974 wet season resulted in an average yield gain of about 1 t/ha ranging from 0.5 to 1.6 tons. On the other hand, the addition of insecticide in Nueva Ecija during the same season resulted in an average yield gain of 0.4 t/ha. But two farms registered gains of close to 1.5 tons, while 6 of the remaining 8 showed less than 0.4 tons clearly not justifying the added expenditure.

The analysis of management package experiments shows that yields did not differ greatly between the farm level and M_2 and M_3 (Table 2). The gain in yield over the farmers' level tended to be substantial at M_4 and M_5, the highest management packages.

For farmers typically spending ₱400 to ₱600 for fertilizer, insecticide, and weed control, the additional cost of inputs required to achieve a significant gain in yield and profits (i.e. M_4 level) tended to be more than the present cost. In all but the wet season in Nueva Ecija added net returns exceeded the added cost of the inputs by M_4 indicating a better than 2 to 1 return on additional expenditures. However, these average figures obscure the high degree of variability among farmers within the same site. Furthermore, the low yields in Nueva Ecija during the wet season suggest that there is considerable risk due to weather and insect and disease damage. Thus, it is uncertain as to whether farmers will be willing to spend such a large amount on additional inputs at these expected average profit margins. However, economic analysis of the factorial plus analysis of the degree of variability (or risk) involved under low and high level of technology may help us to reduce the cost of the input package and raise the profit margin.

Results of experiments in Bicol Region during the dry season conform closely with those in Nueva Ecija and Laguna. In Thailand, however, problems appear to be somewhat different, with factors such as flooding limiting the potential yield gain from added inputs.

Future plans:

We have at present a number of unsolved methodological issues. One of the most important of these is the proper integration of the experimental and survey techniques. The experiments and surveys currently being conducted are large and complex. Once we have completed the detailed analysis now underway, we will need to simplify our approach in order to extend the coverage to a larger area and hence make the results more representative. With these and other methodological issues confronting us, we anticipate only a modest expansion in the size of the network in the near future.

However, we have initiated for the first time this year a two-month training program. The 12 participants in the program come from 4 countries - 4 from Thailand, 4 from the Philippines, 2 from Indonesia and 2 from Sri Lanka. They have been chosen in pairs, an agronomist and economist from each location, and will return to their respective homes to conduct research as a part of the IRAEN project. In keeping with our concept of an interdisciplinary approach to problem solving, all participants receive training in agronomic, economic, and statistical procedures. Thus, for example, the economists must understand the methodology and operating procedures used by the agronomist in conducting experiments. It is largely through this training of agro-economic teams that we hope over the next five years to extend our methodology to other areas.

Ultimately we must give greater attention to the second of our objectives - defining and testing alternative measures to alleviate contraints to increased rice production. This will mean assessing our results in terms of their implications for research, extension, and policy. The work already initiated in the project area Consequences of New Technology will be highly complementary to this latter effort.

Our goals for the project over the next five years might be summarized as follows:

1. to have introduced the idea of constraints studies into the major rice-producing countries in South and Southeast Asia.
2. to have identified to our own satisfaction, several key regions of Asia, the relative size of and the factors contributing to the yield gap.

3. to have developed a methodology that is simple enough to be readily transmitted to researchers in national programs but accurate enough to be acceptable to them.
4. to have initiated efforts through policy makers in several Asian rice-producing countries to alleviate constraints to yields arising from policy decisions.

Table 1. Average contribution of four factors toward improving rice yield, experiments on farms in Laguna and Nueva Ecija, Philippines, 1974 wet season and 1975 dry season a/

Location	No. of Farms	Grain yield (t/ha)			Contribution to the Gap (%)			
		At farmers' input level	At high input level	Gap	Fertilizer level	Insect control	Weed Control	Land Preparation
				Wet Season				
Laguna	10	3.9 (1.9-5.3)	5.9 (3.6-8.5)	2.0 (0.9-3.1)	56	34	10	-
N. Ecija	10	1.8 (1.1-2.4)	2.3 (1.4-4.0)	0.5 (-0.9-1.6)	0	60	30	10
				Dry Season				
Laguna	9	4.2 (2.7-5.6)	6.8 (5.2-8.6)	2.6 (1.8-3.6)	52	39	9	-
N. Ecija	3	4.3 (3.0-5.4)	5.2 (4.1-6.9)	0.9 (0.1-1.5)	23	27	47	3

a/ Values in parenthesis below yields show the range in yields.

Table 2. Average Yield, Added Cost and Added Net Return Above Farm Level for Management Package Experiments in Laguna and Nueva Ecija, Philippines, 1974 Wet Season and 1975 Dry Season

Management Package	Laguna			Nueva Ecija		
	Yield (t/ha)	Added Cost (₱/ha)	Added Net Return (₱/ha)	Yield (t/ha)	Added Cost (₱/ha)	Added Net Return (₱/ha)
			Wet Season			
Farm Level	3.9	-	-	1.7	-	-
M_2	3.8	-178	273	1.9	2	161
M_3	4.2	126	277	2.1	393	16
M_4	5.1	564	625	2.4	906	-248
M_5	5.2	1107	272	2.2	1548	-1054
			Dry Season			
Farm Level	4.2	-	-	4.5	-	-
M_2	3.5	-105	-593	3.6	-483	-450
M_3	4.1	135	-259	4.2	-128	-205
M_4	5.5	645	674	5.5	369	598
M_5	5.7	1224	307	6.1	1041	1102

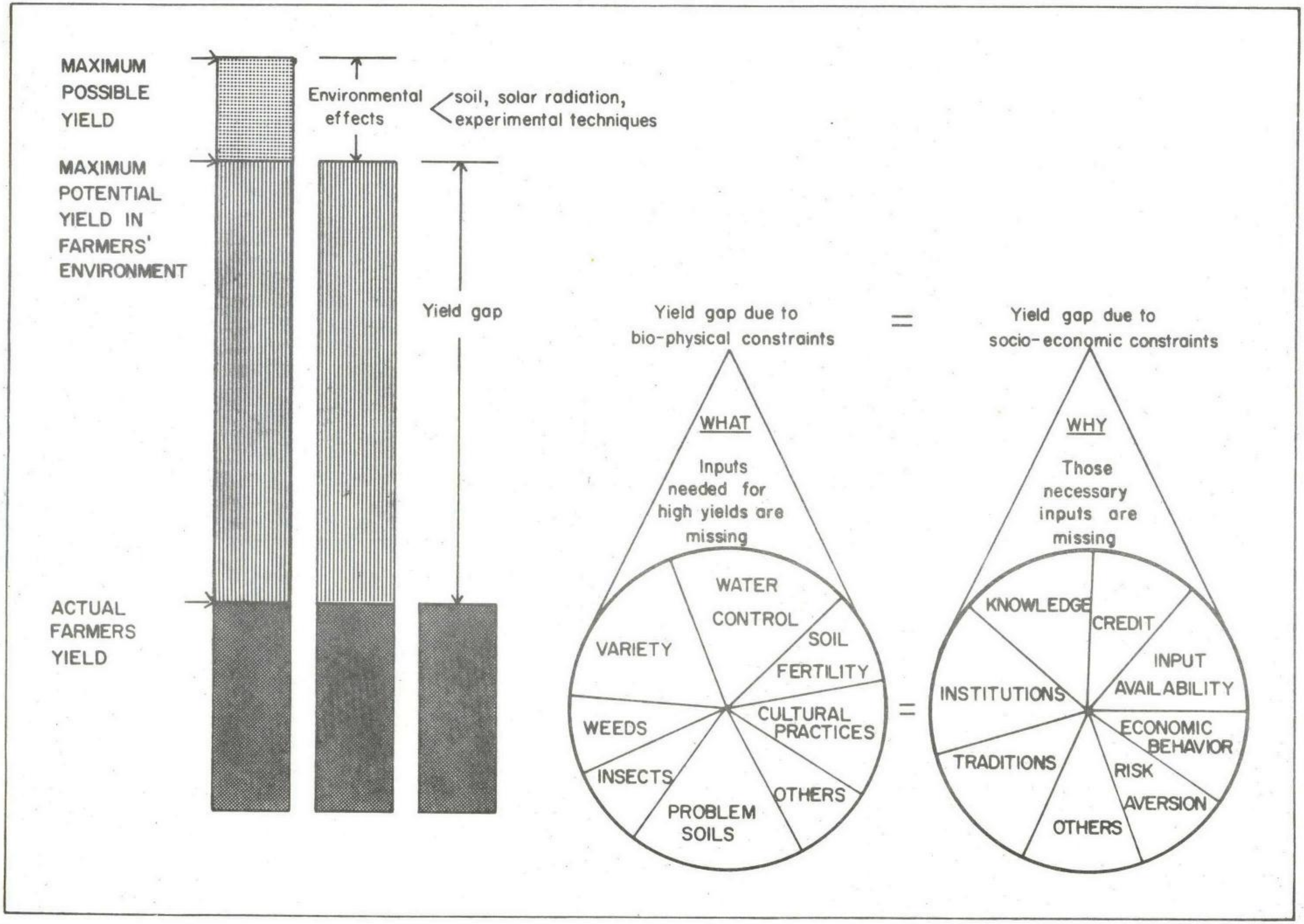

Figure 1. A model explaining the yield gap between potential and actual farmers' yield.

CROPPING SYSTEMS

Crop improvement efforts directed toward the Asian rice farmer have as their goal an increase in farm productivity and efficiency with a resulting increased income to the farm family.

IRRI's efforts have thus been directed toward two major areas:

1. Better rice varieties and the production of technology to effectively use them;
2. Development of a cropping systems technology to increase cropping intensity on Asia's rice farms, making more efficient use of available farm resources.

This second aspect is the focus of the cropping systems program.

OVERALL OBJECTIVES:

The objectives of IRRI's cropping systems program are:

1. To develop research methodology in cropping systems and to extend that methodology to cooperating programs;
2. To develop and assemble specific multiple cropping technology for our target agroclimatic zones.
3. To feed back information on needed basic and developmental research to the concerned agencies.
4. To encourage and assist national production programs in our target agroclimatic zones in achieving increased farm productivity through increased cropping intensity.

The IRRI cropping systems program should be evaluated in 1980 in terms of the increase in cropping intensity and productivity in target agroclimatic zones as a result of IRRI's input into national programs both in terms of program development and specific technology.

THE POTENTIAL FOR INCREASE OF CROPPING INTENSITY

Asia's rice is largely produced on small farms (1/2 of all farms are less than 1 ha, 3/4 are less than 2 ha) without irrigation. Of that portion which is irrigated (19 percent in Southeast Asia), only a small fraction receives year-round water. In these latter areas continuous rice is grown, with 5 crops in two years being a common practice. Partially irrigated areas produce one or at most two crops of rice a year, depending on the duration of water availability. In a very few such areas the main crop of rice will be followed by an upland crop of short duration which makes use of a limited water supply insufficient for a second crop of rice. In rainfed areas (which produce 70 percent of Asia's total rice) only a single crop of rice is grown. In more and more of these rainfed areas farmers are beginning to follow rice with other crops to better utilize their available growing season.

Data from Burma illustrate the prevalence and variety of multiple cropping patterns.

Cropping pattern		Area planted (1000 ha)
Rice-rice	Rainfed	44
Rice-peanut	"	178
Rice-chickpea	"	133
Rice-black mung bean	"	58
Rice-other pulses	"	44
Sesame-rice	"	133
Jute-rice	"	89
Jute-rice-peanut	"	13
Cotton-rice	"	80
Non-rice double cropping	"	267
Non-rice mixed cropping	"	58
Total cropped area in Burma		9330

Thus about 13 percent of the area is double cropped, including the irrigated areas.

Other countries have a somewhat higher cropping index (Dalrymple, 1971).[1] A close look at areas where cropping intensity is high will indicate that they usually have physical resources typical of large portions of Asia. One can even find, in Indonesia for instance, areas of low rainfall having an extremely high cropping intensity. Here population pressure on the land has forced farmers into efficient utilization of their physical resources.

Initial estimates of the portions of Asia falling into different rainfall categories show that a major portion of the land area can support two crops a year as seen by the following:

Percentage of land in Bangladesh, Indonesia, and the Philippines that fall under 5 major rainfall categories.

Rainfall category		Bangladesh	Indonesia	Philippines
I	less than 3 wet* months		25	12
II	3 - 4 wet months	23	40	28
III	5 - 6 wet months	72	30	37
IV	7 - 8 wet months	5	5	21
V	more than 8 wet months			2

* 200 mm or more per month

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[1] Dalrymple, D.G. 1971. Survey of multiple cropping in less developed nations. USDA, Washington D.C. (sample multiple cropping indexes: China 147, India 114, Indonesia, 126).

Research data combined with farmer experience in the more intensively cropped areas indicate that with three wet months, rice and a short duration upland crop can usually be grown. With 5 or more wet months, two crops of rice are possible if the first is direct-seeded using an early-maturing variety. Five months of rain can support a range of upland crops following rice, depending on soil type.

It is evident that there is great scope for increasing cropping intensity in the rainfed and partially irrigated rice farms of Asia.

The crops that are most suited to the large portion of these areas and for which markets are most readily available are, in addition to rice:

The legumes : 1. mung bean
2. soybean
3. cowpea
4. peanut
Coarse grain : 5. corn
6. sorghum
Root crops : 7. sweet potato
8. cassava

In portions of the region sesame, chickpea, wheat, jute, or cotton are major crops with rice.

It is estimated that the above list includes roughly 90 percent of the area presently double-cropped with rice, with vegetable making up most of the rest. The first 6 crops probably cover 75 percent of the area as a whole, and in the warmer humid regions they are almost exclusively used. The first 8 crops are being used in IRRI's core program, while some of our cooperators use one or more of the others.

IRRI PROGRAM ORIENTATION

The relative attention given to different aspects of the cropping systems program changes over time as objectives are accomplished and as cooperating national programs become functional.

AGROCLIMATIC ZONE DESCRIPTION[1]

Cropping patterns and crop intensity are highly environment-specific. Key factors determining their make up are: amount and duration of water availability, soil type (determining fertility, drainage and tillage characteristics), farm size and labor density, and markets. It is essential, both for purposes of locating test sites as well as for extrapolation of test results across areas, that the critical parameters be suitably described. Work to date has concentrated on delineating rainfall zones having given crop potential. During 1976 and 1977 the rainfall and soil classifications will be largely finished for Southeast Asia. Present cropping systems work is now being conducted in specific zones classified by water availability and soil type. We find that these two parameters give the smallest geographical area of classification, while market availability and labor density give the highest.

The initial approximation of soil and water classification was done by a consultant team in 1973. During 1974-75 the Bangladesh climatological survey was completed. The climatological definition of the Philippines and of Java will be completed in 1975. We have, in 1975,

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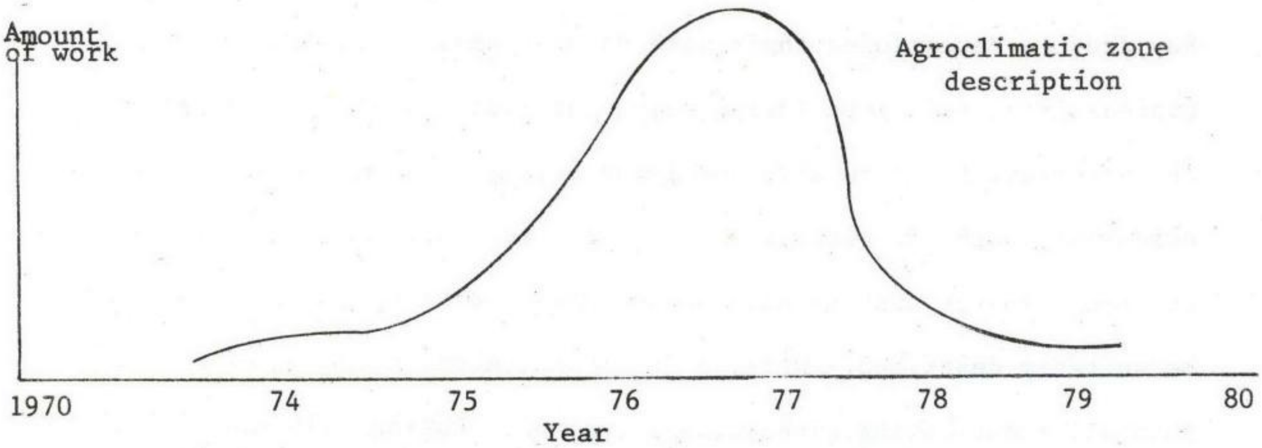
[1] Project Leader - R. R. Harwood, Agronomist

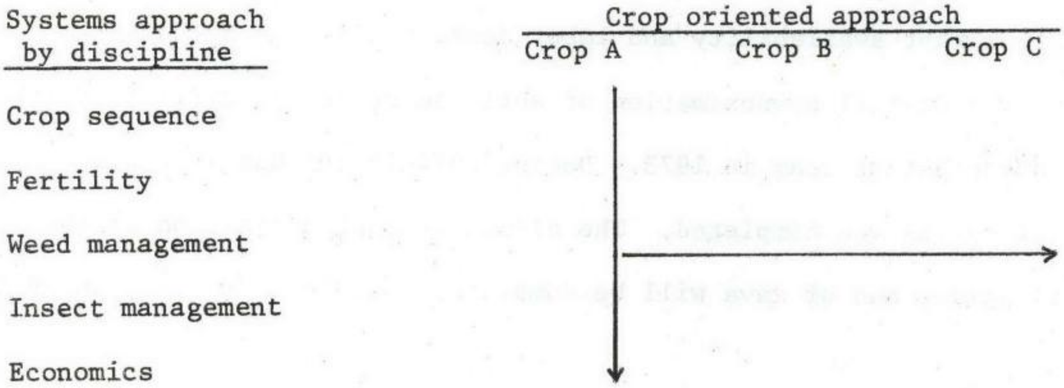
9 man-months of a climatologist's time. In 1976 a senior scientist will be added for 6 months and a joint program carried out with Reading University with ODA support. During 1976 also a full man-year of senior scientist time will be devoted to soil classification. The classification of socio-economic parameters will follow:

A time profile of this total classification effort is as follows:



DEVELOPMENT OF CROPPING SYSTEMS RESEARCH METHODOLOGY

The development of environment-specific cropping patterns and the various aspects of their management requires an approach oriented toward the entire pattern rather than toward individual crops as follows:



The entire program integrates research in both directions, and is always pattern-oriented.

While components of a cropping system may be researched in the controlled environment of experiment stations or even in the semi-controlled environment of research-managed trials in farmers' fields, the entire system can be evaluated only under farmer management. We have thus developed the concept of "farmer-participant" research, where the farmer becomes a member of the research team. His particular contributions to the team are his skill in managing his own resources, and his keen sense of judgement in evaluating suitable technology in his own environment.

These research techniques have been worked out and are being extended to cooperating programs in the region.

CROPPING SYSTEMS NETWORK[1/]

Justification:

The key element in the IRRI network program is the establishment of a network of experimental sites in major rice growing areas in Asia in collaboration with national programs. The test sites are carefully selected to represent the major areas of responsibility for our collaborating national programs and the agroclimatic zones of the rice growing areas. At least one test site will be selected from each major rice growing country.

The objectives of this network are several fold:

1. To provide a mechanism for joint program planning and review between the major national programs of the region and IRRI.

[1/] Project Leaders - V. R. Carangal, Network Coordinator and
R. R. Harwood, Agronomist

2. To provide a series of data points on the tropical Asian agroclimatic grid for determining the cropping system potential in major zones of the region.
3. To enable IRRI to extend relevant methodology and technology into national programs.
4. To provide a mechanism for long-term upgrading of national efforts.

Summary of accomplishments:

Seven experimental sites are operational in 1975. These are:

1. Oton and Tigbawan, Iloilo, Philippines - rainfed and partially irrigated rice;
2. Manaoag, Pangasinan, Philippines - rainfed and partially irrigated rice;
3. Tanauan, Batangas, Philippines - upland rice;
4. Indramayu, West Java, Indonesia - partially irrigated rice area;
5. Central Lumpang, Indonesia - upland rice; rainfed and partially irrigated rice;
6. Joydepur, Bangladesh - rainfed and partially irrigated rice

We have identified this year four sites in Thailand (all rainfed rice areas), three sites in Sri Lanka (rainfed and partially irrigated rice area) and one site in Malaysia. Next year additional sites will be identified in India, South Korea, Burma, and Nepal. By 1977, we expect to have a network of 20 experimental sites collaboratively working with IRRI in the region.

Collaborative planning:

A working group was created to help IRRI develop general plans for collaborative research in the network, review research results, evaluate, and where appropriate, modify the research program and develop annual work plans. The working group is composed of program leaders from collaborating countries, the IRRI program leader and network coordinator, and two scientists invited from outside the network. The present members are the following:

1. Richard R. Harwood - IRRI
2. Damkheong Chandrapanya - Dept. of Agriculture, Thailand
3. Diosdado Carandang - Univ. of the Philippines at Los Baños
4. Walter Fernando - Dept. of Agriculture, Sri Lanka
5. Virgilio Carangal - IRRI
6. Ajit Singh Sidhu - MARDI, Malaysai
7. Sjarifuddin - CRIA, Indonesia
8. Zahidul Hoque - Bangladesh Rice Research Institute
9. B. Krantz - ICRISAT, India
10. Dave Norman - Ahmadu Bello University, Nigeria

The group first met after the cropping systems workshop at IRRI and will meet again in Indonesia on November 3 to 8, 1975. We plan to meet in countries where the collaborative work is underway to give the members an opportunity to see each other's work and also to visit the national cropping system research program.

Periodical workshops and seminars are a part of this program.

Recommended procedure in each site: The cropping systems methodology developed at IRRI was further refined in the recent cropping systems workshop at IRRI (march 17-21, 1975). The working group recommended a three-phase approach including the definition, design, and testing of systems technology based on farmers' involvement.

Experiments will be done in farmers' fields with farmers involved in conducting the experiments. Some trials will be completely managed by research workers but all the cropping pattern trials will be managed by farmers with assistance from the research workers. The major research work in each site is as follows:

1. Study existing conditions;
2. Development of improved cropping patterns;
3. Fertilizer, weed control, insect control experiments which are superimposed in most cases on the cropping pattern experiments.
4. Varietal evaluation of food crops (rice, corn, sorghum, soybeans, mung, peanut, cowpea, and sweet potato);
5. Socio-economic surveys and analysis.

The studies mentioned above are being conducted in the three Philippine outreach sites. The details of these studies will be discussed by the scientists concerned in their presentations. In Indonesia, the work started in August, 1975 and a survey of existing conditions in the two sites is finished. Plantings started in October, 1975.

Composition of the research team: The team in each site should have a minimum of five professional staff composed of a coordinator, two agronomists, an economist, and a crop protection specialist plus field assistants. The number will vary from site to site depending on the volume of work. The team will live in the project area in order to insure efficient implementation of the research projects. The extension worker covering the selected villages, although not a regular member of the team, should be involved in the baseline survey and in selection of farmer cooperators. He should be informed of the research developments in the project. Likewise, the extension chiefs at the provincial level should be involved in selecting the experimental sites and be informed of the progress of the research. This way research findings can easily be fed to their ongoing production programs.

Tie-up with national research systsms: The collaborative research is conducted with national research programs. In some countries, the collaborative research may be the beginning of a new cropping system research program while in others the program hopes to strengthen and intensify present research efforts.

In the Philippines, the three sites are considered part of the national research program. IRRI staff are directly managing the sites in cooperation with the Bureau of Plant Industry, a research agency of the Departmetn of Agriculture. The IRRI program leader is a member of the National Multiple Cropping Management Committee, a coordinating committee composed of representatives from different government agencies involved in multiple cropping not only of rice-based but also corn-based systems. IRRI is also involved in the applied research and production programs in the Philippines.

The two experimental sites in Indonesia are part of the national research system. The project leader is also the head of the cropping systems project in the Central Research Institute for Agriculture, the institute implementing the cropping systems research program. With the collaborative project, research will be intensified in cropping systems with emphasis on rainfed and partially irrigated rice areas. It includes training of extension workers not only in the two research sites but also at the IRRI station, and a mechanism for establishing applied research in key locations similar to the two test sites.

Obviously, the tie-up with national programs will vary from country to country. It will depend on the existing research programs, the organizational set-up of the cooperating agency, and the national production programs. We will not set up an independent program but will work with existing organizations.

Future plans:

By 1977 approximately 20 sites will be operational. The IRRI program inputs will then begin to give more attention to support of forthcoming national production programs.

TRAINING[1]

Justification:

The training element is critical to the strenghtening of national program capability in cropping systems in basic and applied research as well as in production efforts. Several avenues are available for this training, in the form of seminars, workshops, short courses, individual in-service participation, and degree and post-doctoral fellowships. The central aspect of this training is the formal training course conducted by staff of the Rice Production Training and Applied Research Department.

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[1] Project Leader - L. D. Haws, Senior Scientist

Aimed at training research and production extension personnel for the IRRI outreach program focusing on the development of strong national programs.

The training component of the cropping systems program is designed to train personnel from cooperating countries in research and extension techniques. The first two or three training programs are organized to train research people in research methodology. This includes establishment of field plots, collection and analysis of data, and writing a final report.

The second phase of the training component will be to train teams of trainers in extension and production technology so that strong training programs can be started or strengthened in the art of cropping systems.

Objectives:

A course in cropping systems was first offered by Dr. Bradfield in 1969 at IRRI. Since that time, 96 students have been trained in the technology of multiple cropping. The course was taught in that department until 1975, at which time the responsibility of training was given to the Rice Production, Training and Research Department.

The frist cropping systems course in the RPTR was offered in January 1975, to 25 students from five cooperating countries. The objective of this course was to produce trainees who will be able to:

1. Know and perform cultural practices involved in growing the various field crops commonly used in cropping systems.
2. Identify and solve production constraints of these crops when grown alone or in combination with other crops.

3. Conduct scientifically designed, applied and adaptive research to solve problems in cropping systems in their respective areas.
4. Recognize and apply the important principles of communication to extend information and to train researchers, extension workers and farmers in the new technology of crop production.

Summary of accomplishments:

The activities of the students were divided almost equally each day into practical and applied work with the mornings being devoted to work in the fields and lectures presented in the afternoon. An expression of involvement by the staff of both IRRI and UPLB can be shown by the fact that 84 resource speakers were involved in the course. All lectures were recorded and catalogued for use by students who, because of language problems, were not able to understand in detail the lecture material as presented orally. These tapes could be checked out to individual students at their convenience. Also, a two volume syllabus (about 1100 pages) of the lectures given was compiled. Each student received a copy of this syllabus and a set of slides to aid him in his work when he returned to his home country.

The first cropping systems course was held from January to June 1975. These dates have now been changed in an effort to have the training course held during the time of year when the crops to be studied are grown. Therefore, the cropping systems course will be held from October to February following the rice production training course.

Field experiments are also conducted as a major part of the training course. The students outlined and established research experiments in the field. A partial list of these experiments are listed here.

1. The effect of N rates on the yield of sweet corn intercropped with mungbean, peanut and sweet potato.
2. The effects of N-levels on the yield of field corn at various plant population.
3. Various crop combinations based on corn.
4. Comparison of different levels of management on peanut production.
5. Intercropping corn with 2 mung varieties under four levels of weed management.
6. Corn insect control applied research trial
7. Herbicide screening in corn.
8. Effects of crops and crop combinations on some major insect pests incidence.

Future plans:

The Cropping Systems Training Course as now offered at IRRI is believed to be a very satisfactory beginning. However, a maximum of only 30-35 students can be accommodated each year. With the need for many trained people in this area, the number that can be trained now is completely unsatisfactory.

In order to influence many more people in the area of cropping systems training, two main efforts will be made in the coming years to overcome this shortage of trained people.

1. Recruit teams of people to be trained at IRRI. These trainees can then help in the outreach program by establishing training programs in their own country.
2. Prepare a course in cropping systems to be used in the countries of the trainees. This will be accomplished by recording edited lectures presented at IRRI. The language of the country to use the tape will be used. Slides will be made to demonstrate the needed reference points. Slides and tapes will then be synchronized for presentation. All an institute would need to present a course similar to the one given at IRRI would be:
    a. A team trained at IRRI or other training center
    b. Syllabus
    c. Tape-projection combination
    d. Taped lectures
    e. Slides of techniques
    f. Classroom and land for applied research plots.

A summary of the total training effort to date is given as follows:

Man-months of formal training*

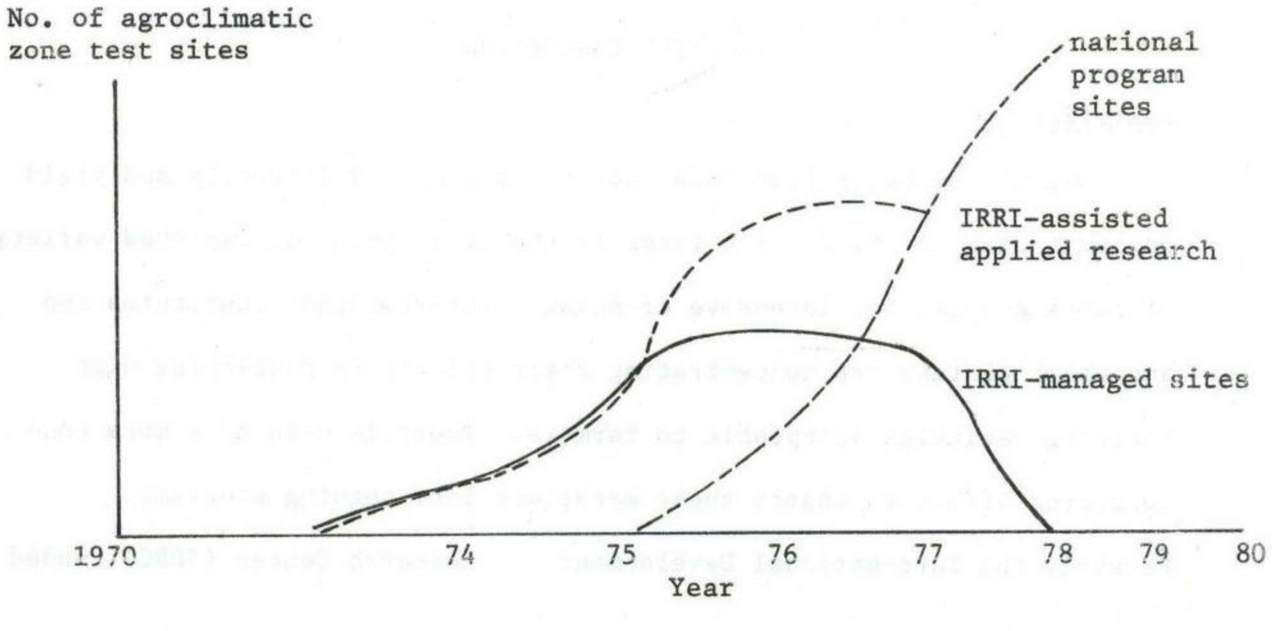
Category	1969	1970	1971	1972	1973	1974	1975	1976	1980
Non-degree research training	60	96	96	20	12	76	125	200	200
Teacher training							15	30	100
Degree scholars	12	2	12	12	18	54	54	100	300
Post-doctoral					6	10		24	60

* short courses in production (2-3 weeks) are included under RPTR.

THE DEVELOPMENT AND EVALUATION OF TECHNOLOGY

CROPPING PATTERN STUDIES[1]

The complete research package on cropping patterns is being carried out by IRRI with assistance from the Bureau of Plant Industry in three locations in the Philippines. The first site in an upland rice growing area of Batangas, is in its third year. This site is representative of the physical potential in many upland rice areas of the Philippines. Research results have been reported in several papers (Herrera, et.al., 1975; Samson, et al., 1975; Garrity, et al., 1975). Research will be phased down on this site in 1976. The other two sites are in rainfed lowland rice areas. Research there is in its first year. Approximately 100 farmer cooperators are involved at each site in cropping pattern studies and in supportive research. IRRI will maintain 3 sites through 1977 when it will phase down its cropping pattern studies as national programs come on line with additional sites. These network sites are summarized below:



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[1] Project Leader - R. R. Harwood, Agronomist

Availability of production technology for specific zones

The first production recommendations for an agroclimatic zone will be made for a portion of the upland rice area in the Philippines in early 1976. The recommendations will be made in the form of cropping pattern alternatives, their resource use, management requirements and expected returns. Recommendations for rainfed paddy areas will begin in 1976, with data increasing rapidly as the many national programs become active.

Extrapolation of results across zones

With up to 30 sites potentially on line by 1978, together with numerous applied research test sites, an extensive data matrix will be available. From these data the shifts in crop potential can be seen as water availability, soil type, and other parameters change. IRRI research will then enter its ultimate phase, that of extrapolation of production potential across zones. This will be computer-assisted, based on the data bank being constructed from the many test sites.

VARIETAL EVALUATION[1]

Justification:

One of the major inputs in increasing cropping intensity and yield per unit area in small scale farms is the development of improved varieties of crops adapted for intensive cropping. International Institutes and and other centers are concentrating their efforts in developing high yielding varieties acceptable to farmers. There is need of a more concentrated effort to insert these materials into ongoing programs. Recently the International Development Research Center (IDRC) funded

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[1] Project Leader - V. R. Carangal, Network Coordinator

the University of the Philippines at Los Baños (UPLB) to screen varieties and lines developed by the international institutes and centers for characters of major importance in intensive cropping. UPLB is concentrating on upland crops such as corn, sorghum, soybeans, mungbeans, sweet potato, tomato, and eggplant. IRRI is screening other important food crops suited to planting after rice such as peanut and cowpea. Of course IRRI is developing rice varieties through its GEU program.

Accomplishments:

The most promising varieties and lines from the screening together with locally developed varieties are tested in the cropping systems network of experimental sites throughout South and Southeast Asia. In addition, we are providing trials to institutions and organizations working on cropping systems in countries collaborating with the network. The cooperators in 1975 are the following:

1. Bangladesh - Bangladesh Rice Research Institute
2. Indonesia - Central Agriculture Research Institute
3. Philippines - IRRI outreach sites in Batangas, Iloilo and Pangasinan
4. Sri Lanka - Agricultural Research Station, Maha Illuppallama
5. Burma - Agricultural Research Institute, Rangoon
6. Malaysia - Malaysia Agricultural Research and Development Institute
7. Thailand - Dept. of Agriculture, Kasetsart University and Khon Kaen University

Legumes, corn, sorghum, and sweet potato will be evaluated after the main crop of rice. Corn will also be tested before rice. The evaluation program is not a uniform testing. However, there will be uniform plot size, replication number, and data collection. The number of entries will vary from country to country depending on the extent of their breeding program. UPLB and IRRI will contribute from 10 to 15 entries. The number of entries per crop and number of trials for distribution in 1975 are shown in the table below.

		Number of trials							
Crop	No. of entries	Thailand	Indonesia	Sri Lanka	Burma	Malaysia	Bangladesh	Philippines	Total
Corn	11	2	2	1	2	-	1	6	13
Sorghum	14	4	2	1	2	1	1	6	16
Soybeans	15	4	2	1	2	1	1	4	14
Mung bean	10	6	2	1	2	1	1	6	18
Peanut	10	-	-	1	2	-	2	1	5
Cowpea	11	4	2	1	2	1	1	6	16
Sweet potato	10	increase	-	-	-	-	increase	3	3

Sweet potato roots were sent to Thailand and Bangladesh for seed increase. Only two corn trials were planted in the Philippines and Bangladesh, one soybean trial in Thailand and two trials each of cowpea and mung bean in Thailand. Data are not yet available. The rest of the trials indicated above will be planted after rice from September to December, 1975.

In the Philippines we evaluated the promising lowland rice varieties developed by the national breeding program and IRRI in Iloilo and Pangasinan outreach sites. One set was direct-seeded in May at each site, and this was followed by transplanting in September. Another was transplanted at each site during the regular season. Promising upland rice varieties are also evaluated in the Batangas outreach. (Data will be available in November).

One hundred eight cowpea lines from International Institute of Tropical Agriculture were planted in one-row to two-row plots for seed increase. In October, we will conduct a replicated trial for observation to identify the promising varieties. Twenty-three peanut varieties from Thailand and India were introduced and increased for observation in a replicated trial in October.

We are introducing more improved varieties of cowpea from the International Institute of Tropical Agriculture and other national programs and peanut from ICRISAT and the U.S.A. for evaluation to identify varieties suited after the main crop of rice.

Future plans:

The number of trials will increase in 1976 with the increase in the number of experimental sites involved in the cropping systems network. We plan to evaluate the promising varieties of upland crops including rice in each site. In addition, institutions and organizations involved in national coordinated cropping systems research will be included in the evaluation program.

PEST MANAGEMENT[1/]

Objectives:

To provide a practical pest management package of recommendations for each cropping pattern that can be followed by a good farmer. The technology will be fitted to the conditions at each test site and tested on that site.

Present pest management technology concentrates on each crop individually. Our objective is year-round pest management fitted to the resources of the small farmer (limited capital and land combined with high labor capability). We are primarily interested in using the available technology already developed in pest management and will fit this technology to the conditions of each site. This technology will mainly be insecticides.

Summary of accomplishments:

For each site we have prepared a profile in outline form listing for each crop the major and minor insect pests as well as their natural enemies. This will be revised as we learn more and will help us to interpret the pest complex in terms of future research needs, who does the research, and being able to compare pest complexes between sites, both in the Philippines in the network.

An outline in rough form is presented below for Batangas, the first of 3 sites for which we have the most information.

A total of ten feasible cropping patterns are being studied for their insect management problems. These patterns include the 8 major field crops studied in the cropping systems program.

[1/] Project Leader - J. A. Litsinger, Associate Entomologist

Profile of the Major Insect Pests of Batangas Cropping Pattern

Rice

- White grub
  - Leucopholia irrorata
- Rice bug
  - Leptocorisa acuta

Corn

- Corn borer
  - Ostrinia furnacalis
- Earworm
  - Helicoverpa (Heliothis) armigera
- Rice weevil (storage)
  - Sitophilus oryzae

Mungbean - Cowpea - Soybean

- Aphid
  - Aphis craccivora
- Bean fly
  - Ophiomyia phaseoli
- Pod borers
  - Lycaenidae - Catochrysops crejus
  - Helicoverpa (Heliothis) armigera
  - Maruca testulalis
- Bruchid weevil
  - Callosobruchus
- Armyworm - Cutworm - Semilooper
  - Pseudaletia, Chrysodeixis
  - Spodoptera, Mocis

Sorghum

- Armyworm - Cutworm - Semilooper
  - Pseudaletia separata
  - Spodoptera litura
  - Chrysodeixis chalcites
- Webworm
  - Pyralidae (unidentified)

Sweet potato

Sweet potato weevil
Cylas formicarius formicarius

Armyworm - cutworm
Pseudaletia separata
Spodoptera litura
Mocis frugalis

Peanut

None

Future plans:

The pest management research will concentrate on these crops grown in the proper sequence and will provide an input on the cost of crop protection for each pattern, leading to an assessment of the feasibility of growing that cropping pattern. It may turn out that the pest problems are too great for a particular pattern and that the farmer should turn to other alternative ones.

1. Methods of control:

Resistant varieties - Lowland rice is far ahead of other crops in having resistance to insect pests. The upland crops including upland rice generally do not possess resistance. As the varieties become available they will be tested at each site. We are hopeful that in the near future we will have at least some insect and disease resistance in most crops.

Biocontrol - We are aware that there exist powerful entomophagous agents acting in farmers' fields on at least some pests, probably those that are of minor status now. Basically we don't want to introduce new technology (insecticides) which will upset the presently-acting parasites and predators.

Our role will be to determine the relative effectiveness of these agents presently acting in farmers' fields and as much as possible maintain that effectiveness so as not to induce more pest problems. Predators tend to move from crop to crop and hence can be managed over the cropping season. We are encouraging their survival from crop to crop.

Cultural control - We will not greatly emphasize this method in terms of experimentation on our part. Most of the benefits here, mainly time of planting and sanitation practices will be learned from field observations and sampling over successive plantings of each crop. We plan to work on the effect of weeds and weeding on insect pests. Intercropping has been shown in our trials to reduce some insect pests but the benefits are little known and hence won't receive our emphasis for some time.

Insecticidal control - This will be the mainstay for our pest management technology. Right now for most pests there are recommended insecticides that have been tested elsewhere. Our role will be to test for methods of most efficient application in terms of residual activity and minimum effective dosages. This will include proper timing of application. We will work more intensively on those pests which have had the least amount of testing, emphasizing the most important pests at each site.

We will emphasize those insecticides that are available to farmers now. If for some reason these are inadequate we will test others. This test work will involve two aspects: The first is the more basic aspect of effect of the insecticides on the total insect community and the second is production testing for production recommendation.

2. Comparison of pest profiles between sites:

Similar pest profiles will be drawn up for Pangasinan and Iloilo. These profiles will help when it comes to extending the pest management technology to other geographic areas of similar rainfall patterns and even will allow interpretations to be made for areas of dissimilar rainfall patterns. This will provide a format for determining what pests to expect and the probable pest management strategies.

The presence or absence of biocontrol agents between areas of similar rainfall patterns will be instructive in terms of future projects involving the transfer or parasites and predators between regions. This is important within the Philippines as well as in the region of the Cropping Systems Network in Asia.

3. Plant diseases, nematodes, and rodents:

Our emphasis will be on insect pests but we cannot exclude diseases, nematodes and rodents from our package of technology. UPLB has a large Department of Plant Pathology and their results plus those of other institutions, namely AVRDC, will be incorporated.

These problems have less options in terms of pest management solutions and are beyond our scope of IRRI research emphasis in terms of our basic research other than to screen for resistant varieties.

Nematodes - We are engaged in a cooperative project with UPLB on nematode control by crop rotation. Nematodes appear to be important only in upland areas.

Rodents - The Rodent Research Center is located nearby to IRRI and has a very active program in practical methods of rodent control in the field. Rodenticides are available and can be used where necessary.

4. Cooperative tie-ups:

As we are working on so many crops and pests it is important to learn of new developments coming from other institutions as well as research and production groups. We are endeavoring to understand the farmers practices in pest management and the resources that he has at his disposal, land, capital, labor. The economics section of C.S. IRRI is a source of further information on farmers practices.

5. C. S. Network:

We have a close tie-up in Indonesia with the entomologists at CRIA where there is a multiple cropping entomologist undergoing pest management trials in the 2 sites. The tie-up will be on a professional basis where we plan to exchange scientific information and coordinate research projects.

Similar arrangements will be made in other Asian countries as the network becomes more developed.

WEED MANAGEMENT[1]

Justification:

Luxuriant weed growth is a major problem of tropical agriculture. It is estimated that crop losses due to weeds in the tropics are two to three times greater than in the temperate zone.

An assessment of the major tropical crops would probably indicate that weed problems have either limited the yield of the crop or are a major item in the cost of production. In many instances, the farmer spends more time weeding than on any other farm operation. In fact it has been postulated that the principal limiting factor to the size of tropical farms is the number of weedings during the period following planting. One of the greatest limitations to the introduction and acceptance of multiple cropping throughout the world could be weeds and the problems associated with controlling them.

Weeds are probably a greater problem in a sole crop or in simple crop associations than in the multicrop multistoried associations that occur in many parts of the tropics. The complete cover provided by a mixture of crops not only helps in protecting the soil but may reduce the need for weeding by competing with weeds.

In recently cleared fields or newly cropped areas broadleaved weeds are the major problem but in fields that have been cropped several years grasses -- which are said to be more difficult to control -- provide the principal competition. If more crops are grown in sequence per year, the tendency for grass weeds to be more prevalent in older crop areas could well be accelerated.

[1] Project Leader: K. Moody, Associate Agronomist and S. K. De Datta, Agronomist

The majority of the weeding in the developing countries is carried out by hand or with simple hand tools. These methods are generally effective means of weed control but they are tedious, time consuming and require much labour. Labour is expensive and at times in short supply either because it cannot meet the high requirement at a given time or because it is permanently inadequate.

For large scale farms herbicides may offer the most practical, effective and economical means of reducing weed competition, crop losses and production costs. For smaller scale farms the problem remains much more difficult. The cropping pattern that the small-scale farmer uses does not lend itself to the introduction of herbicides. In addition, for economic and educational reasons herbicides cannot be exploited nearly so readily on small-scale farms.

Repeated use of the same herbicides over a period of years leads to a build up of tolerant weeds. This can be prevented by rotating crops, rotating herbicides or by removal of these tolerant weeds by other weed control methods when they appear.

Despite the great potential of herbicides weed control in cropping systems in the tropics will not depend on them alone but will probably be based on a combination of all available means of weed control -- cultural, mechanical, chemical and biological.

Objectives:

To provide a weed management package for the major cropping patterns used by rice farmers, starting with the patterns presently used at the outreach test sites.

Summary of accomplishments:

In all cases an integrated approach is being used combining tillage, crop sequence, time of planting, competitiveness of the variety, plant spacing and in many cases, chemical. It has been found that in intensive sequences the weed problem itself is really determined by past weed management practices. Our management techniques involve manipulation of weeds across the entire cropping pattern.

Along these lines, recent trials at IRRI have indicated that:

1. a. The use of herbicides to control annual weeds in transplanted rice has created ideal conditions for Scirpus maritimus -- a difficult to control perennial sedge -- to multiply rapidly.
   b. Rotating an upland crop (corn/peanut intercrop) with transplanted rice, reduced greatly the amount of S. maritimus, compared with herbicides.
2. For long term control of the more difficult and persistent weed species a low rate of herbicide followed by light weeding and relatively high plant densities is preferable over other treatments designed to give a commercially practical level of weed control.
3. A greater increase in weed density occurs in the later stages of growth of short-statured crops (rice and legumes) than with tall-statured crops (corn and sorghum). Shading by the tall crops did not alter the species of weeds present.
4. In upland rice, combinations of dense stands or leafy varieties, low rates of herbicide and limited mechanical tillage gave good weed control and greatly reduced troublesome weeds such as

Cyperus rotundus. At low chemical rates, the predominant weed in the second season was Digitaria sanguinalis -- a comparatively easy to control weed -- which affects crop yield less than C. rotundus.

5. A lack of vigor and decrease in total growth occurs with certain photo-period responsive mungbean varieties when planted between November and January. The result of this lack of vigor and failure to achieve complete ground cover leads to aggravation of an already difficult weed control problem.
6. The response of rice to nitrogen fertilizer application is markedly influenced by the adequacy of weed control.

Future plans:

1. To examine existing and proposed cropping patterns in the outreach sites to determine weed problems and suggest possible means of alleviating them. To suggest possible cropping patterns that may be superior on the basis of weed control to those in existence or those proposed.
2. To screen various crops and varieties for their competitive ability against weeds.
3. To determine optimum planting densities, row spacings, etc. for greatest competition against weeds.
4. To examine various land preparation techniques during the dry season and between crops in the wet season in an attempt to reduce time spent on these operations and postplanting weed control without loss in yield or increase in time spent on some other field operations (e.g. planting).

5. To determine whether intercropping and mixed cropping are advantageous with respect to weed control.
6. To determine the effect of time of planting following the start of the wet season on subsequent weed growth and weed control.
7. To examine in association with the entomologist the effect of weeds growing in association with the crop and the removal of these weeds on insects and diseases.
8. To try to determine why weeds are sometimes worse in type and intensity in scientific trials in farmers' fields than those in the adjacent fields when the farmer uses his cultural practices.
9. To examine the effect of cropping patterns and agronomic practices on weed populations in an endeavour to prevent the build up of undesirable weed species or if these species have built up to intolerable levels to try to learn by manipulating cropping sequences and weed control practices how to reduce them to acceptable levels or to replace them with easier to control weeds.
10. To determine optimum economic levels of weed control in various crops and cropping systems by comparing available weed control techniques -- alone and in combination.

HERBICIDE SCREENING IN UPLAND CROPS[1]

Objectives:

To endeavor to find a herbicide that will kill the majority of weeds in crops that are most suited for adoption into multiple cropping programs in Asia without causing crop damage.

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[1] Project Leader - S.K. De Datta, Agronomist and K. Moody, Associate Agronomist

Justification:

In general, weed control practices presently used in the developing countries are slow and arduous. Quite often weeding is delayed until planting is finished due to insufficient labor being available to carry out both operations. By the time weeding is started crop yield reductions have already occurred.

The answer to these problems may be in the use of herbicides which can be more selective and thorough in their action than mechanical methods of control and require much less time in their application.

Some people have expressed the concern that herbicides are too costly to be used by the majority of farmers in the tropics. However, in many parts of the world, increasing labor costs and the unavailability of labor at critical times are rapidly causing the use of herbicides to become more economical than hand labor. However, there are problems associated with the introduction of herbicides into the small scale farmer's operations.

Farmers in developing countries typically grow several crops each of which may require a different herbicide. The possibility of mistaken usage, with serious crop damage resulting obviously arises. It would be ideal if there was one herbicide that would be safe for use in all the crops grown in a given locality.

In many areas in order to reduce weed control problems and to maximize land usage upland rice is often grown in association with other crops. Herbicides must therefore be evaluated for their possible effects on crops grown in association with or in sequence following upland rice.

Any herbicide that is safe in several unrelated crops is also likely to be ineffective against several weed species. These tolerant weeds can be controlled easily by other weed control methods provided that the herbicide quantitatively controls the major weed species present.

Results obtained:

In 1975, two herbicides -- butachlor and butralin -- applied preemergence at 2 kg a.i./ha controlled the majority of weeds in upland rice, corn, sorghum, peanut and mung bean without causing crop damage. Weeds not controlled by these herbicides were Cyperus rotundus, Commelina diffusa, C. benghalensis and Ageratum conyzoides. A new coded compound MON 0358 looked promising for weed control in rice and several other upland crops.

Planned research:

To continue to search for one or more herbicides that will control a wide spectrum of weeds in all the crops grown in association with rice or in a given area without causing crop damage.

SOILS RESEARCH

A senior scientist will be added in 1976 to add strength to present work in this area. Classification of tillage characteristics of the major paddy soils at different moisture levels will give an approximation for the probabilities for successful tillage over time at given locations. The methods for conversion from puddled to upland conditions will continue to be studied for a range of soil types.

Fertility studies will concentrate on efficiency of use of fertilizers in different crop patterns. The total amounts required differ markedly with both crop pattern and how and when it is applied. When lowland paddy is rotated with upland crops this consideration becomes critical. Results from these trials will then be incorporated into zonal recommendations for the patterns.

ECONOMICS OF RICE-BASED CROPPING SYSTEMS[1]

Justification and objectives:

Economic research is undertaken to assist in the initial design of more productive rice-based cropping patterns, and once their biological feasibility has been shown, to evaluate their acceptability to farmers and their potential impact on food production.

At the design stage, the effort is two-fold:

1. locating economic phenomena in existing cropping systems which are related to multiple cropping and which can be technically improved, extended to other locations, or otherwise exploited; and
2. from study of the levels of farmers' resources and their present utilization, recommending areas of biological research that are most likely to increase the productivity of farms through multiple cropping.

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[1] Project Leader - E. C. Price, Associate Agricultural Economist

Farmer acceptance of a new multiple-cropping technology is clearly necessary before it can result in increased food production. Therefore tests of acceptability are conducted by assessing the farm level economics of the technology -- mainly its profitability. Also, in order to arrange priorities for research and extension of multiple cropping technology, evaluation is also conducted of the size of the potential increment in food production, the locations where the technology is applicable, and who are the likely beneficiaries of the new technology.

Summary of accomplishments:

Much of the effort since a program in cropping systems economics was begun at IRRI, has been toward the development and testing of a methodology, and formation and training of a research staff.[2] But significant advances into the design and evaluation of multiple cropping technology have also been made[3].

Field work was begun in 1973 in Batangas, Philippines, and in 1975 it was extended to several barrios in Iloilo and Pangasinan Provinces. A similar methodology as that which has been used at these locations, also intended for the design and evaluation of multiple cropping technology, has been adopted for research at two sites in Indonesia and at two sites in Thailand with IRRI collaboration.

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[2] Banta, G.R. 1972. Economic evaluation of multiple cropping systems. IRRI Saturday Seminar series.
Banta, G.R. 1973. Procedures and tools of economic evaluation of multiple cropping. Paper presented at the 1st Multiple Cropping Workshop, Indonesia, Sept 18-20, 1973.

[3] Banta, G.R. 1974. A philosophy of surveying cropping systems., IRRI
Antonio, E.V. and G.R. Banta. 1974. Multiple cropping in a Batangas barrio. IRRI Saturday seminar series.
Banta, G.R. 1974. Preliminary findings on resources characteristics and their utilization on corn farms in the Philippines. IRRI
Frio, A.L. and G.R. Banta. 1974. Socio-economic factors associated with systems in selected Batangas barrios. IRRI Saturday seminar series.

Design of more productive cropping patterns:

The design of more productive cropping patterns is mainly in the hands of biological scientists. For its part, the economics research into the design of cropping patterns is based on two postulates:

1. The principles according to which farmers themselves have designed cropping patterns, if discovered, can be a guide to a more productive technology, and
2. New cropping patterns which utilize farm resources more fully than present patterns are likely to be more productive.

In either case, the necessary analysis must be based on a thorough examination of existing farm resources and technology.

Within seven research projects on the economics of cropping systems, the subprojects which mainly contribute to design of new patterns are:

1. Weekly land, labor, and cash utilization on farms in three Philippine locales
2. Cost and returns of farmers cropping patterns in three Philippine locales
3. The role of critical inputs in differentiating cropping systems by locale
4. Trends and seasonal variation in prices of major food crops in countries of Southeast Asia.

Some of the research results obtained within the past year lead to the following diverse and tentative conclusions regarding pattern design in three Philippine settings:

1. The management capacity of farmers is a stronger determinant of cropping intensity than labor availability or size of farm
2. Cash inputs are highly complementary with the labor input such that certain kinds of cash intensive technology is likely to be labor-absorbing.
3. Water control is a major component of the technology of rainfed farming; variability of rainfall is a strong determinant of the level of investment in bunds and drainage, and consequently of the costs and feasibility of multiple cropping.

Pattern evaluation:

There have been several approaches to the evaluation of new cropping patterns and they are indicated by the subprojects listed below which contribute mainly to this objective.

1. Cost and returns of experimental cropping patterns
2. Role of critical inputs in determining the adoption of new cropping systems
3. Systems analysis and simulation of rice-based cropping patterns at the farm level.
4. Macro analysis of cropping systems in agroclimatic zones of Southeast Asia.

Under the first subproject, the straight-forward analysis of the profitability of new cropping patterns is conducted. This presently is the most frequently used approach but increasingly a simulation model, which incorporates a cost and returns routine, will be used.

Cost and returns analysis of agronomic trials in Batangas barrios in 1974-1975 supported recommendations to a Philippine government agency for applied research trials for the 1975-76 crop years. These trials and their evaluation will also likely result in the development of a Philippine program to encourage farmers to produce sorghum after rice in Batangas.

The last subproject, macro analysis of cropping systems by agroclimatic zone is an attempt to analytically extend the results from research at the Philippines outreach sites and from collaborating sites in other countries, to zones where work is not conducted but the resources and economic characteristics of which are known.

Future plans:

The program for economic analysis of cropping systems at IRRI is expected to increasingly focus on cross-national applicability of research results, based on a mapping of agroclimatic and economic variables, and to increasingly collaborate with researchers elsewhere. The latter will be facilitated by a program for short-term training at IRRI in the economic analysis of cropping systems, and the standardization of survey forms and data formats among cropping systems researchers.

CONTINUING DEVELOPMENT OF PRODUCTION TECHNOLOGY

The problem research areas of varietal testing, soil fertility, weed management, insect management, and socio-economic evaluation within the context of adapted crop patterns will continue through 1980, even after national programs have assumed most of the responsibility for crop pattern studies. This, combined with concentration on functional models contributing to the ability to extrapolate over climatic zones will then be the major research contribution.

APPLIED RESEARCH AND PRODUCTION PROGRAMS[1]

Justification:

The transfer of knowledge from the basic researcher to the farmer has been a major constraint to increasing the welfare of the farm population from the beginning of the modern era. Our concept of applied research is to receive information from research institutions, to assemble and test it in farmer's fields and to develop a package of inputs which will reduce risk, and increase the farmer's income. Finally, to help develop a national program in which the package of technology can be used by all who want it. This is the major challenge and justification for this portion of the program in the training and applied research department.

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[1] Project Leader - L. D. Haws, Senior Scientist

Objectives:

1. To increase the well-being of the Asian farmer by:
    a. Providing the technology that will increase yields in rice and upland crops in his farm
    b. Helping to determine production constraints and eliminating them.
    c. Establishing, through provincial and national agencies, production programs.

Summary of accomplishments:

Sweet Corn Project

With the wonderful year-round climate in the Philippines,one can plant almost any plant anytime of the year and it will grow. Generally, in Luzon, Mindanao and Iloilo, there is sufficient ground water to start crops in April before the start of the rainy season. The supply of water is also sufficient to prevent loss from drought that may occur during the rainy period or to finish upland crops that may be planted after the last rice crop has been harvested.

A major constraint on upland crops, however, is a suitable stable market. Soybeans, corn and sorghum are all imported into the Philippines but they can all be grown in abundance here. With this in mind, a project was started with sweet corn to see if a market could be developed for this product. Commissary officers were contacted at the Air Force Base at Clark Field and the Submarine Base at Subic Bay. They have a combined population of about 50,000 people. They also have the possibilities of purchasing food for many thousand more. They were immediately interested in purchasing the corn or any other vegetable that could be furnished in good quantity and quality. The farmer-cooperator in this project was soon making ₱15,000/ha for sweet corn. Contacts were made with other food outlets, i.e. supermarkets and restaurants. The Manager of A & W Rootbeer wanted to become an agent and sell the corn in the Greater Manila area where he had established contacts. It was evident from this small experiment that markets can be developed even if one has to start from a very low base and build it up.

A similar program has been started for sorghum and it appears that there are many people trying to buy sorghum. Someone must work to bring together the producer and the buyer of the product. In my opinion, this should become a very important part of the applied research program.

IRRI-ACA-DAR Cooperative Project:

The Department of Agrarian Reform (DAR) has approximately 477 compact farms throughout the Philippine Republic that they are trying to develop into economic agricultural units. These farms occupy about 300,000 hectares of land. The Agriucltural Credit Administration (ACA) is responsible for making loans to these farmers of DAR to aid in the development of the farm lands.

Working with the officials of ACA-DAR in Urdaneta, a project was organized in which IRRI would provide technical help for direct-seeding rice in two compact farms in Pangasinan. This project was entitled "Supplemental irrigation in producing direct-seeded rainfed rice". The objective of the project was to use the ground water available at these farms to start a rainfed crop of rice at the correct time or at the onset of the rains (April 15). This ground water could also be used in case of a dry period during the rainy season and save a crop and thus reduce the risk of crop failure due to drought.

The project was started later in the season than desired but about 400 hectates of rice were brought into the project. Funding was late and as a result most of the pumps were not installed on time. However, even without the pumps, many good harvests of IR1561 were obtained. The farmers are in the midst of harvesting their crops at this time and results (yields) will be available for the review in December. This project will continue for the next year with upland crops now being planted for a second crop and the rice crop being planted next year (April 15). Pumps are now with the farmers for use next year. If this technology can be demonstrated successfully in Pangasinan, the results can be introduced into the 477 compact framrs of DAR with immediate benefits to these new land holders.

IRRI-PCAR Cropping Systems Project

This is a joint project between IRRI and the Philippine Council for Agricultural Research (PCAR). This project involves 32 provinces in the Philippine Republic. The project has two main objectives:

1. To evaluate the potential of producing a second crop of rice or various upland crops following the direct-seeded rice crop in rainfed (bunded) rice areas.
2. To evaluate the economics of the two- and three-crop system as compared to the traditional method of rice and upland crops.

The harvests from the first crop of rice are being evaluated at this time and results will be available for the December meeting.

The upland crops have been planted in 10 locations in northern Luzon on light soils. Additional upland crops will be planted on heavy soils after the second rice crop is harvested. This project should demonstrate the possibility fo getting two crops of rice and at least one upland crop on heavy soils and one rice crop and two upland crops on light soils.

Both these projects have been institutionalized so that the results obtained from the applied research plots can be moved directly into a provincial or national program to increase production, and thus the farmer's income. As a result of this work, the farmer's standard of living will be considerably increased.

Production programs

IRRI scientists are now serving on the national management committees guiding production programs in the Philippines. The first such program is now underway and will target around 50,000 hectares in several provinces to come under multiple cropping from the present single crop in 1976. An Indonesian program is likely, based on test site results in 1977. The network coordinator, as his organizing role phases down in 1976, 1977, will spend more of his time with such programs, while Dr. Haws will concentrate his attention on coordinating the technical support and working as a member of the production management committees.

Future plans:

There are three main areas where work will be concentrated over the next five years.

1. Adapting research results to national needs. This will remain a major effort in our applied research program. The work will

involve an economic analysis for production costs and returns of eight upland crops, i.e. Peanut, Corn, Mung, Cowpea, Sweet potato, Irish potato, Sorghum, Soybeans planted after rice.

2. Market evaluation. In cooperation with appropriate national scientists, efforts will be made to locate and establish markets, local and international, for the upland crops mentioned above.
3. National production programs. Enough information has been gained in the Philippines and elsewhere so that we are confident we can teach the techniques of organizing production programs with rice and some upland crops. This work will be carried out in countries where our outreach programs are established. We will serve on national management committees to help organize these programs.

MACHINERY DEVELOPMENT AND MANAGEMENT

POST-PRODUCTION TECHNOLOGY AND MANAGEMENT[1]

IRRI presently has a relatively small program in post-production research representing about 1 percent of the overall Institute budget. The activities of this program focus on economic and engineering studies of post-production practices at the farm and village level, empirical evaluation of the sources and magnitude of qualitative and quantitative losses, checks on changes in nutritive quality ascribable to inherent varietal characteristics, and engineering design work to improve the availability and performance of technology used in post-production systems.

Objectives:

The departments of agricultural economics, engineering, cereal chemistry, and, to a limited degree, entomology are involved in post-production research. The specific objectives of this program are:

1. to assess the technical and economic characteristics of existing rice post-production systems;
2. to analyze, through experiments and field studies, the sources and levels of quantitative and qualitative losses and their relationship with post-production practices;
3. to assess the impact of alternative economic and policy measures on the volume and quality of rice made available for market sale;

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[1] Project Leader - B. Duff, Associate Agricultural Economist

4. to examine the physical and chemical characteristics of rice which affect the technical and economic performance of post-porduction systems; and
5. to develop suitable technological alternatives to improve the efficiency and effectiveness of post-production operations.

The overall objective is to increase the availability of rice, particularly the marketable surplus or that portion moving into markets outside the farmer's household. Improvements in the timing and method of harvesting, threshing, handling, drying, storage, and processing can lead, either singularly or in combination, to significant increases in output. Reductions in field and processing losses represent one possibility. Another alternative is to alleviate bottlenecks in post-production operations which act as constraints to increased cropping intensity. A third is to improve the productivity of farm level resources permitting expanded output through increases in cropped area.

Justification:

In a recent speech before the United Nations, United States Secretary of State Henry Kissinger cited the lack of resources, policies and technology in post-production handling of increased food supplies as a major justification for expanded activities in this field.* Unfortunately, little is known about the nature or magnitude of this problem. In the field of rice production and processing, particularly within the small farm sector of the developing nations, estimates of losses vary tremendously. Given this uncertainty in defining the problem, it is extremely difficult to fix priorities for research and development activities in

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*Henry A. Kissinger, "Economic Growth and the Developing World", An address before the United Nations General Assembly, September 1975.

this field. As a first step in clarifying these issues, there is a clear need to examine the sources, levels and nature of post-production losses. It is also increasingly evident that the problem is not merely a technical one, but is significantly effected by prevailing economic conditions facing farmers, processors, and consumers. It is also clear that interdisciplinary research of the type which can be carried out at IRRI is necessary to fully identify, analyze, and formulate solutions to these problems.

In the field of equipment development, the post-production requirements of small farmers and processors have largely been neglected by public and private sector agencies, institutions and firms. The needs of large commercial firms largely have been met through the transfer of technological knowledge from the advanced nations. A lack of incentives, knowhow and research have largely precluded similar transfers and/or developments affecting the subsistence sector in the developing countries. With over 50 percent of the rice crop retained in the rural areas for household consumption, it is imperative that improvements reflecting the needs of this sector be developed and introduced. These improvements will increase not only the availability and quality of rice, but will also measurably improve the potential for mobilizing a larger marketable surplus in nonfarm markets.

Without concurrent changes in the post-production stages of the rice industry, it will be difficult, if not impossible, to consolidate and fully realize the benefits of increased rice production stemming from use of improved varieties.

Summary of accomplishments:

During the past two years the post-production program has been conducting a series of sequential studies to inventory existing practices in post-production systems. These studies have been programmed in four distinct phases. In the first phase, a field study of 600 farmers in three regions of the Philippines was conducted to assess the level and type of technology employed, relative costs and technical efficiencies of individual elements within existing systems. Data from this study is being employed to identify economically viable areas for further research and possible equipment development.

The second phase consists of a survey of 180 rice mills in the Philippines, principally small village level operations. In this instance, the objective is to determine the economic characteristics which govern the operation, location and viability of these units. A similar exercise is currently underway in Thailand to provide a comparative basis for assessing relative efficiency between countries.

The third stage in this particular study is a mill level engineering study of processing efficiency. From the initial 180 rice mills included in the second phase, approximately 30 mills have been selected for carefully controlled sample milling experiments. From this evaluation, a clearer picture of milling and field level operations will emerge.

From the first and second phases, actual and potential post-production systems have been identified for further study. In the fourth stage, pilot area trials embodying elements of these comparative systems are being implemented at two regional locations in the Philippines. As a result of these pilot trials, a comprehensive picture is being developed describing the performance of alternative methods and combinations of techniques. Field losses at each stage within each individual system are being assessed. In addition, paddy samples taken at each stage (harvesting, threshing, drying, milling) allow determination of quality changes resulting from untimely harvest, lack of proper drying and other constraints in the system. A similar series of pilot trials involving alternative elements of small-scale milling systems is also being undertaken.

In combination with the economics department, an empirically based statistical analysis was conducted to determine the factors affecting the magnitude of the marketable surplus. The study indicates that subsistence requirements are not significantly affected by changes in market prices. The marketable surplus is, however, quite sensitive to changes in total production. Hence, reduction in losses and/or increases in output resulting from technological changes such as new varieties and new techniques or infrastructure development such as irrigation can have a substantial impact on nonfarm sales.

A comparative series of solar drying trials were conducted in the Philippines and Vietnam to determine the efficiency and economics of alternative drying surfaces. Several low-cost surface areas including polyethylene sheets, gunny sacks, woven mats, asphalt and concrete were utilized in this study.

The machinery design and development program has a number of projects in the post-production area. Included are threshers, grain cleaners, grain dryers, milling machines and rice whitening equipment.

The IRRI-designed axial flow thresher has entered commercial production and is now available in five countries. A small batch-type grain dryer designed to be used in combination with the mechanical thresher has also entered the market. Grain cleaning equipment is under evaluation and prototype development. Small-scale milling machinery designed to update existing Engleberg hullers is also under development. These machines are devised for village and individual farm-level operations.

Future plans:

Future activities under the post-production program include:

1. Further field work to quantify the quantitative and economic magnitude of post-production losses;
2. Examination of the relationship between economic policies and the technical performance of elements and combinations of elements in post-production systems;
3. Expanded analytical work to assess the impact of post-production techniques on qualitative changes, particularly those affecting the nutritional value, which take place as grain moves through a particular system;
4. Examining the impact of alternative farm and village level storage methods on grain quality and volume;
5. The development of a series of post-production systems models designed to:
    a) assess the nature and importance of interactions between elements of individual systems;

b) examine the impact of alternative techniques and combinations of techniques on output and cost;

c) establish priorities for further post-production research, and

d) identify and quantify design parameters for equipment design and development activities.

6. The development of an informal mechanism for the identification and exchange of data and program information among institutions involved in rice post-production research and development activities.

MACHINERY DEVELOPMENT[1/]

The IRRI small-scale mechanization program was initiated in 1965 as a special project funded under a research contract with USAID. Actual machinery design and development activities began in 1967 and have been expanded in recent years. The following sections contain the objectives, justification and operational policies governing the activities of this program.

Objectives:

Appropriate small farm mechanization can expand rice production in both a quantitative and qualitative dimension. The overall objective of the IRRI mechanization development program is to increase the income and welfare of small rice farmers. Use of improved mechanical technologies contribute directly to this objective by increasing production through a) increased yields, b) removal of resource constraints, c) reductions in field and post-production losses, d) increased cropping intensity, e) improvements in the timing and efficiency of specific operations, and f) improvements in the quality and value of production. Appropriate machine designs also provide potential reductions in production costs—a direct benefit to the consumer—through a) improvements in resource utilization and productivity and b) through the availability of a wider range of alternative techniques which are complementary with onfarm labor and capital resources. Mechanization based on local production also reduces foreign exchange cost, creates expanded opportunities in rural based industries, strengthens backward linkages between agricultural and other sectors of the economy and enhances formal and informal training

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[1/] Project Leaders - A. U. Khan, Agricultural Engineer, D. Kuether,
Associate Agricultural Engineer, J. A. McMennamy,
Associate Agricultural Engineer and B. Duff,
Associate Agricultural Economist

opportunities in small-scale manufacturing. These objectives are not mutually exclusive nor exhaustive. They demonstrate the high degree of interdependence which develops between agriculture and other sectors of the economy as agricultural development occurs.

The evidence from experiments, field surveys and pilot trials conducted by IRRI and others indicates that there are substantial benefits to be derived from improvements in the manner and timing with which critical tasks and operations in the production and post-production sequence are performed.

Justification

At present, there is little machinery development activity related specifically to needs of small farmers. Commercial farm machinery manufacturers in the developed world have little incentive to produce designs which are appropriate to small farmer needs. Their major interest has been to introduce existing designs through established marketing channels. Conversely, existing mechanization programs in the developing countries have tended to concentrate on research rather than the design and local manufacture of equipment. The result has been few significant contributions to the needs of small farm owners or operators. The private manufacturing sector in the developing countries also has little incentive nor capability to perform this task. Difficulties in capturing and retaining the benefits of innovative research in the absence of effective patent or legal protection and the absence of financial and monetary incentive precludes commercial research and development by all except the very largest firms. In addition, the general lack of engineering and technical expertise and the inability to effectively couple the needs of small-scale agriculture with engineering development work has further hindered growth of the indigenous farm equipment industry. In summary, there exists a definite need for research and development work on problems of small farm mechanization in the rice-producing nations. It is unlikely that this task will, however, be undertaken by either government supported institutions or the private sector.

The following are the four major reasons for IRRI's machinery development program.

1. Unavailability of suitable alternatives to carry on work of this type. As mentioned previously, there is little public or private sector incentive or interest in providing the necessary research and development support to small and medium scale industry which would make possible the development of suitable equipment designs. These designs are not available from the industrialized countries. In the absence of the IRRI mechanization program, it is doubtful that a similar effort could or would exist.
2. Mechanization technologies are rapidly becoming an integral input in the package of improvements necessary to achieve and realize the benefits of increased rice production. This is most apparent in situations involving expanded cultivated area or increased cropping intensity.
3. The close and constant contact that members of the engineering program have with other disciplines and program areas at the Institute is critical in assessing the nature and scope of machinery requirements in rice production and is available at

no other institution. As long as the objectives of the engineering design program are to develop machinery for rice and associated crops, the interdisciplinary working environment provided at IRRI will remain essential and unique.

4. IRRI has developed over the years an appreciable infrastructure throughout the rice growing world. This network provides the engineering program with a necessary set of linkages in transferring and adapting designs to conditions outside the Philippines.

Program Methodology and Organization

In the interest of improving past performance, previous reviews have made suggestions concerning the methodology and emphasis of the program. As a result of these findings the department has been reorganized along functional lines as indicated in the attached organization chart. It has four sections:

1. Machinery research
2. Mechanization systems
3. Machinery design, and
4. Industrial extension

These four sections complement each other in the development of appropriate, demand-oriented agricultural machines. The new organizational structure permits a more systematic evaluation and selection of new machinery projects and results in a better assessment of the real needs of small farmers.

The machinery research section is responsible for and is currently engaged in determining mechanization requirements of the small rice farmer, testing prototype designs to ensure that pre-determined performance objectives are met, conducting short-term training in the manufacture and utilization of IRRI-designed machines, and conducting research to establish farmers' needs and practices.

The objectives of the mechanization systems section are:

1. to quantify the nature and magnitude of constraints in rice production and post-production operations which may be mitigated by use of improved practices and technology,
2. to develop a microanalytical framework to examine the impact of interactions among and between tasks in the rice production and post-production sequence over a range of agro-climatic and economic environments,
3. to examine alternative institutional and organizational patterns necessary for efficient ownership and use of small-scale mechanization,
4. to examine and evaluate those socio-economic and policy factors affecting adoption and use of mechanization by small farmers, including changes in employment and income, and
5. to evaluate economic policies and other factors affecting adoption and use of improved designs by small and medium scale manufacturers.

The output from the studies of the mechanization research and systems sections provide the machinery program with information describing critical points in the production and post-production sequence where improved equipment designs offer potential for lifting constraints and increasing output. The studies are also used to evaluate and project the impact of technological improvements on incomes, employment, the level of benefits and costs, and the types of policies necessary to induce adoption of particular machines.

Field work to support these activities consists of a series of field experiments, surveys and pilot area trials designed to quantify the impact of alternative techniques on output, costs, benefits, employment and income. These sections also work closely with the industrial sector to develop information describing changes in employment and industrial productivity which result from manufacture of improved agricultural machinery designs.

The machinery design section uses information developed by the mechanization systems and machinery research sections, along with feedback from the industrial extension section, to design and develop the small-scale agricultural machines used in the production and processing of rice in the developing countries. An effort is made to develop designs that can be locally produced using existing manufacturing capabilities.

The object of the industrial extension program is to promote the use of IRRI machinery designs by:

1. publicizing the program and establish an information distribution network,
2. providing drawings of IRRI-designs to interested manufacturers, and
3. providing assistance to manufacturers in their efforts to adopt IRRI designs to local farming manufacturing, and marketing conditions.

About 30,000 IRRI-design machines have been produced in Asia and a sizeable farm machinery industry has been established in the Philippines. Recognizing the need for intensified efforts in extension of designs and technical support to other developing countries, the Technical Assistance Bureau of the USAID has provided support for a program that will place engineering extension teams in Thailand, Pakistan and the Philippines.

Review of Program Activities and Achievements:

To prove an explanation of both the nature and relevance of work completed and in progress by the farm machinery program, the following review disaggregates rice production and post-production operations into discrete steps.

Irrigation -

Studies made by IRRI's water management program have shown that improvement in both the timing and quantity of irrigation can increase and intesify rice production. The machinery development program has several projects aimed at providing low-cost irrigation equipment to small rice farmers. These include manual and powered low-lift pumps and simple windmills.

Land preparation -

Economic studies conducted at IRRI show that timeliness of land preparation is a major reason for farmers shift to mechanization and can lead to significant improvements in yields through fewer delays in planting. Also, the machinery research section of the agricultural engineering department at IRRI has conducted hard pan studies which show that large four-wheel tractors are not always a viable choice to mechanize land preparation. The 5-7 hp tiller developed at IRRI gives the small rice farmer the capability he needs to till lowland or upland fields in a timely and economic manner. The tiller is currently produced by 12 companies in five Asian countries and is selling for about half the price of imported power tillers of comparable size. Over 10,000 of these machines have been produced since the design was released in 1972.

Application of chemicals -

Studies conducted by IRRI's agronomy department have shown that deep-placement of fertilizer almost doubles fertilizer efficiency when compared with present broadcast practices. Projects to develop deep-placement applicators are underway so that farmers can take advantage of this discovery. It is hoped that the same equipment can be used for both fertilizer and insecticides. IRRI entomologists have stated that "the rootzone application of insecticides potentially is the cheapest and most effective methods of applying insecticides."

Weeding -

IRRI economists and agronomists have shown that controlling weeds can increase yields and water efficiency. In response, the machinery development program has projects to develop mechanical weeders and herbicide applicators. Uncontrolled growth of weeds is a major constraint to expanded rice production, particularly in rainfed and upland areas.

Threshing -

The mechanization systems section has found that timeliness of harvest is critical in optimizing rice yields. Delays of one or two days can reduce yields and quality significantly, particularly if the crop is being harvested during the rainy season. The IRRI axial flow thresher which can thresh high moisture paddy has helped remove this constraint on production and reduces threshing losses by about 2% over traditional threshing methods. It has gained rapid popularity and is now commercially produced in eight Asian countries.

Drying -

Inadequate post-production practices and management can create a 6 to 20% loss of food available for consumption. Some of this loss can be saved through improved threshing equipment; however, a high percentage of the loss results from improper drying which produces spoilage and low mill recovery rates. The IRRI designed one ton batch dryer reduces high moisture paddy to safe storage levels quickly and economically. When combined in operations with the axial flow thresher, it is possible to reduce overall losses resulting from poor timing and wet season harvests. The dryer is now produced in three countries.

Other machines under development include parboiling equipment, moisture meter, a grain cleaner and a range of improvements for village level milling operations.

The program has demonstrated that agricultural mechanization can be successful in the LDC's if appropriate machines can be made available at reasonable prices to the farmer. Also, indigenous manufacture is possible if machines are developed to take advantage of existing low-volume production technology.

Future plans:

Reorganization of the department along functional lines and the expanded industrial extension effort have been mentioned. There has also been a shift in the overall emphasis of the program with increased attention to problems associated with upland farming, multicrop operations, drying and processing, irrigation and water control, and utilization of low cost energy.

Future plans call for greater complementarity between engineering and other departments and programs at IRRI, a broadening in the scope of Industrial Liaison activities, provisions for greater opportunities for training of manufacturers and technicians and movement to a systematic approach in project selection and priority.

Positive working interactions are being developed with IRRI programs in Water Management, Agronomy and Entomology, Cropping Systems, Training and Applied Research, Economics and Post-Production Technology. Each of these programs/departments have projects involving potential mechanization applications.

Growing interest in Africa and Latin America in the possible adaptation and use of IRRI designs has lead to exploratory steps for possible industrial liaison activities in these regions. Implementation of funded programs in Thailand and Pakistan with the later addition of ancillary country programs in surrounding areas will improve the capability to effectively deliver design information. It will also provide a vital link in the identification of possible new projects.

Moving to a systems approach to establish project priorities will focus design and development efforts on areas of greatest need and potential. The systems research will also assist the industrial liaison effort by outlining the set of technical and economic conditions necessary for efficient use of particular machines and specifying the sequence in which these innovations should be introduced.

There will be increased emphasis on the role of training to facilitate the transfer and diffusion of design information. Two week training programs will be held at least twice each year and will be complemented by a farm machinery manufacturing workshop every two years. Promising graduate and post-graduate work will be encouraged when such projects are complementary with overall program objectives and supplement existing departmental resources.

In the area of design and development, the following project areas are being evaluated for future work:

1. lightweight threshing, spraying and weeding machines that can be handcarried by one to four men to fields lacking access roads.
2. harvesting and reaping equipment
3. land leveling equipment to improve water distribution and use
4. transplanting equipment to alleviate peak labor constraints
5. small, low cost combine
6. solar drying and collection equipment
7. paddy separation, classification and grading equipment
8. compilation and possible distribution of design information on small internal combustion engines.

Engineering development activities require considerable time and resources to produce commercially viable products. The unique nature of the IRRI engineering program has also made it necessary to establish the efficacy of appropriate mechanical technology and its relevance to the broader Institute objectives of increasing the quantity and availability of rice. Past experience now coupled with a strong industrial liaison program will ensure that future design projects move more rapidly into production and use by small farmers.

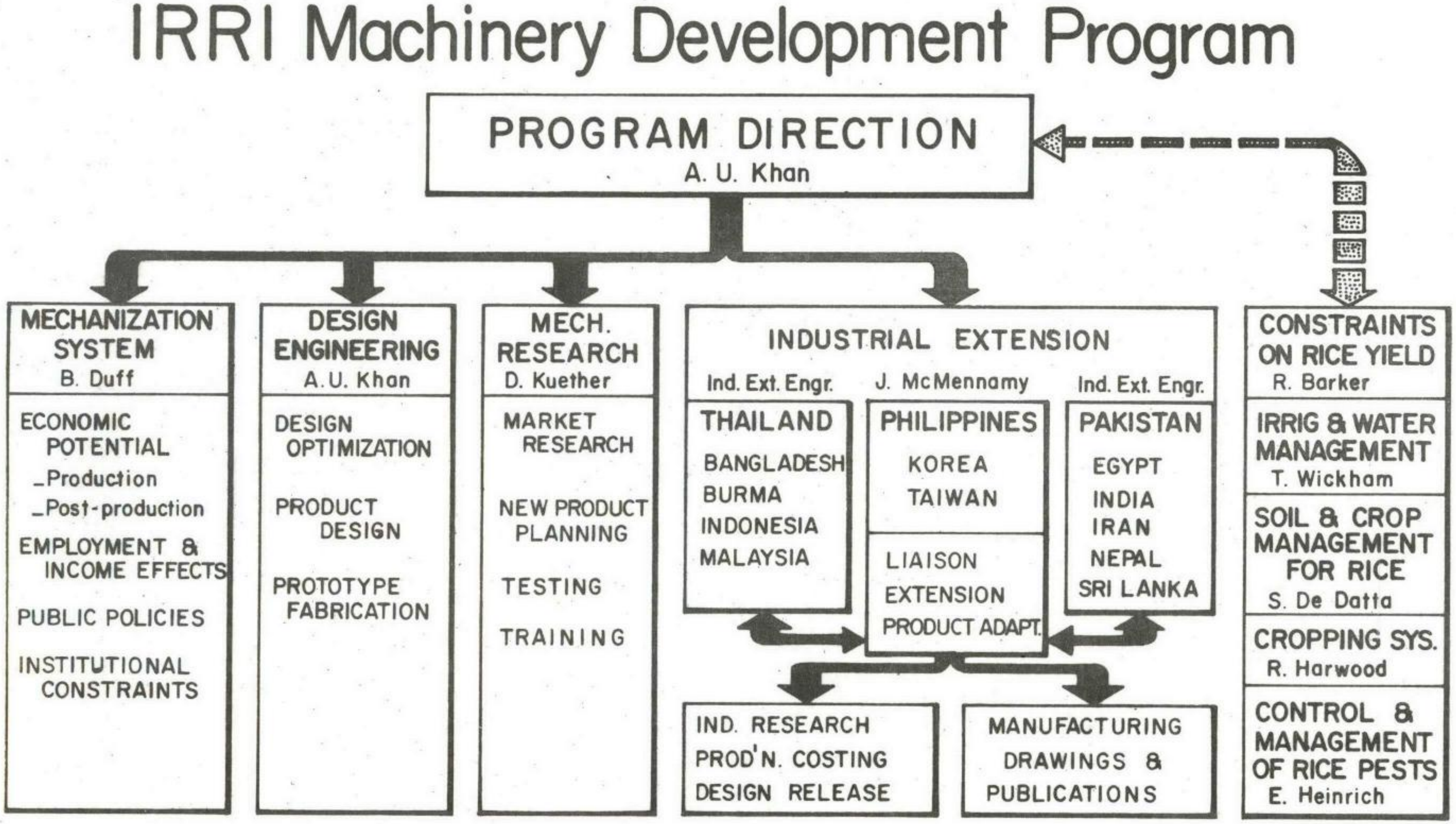

Fig. 1 Agricultural Engineering Department Organization.

CONSEQUENCES OF NEW TECHNOLOGY[1]

The introduction of improved agricultural technologies is often considered solely from the viewpoint of increased production, but the ultimate goal of technology development in the low-income countries of the world is the improvement of welfare. Rice production is only one of several elements that determine the welfare of society. It is, therefore, important to examine the likely consequences of the introduction of new technologies on the general welfare of the people in the countries affected through its impacts on various facets of economy and society. Research in this area includes projects that examine how the new rice technology has affected the welfare of individuals in rice-dependent societies, as well as evaluating how alternative courses of technology development might affect their welfare.

CONSEQUENCES OF
NEW TECHNOLOGY

The objectives of our research are as follows:

1. Examine the effects of the introduction of new rice technology (or of alternative technologies being planned) on production, incomes, distribution of incomes, and employment.
2. Identify the impact of the new technology on the farmer-input supplier-miller, wholesaler, retailer-consumer system.
3. Evaluate programs and policies designed to promote the adoption of technology and increased production in terms of their benefits to various groups in society.

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[1] Project Leaders - R. Barker. Y. Hayami and R. W. Herdt, Agricultural Economists.

Research on constraints to increased production and on consequences of new technology are, of course, closely linked. There is no sharp dividing line, although the areas of research are sometimes referred to, respectively, as "first and second generation problems." The research on constraints focuses on the gap between potential and actual output (Fig. 1). However, we view the work on consequences as broader in scope. It is not the effect of technology alone, but rather the effect of technology as it is introduced into a particular institutional and policy setting to which this project is addressed. The introduction of the technology may make it desirable to modify certain institutions or policies. On the other hand, the existence of a specific institutional structure will effect the preference for certain technologies from the standpoint of both economic efficiency and social equity.

The problem area of consequences is very broad. Clearly, it is not possible to cover the whole area with the modest size staff of IRRI economists. Nor is it advisable to allocate the major efforts of our economics staff for this program area, since our comparative advantage lies in the area more directly related to production. However, considering the fact that the new technology has often been criticized in popular writings on scientifically false grounds, it is critical for us to provide the correct information on the true linkage between technological development and the second generation problems. Such information is often obtained as by-product of experiments and surveys oriented toward direct production problems. On the other hand, since production problems are basically conditioned by the broader socio-economic environments, the analysis of second generation impacts is required to place the production problems in proper perspective. Thus, constraints and consequences programs are highly complementary. A modest amount of research on consequences is necessary to make the constraints studies meaningful and useful for policy purposes alones.

Results

The specific projects currently being conducted are identified in Fig. 1. The results of research related to output growth, price policy, and the distribution of benefits are discussed in that order.

Studies of sources of output growth have broadened our understanding of the relative contributions of the expansion of irrigation, more intensive cropping, and the use of modern inputs such as seed and fertilizer to the growth in rice production. Partly as a result of this analysis, social science research at IRRI was successful in documenting as early as 1965 that irrigation system capacity and management would rapidly become a constraint on the diffusion of high yielding rice varieties. An important component of this research has been the joint effort of economists in four Asian countries to study output growth in agriculture following the same methodology. IRRI economists contributed to the Philippine and Japanese investigations (see H. Southworth, ed., Agricultural Growth in Japan, Taiwan, Korea, and the Philippines, University of Hawaii Press, forthcoming).

Over a period of several years, studies of rice supply and fertilizer demand have been conducted to generate the appropriate price elasticities which are the building blocks of price policy analysis. Based on work completed in 1975 on the demand for fertilizer in Asia, the estimated short-run price elasticity of demand is -0.5. Thus, for example, a 10 percent rise in fertilizer price results in a 5 percent decline in fertilizer consumption. It was further estimated that the output elasticity of rice with respect to fertilizer input was 0.1 showing, for example, that a 10 percent increase in fertilizer would raise the production of rice by 1 percent. This information has proved particularly valuable in assessing the probable impact on rice production of the recent fertilizer shortage and rising fertilizer prices.

The scope of our work in the policy area was broadened this year to include the analysis of government policy alternatives. At the request of the Philippine Secretary of Agriculture, Arturo Tanco, who is also a member of the IRRI Board of Trustees, we examined the reasons behind the recent decline in Philippine fertilizer consumption and evaluated alternative fertilizer pricing policies. Subsequently, we developed in more detail and analytical framework for evaluating the benefits and costs of price support versus fertilizer subsidy. A major conclusion of this study is that when the farm level of fertilizer input is still well below the economic optimum, self-sufficiency in rice production can be achieved at lower cost to the government and greater benefit to society through fertilizer subsidy as compared with rice price support. Past experience shows that it is extremely difficult to maintain a two-price system for fertilizer, subsidizing only the food grain sector, without encouraging a black-market transfer to the export sector. Thus, it would seem more practical for the government to establish a single subsidized price for fertilizer and to compensate for the added cost of the program through an increased export tax on sugar.

Studies of the distribution of benefits have dealt (a) with the sharing of benefits from the new rice technology among the various claimants in the farming community-large farmers, small farmers, landlords, tenants, laborers, and (b) with the impact of the new technology on labor requirements and employment. Much of the basic data for this research has come from farm surveys. Two of our surveys in the Philippines have been conducted periodically over a period of several years in the same location in order to observe in-depth changes occurring through time. This information has been supplemented by our network village level surveys conducted cooperatively with social scientists in six countries and 14 locations in Asia (see Changes in Rice Farming in Selected Areas of Asia, International Rice Research Institute, 1975).

The findings of this research with respect to the distribution of benefits of the new technology can be summarized as follows. The data do not support the hypothesis that small farmers have generally lagged behind largely in the use of new technology that would increase their yields, income, and employment. It appears, however, that the relative size of farm within a community and the degree of concentration of ownership may be more relevant than absolute farm size in the adoption of modern technology. But the pattern is by no means uniform throughout Asia. Disparity between large and small farms in the sharing of benefits is much more apparent in South than in Southeast Asia because of the rather distinctly different nature of the village social structure. Furthermore, our studies in the Philippines suggest that the relative share of benefits to the landlord is declining despite what is generally regarded as the slow progress of land reform.

The adoption of modern technology is generally accompanied by an increase in labor requirements per hectare, but a decrease in labor requirement per unit of output. The adoption of labor-saving technology such as tractors and threshers is not closely associated with the adoption of yield-increasing technology, but is confined to fairly select areas and seems to be strongly influenced by government policies. Even in those areas of fairly rapid mechanization, our studies show in general an increase in labor input per hectare as more hand labor is spent for care of crop practices and for the larger harvest. These facts notwithstanding, there is a general tendency on the part of governments to equate mechanization with modernization, and hence, a need to examine critically the role of mechanization in a given rice farming environment. For this reason, we have been planning to undertake cooperatively with Engineering this year a project to identify a number of typical production systems with alternative combinations of labor and machineries, and to design systems for different environmental conditions and resource endowments. It is expected that this study would produce information that would assist in selecting priorities for our mechanization development program at IRRI.

In addition to the above analyses of income and employment, a model has been constructed during the past year, designed to analyze the relationship between technical change and income distribution taking into consideration the fact that a major portion of the rice crop on Asian farms is consumed in the home rather than sold commercially. The special feature of this model is that it distinguishes between the subsistence and the commercially-oriented farm economy. Our model and its application to the Philippine rice economy indicates that the introduction of modern technology in the production of subsistence crops in less commercialized economies, such as the high yielding varieties of rice in tropical Asia, has an effect of promoting more equal income distribution through the downward pressure exerted on prices and hence, on those farmers with a large proportion of marketed surplus.

Future Plans

In planning for the next five years, it is important to differentiate the projects that are going to be undertaken for short-run (one year), medium-run (two to three years), and long-run (four to five years) periods.

Short-Run

The projects to be accomplished within the next year are those which are now underway and for which both theoretical and methodological frameworks are relatively well established. Belonged to such a category are: (a) Analysis of Changes in the Supply Response of Rice, and (b) Estimation of Social Returns to Rice Research in the Philippines.

The former project will update for the Philippines the earlier study done a decade ago which applied for the period before the development of modern rice varieties. One of the major findings was that there was no significant price response in the yield of rice. Since the introduction of modern varieties has the effect of increasing fertilizer-responsiveness in rice production, it is expected that the yield response to price through the adjustment in fertilizer input would have become significant for recent years. The hypothesis on the structural change in the price response of rice yield due to the introduction of modern varieties is going to be tested on the time-series data of both the Philippines and Thailand. The estimation of supply response parameters for more recent years is necessary for the improvements of policy evaluation studies.

The latter project on the estimation of the rate of returns to investment in rice research is along the tradition of studies on hybrid corn research in the United States and on rice research in Japan (see M. Akino and Y. Hayami, "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development," American Journal of Agricultural Economics, Vol. 57, No. 1, February 1975, pp. 1-11). The data on the costs of rice research at various agencies in the Philippines since 1957 have been collected. The benefits from research will be estimated in terms of consumers' and producers' surpluses resulting from the shift in rice supply curves. The rates of returns to rice research will be calculated by associating the benefits with the costs.

Besides those two studies, it is envisaged that the studies on income distribution and price policy evaluations, which have been accomplished in this year, will be further revised and developed. The study on the shares of farm earnings, based on our long-term Philippine surveys, should be complemented by the analysis on factor-ownership distribution to draw conclusions on the income distribution effects of new rice technology.

The evaluations of rice price-support and fertilizer-subsidy policies should be expanded to compare the effectiveness of such price policies with a longer-run investment in production infrastructure, such as irrigation system. Another direction of extension is to compare impacts of price policies between rice-importing countries (Philippines) and rice-exporting countries (Thailand).

The integrated survey on the economic activities of peasant households in a typical rice village in Laguna has been continuing since last April. Upon its completion, we will try to describe their production-consumption-capital formation activities in a set of double-accounting tables. If this pilot project is successful, we will extend it for medium- to long-run time span, in order to generate basic micro information for consequences projects.

Medium-Run

Studies that are planned for medium-run horizons are those on the effects of new technology on the uses of inputs. Especially, the impacts on labor and land utilization would require major attention. Earlier studies on labor use at micro levels need be reiterated by newer data sets. Those micro studies must be supplemented by the aggregative studies on employment, in relation to the progress of mechanization. Evaluations of the effects of tariff and credit policies on mechanization and farm employment must be undertaken in greater depth. Highly complementary to this effort will be the research just initiated on analysis of rice farming systems.

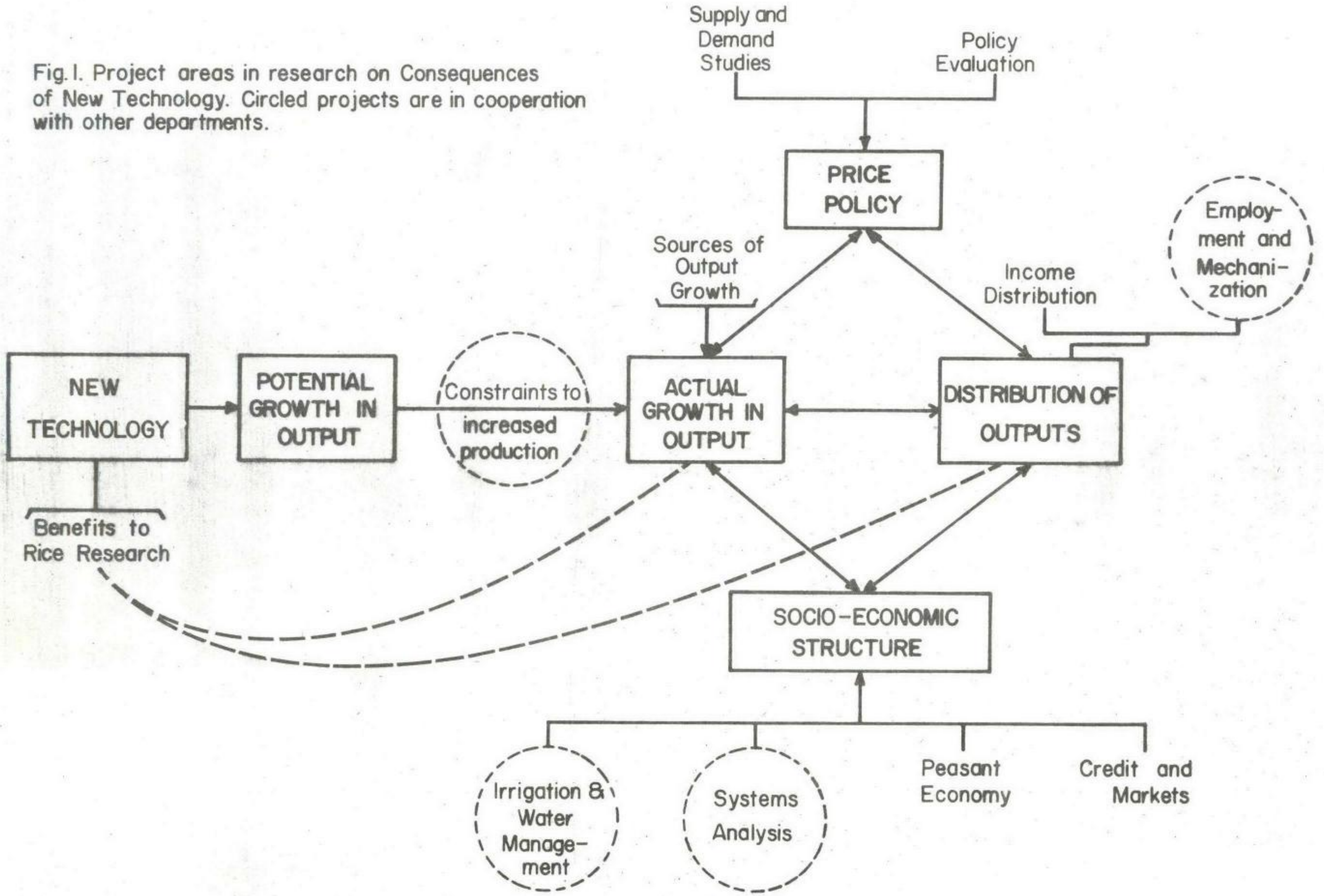
In spite of its obvious importance, the impact of new rice technology on cropping pattern and land utilization has not been analyzed. Substitution among rice and other crops and the development of new cropping system as the results of new rice technology have direct bearing on the total food supply and the welfare of consumers. This problem should be approached in collaboration with the cropping systems program.

Long-Run

There are a number of projects that have to be continued in a long-run basis. For example, the long-term Philippine surveys that have provided the data for the analysis on the changes of factor earnings and earning shares in relation to the income distribution problems should be reiterated every three to four years in order to generate the data basis for the study of technological change and its impacts at farm level. Also, farm budget studies in terms of relatively simple cost-return analysis must be prepared in time-series wise, so that we can trace the historical changes in farm production structure. Monitoring of rice and input prices in relation to government policies is also necessary on a continuing basis.

Besides those routine works, we should try to fill our knowledge gaps in the long-run. So far, we have done very little work on the effects of new rice technology on such agrarian institutions as land tenure, credit and marketing. Probably, those areas do not belong to our comparative advantage. However, it is important to develop gradually our capability to deal with such problems to the extent that they are related to the technologies that the Institute generates. The best way to accomplish this is by encouraging and supporting research undertakings by non-IRRI scientists and Ph.D. degree candidates in this area.

Fig. I. Project areas in research on Consequences of New Technology. Circled projects are in cooperation with other departments.



TRAINING PROGRAM[1]

One of the most important components essential to the successful implementation of national rice programs is the availability of properly trained and highly motivated researchers and extension workers. The International Rice Research Institute contributes its share towards this end through the Institute's training program.

IRRI training programs are integral parts of both its core research program and of its international cooperative efforts. The research scholars/fellows work with IRRI scientists and are in fact part of the team conducting experiments/studies on the different research areas, e.g. evaluation of varieties/lines for resistance to insects, which is a part of the GEU program. The training program also provides trained people for all four categories of IRRI's international cooperative activities: 1) collaborative research; 2) international research networks; 3) strengthening of national capabilities; and 4) coupling of research and action programs.

The specific training programs are:

EXTENSION/PRODUCTION COURSES

1. Six months rice production course - The course is offered once a year to train rice production specialists and extension workers in the principles and practices of modern rice production. Participants are out in the rice paddy/field about one-half of the time learning/improving skills in rice production and the other half in classroom/laboratory learning rice science and the latest in rice production technology.

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[1] M. R. Vega, Assistant Director

The primary purpose of the rice production course is to train individuals to conduct similar training programs in their home countries. Towards this end, participating national programs are urged to send a team composed of 3-4 individuals and who will remain as a team of trainors when they return home. Thirty to thirty-five participate in the course each year.

2. Two weeks rice production courses - The two-week course attempts to, within a short period of time, impart to participants the latest technology of growing rice. Through the use of staggered plantings of rice, the participants are able to perform the various production operations and to observe rice plants at critical stages of growth. Two such courses are regularly offered in a year. One in November is organized and implemented by participants of the six months rice production course as a means of training them how to train others when they return to their respective countries. Another two-week course is offered in December by Institute staff and is intended primarily for IRRI research scholars/fellows training in more specialized research areas. The two-week course can accommodate as many as forty individuals.

RESEARCH-ORIENTED PROGRAMS

1. Degree programs - Participants (research scholars/fellows) work either for the M.S. or Ph.D. degree. The program is carried out in cooperation with various universities but especially with the College of Agriculture, University of

the Philippines at Los Baños.

The course requirement is completed in the cooperating academic institution and the thesis research conducted at IRRI. The M.S. degree normally takes two years to complete; three years is the usual period necessary for the Ph.D. degree.

2. Non-degree programs - A non-degree participant gains valuable research experience by working on a specific research project under the guidance of an Institute scientist. He participates in planning and assumes major responsibility for gathering and analyzing data, and for the preparation of the report. The period of training is primarily determined by the need of the individual, but normally such participants are in residence for 6 to 12 months.
3. Post-doctoral fellowships - Post-doctoral fellows carry out advanced and more independent research under the guidance and/or in collaboration with IRRI scientists. The duration of a post-doctoral fellowship is usually 1 to 2 years.
4. Training programs supportive of international research networks.

   a. Cropping systems training program - The objectives of the five months course are to: train participants how to conduct scientifically designed applied and adaptive research to solve problems in cropping systems in their respective areas; identify and solve production constraints of these crops when grown alone or in combination with other crops; recognize and apply the important concepts of crop science to better utilize farmer resources through improved cropping patterns; and, know and perform cultural practices involved in growing the various field crops commonly used in cropping systems built around rice.

b. GEU training program (4 months) - The program was first offered in 1975 and is designed for individuals involved in the development of varieties and emphasizes the need for a multidisciplinary approach for such an undertaking. A participant from a particular discipline is expected to have a better understanding of the roles that other disciplines play in a team approach to varietal improvement. However, the individual is given the opportunity to spend ample time in the specific problem area (e.g. screening for insect resistance) he will be expected to concentrate when he returns to his country.

c. IRAEN training program - The purpose of the two months training program is to train agronomists and economists in the methodology and techniques being used to determine and measure the constraints preventing Asian rice farmers from exploiting the full potential of the modern rice varieties. The methodology has been developed through use in sites in Thailand, Indonesia, and the Philippines and has been modified through experience here. The IRAEN course was also first offered in 1975.

d. Agricultural Engineering training program - This training program deals on the manufacture and utilization of IRRI designed machines. It is intended for individuals from the engineering staff of our cooperating organizations and manufacturers who are now, or plan to be, closely associated in the manufacture of IRRI machines. Participants should have an engineering background and a practical orientation toward the manufacturing and application of machines. This two-week course was likewise offered in a more formal manner in 1975.

Summary of Accomplishments:

Since the Institute offered educational opportunities to rice research and extension workers, 1,026 individuals have undergone training at IRRI (1975 participants not included). From 1970 to 1974, an average of 143 participants are in residence for all or part of the year each year. About 90 percent of the participants come from South and Southeast Asia where most of the world's rice is grown.

The "alumni" of IRRI's training programs play significant roles in their respective countries' efforts to increase rice production. As cooperators of IRRI scientists, they serve as vital links in the global effort to identify rice varieties and production technologies suitable for the wide range of conditions where rice is grown.

Future Plans:

The Institute will continue to offer the same kinds of educational opportunities to rice research and extension workers. Within the next five years, greater emphasis will be placed in the training programs that are supportive of the different international research networks. These programs include the GEU training program which not only focuses attention to the need for a multidisciplinary team approach to the development of varieties but also supports the International Rice Testing Program. The Cropping Systems training program will continue to provide trained manpower to implement the different applied research trials called for in the various sites forming the rice-based cropping systems network. Agronomists/economists who will conduct studies designed to identify the biological and/or socio-economic constraints to high yields in farmers' fields will be trained in the IRAEN training program. The agricultural engineering course will continue to bring together the sectors of the industry needed to put simple and cheap machineries in farmers' hands, i.e. the researcher involved in the design, development, and evaluation of machines and the manufacturing sector.

The other area of emphasis will be to increase the number of post-doctoral fellowships. The Institute will continue to utilize the post-doctoral fellowships as a means to:

1. assist rice scientists from developing countries who have obtained their degrees from the developed countries get adjusted to the problems they will meet at home,
2. give rice scientists the opportunity to reorient, sharpen and/or up-date their skills, techniques, and knowledge in rice research,
3. serve as a "training ground" for scientists who may be employed by the different international research institutes and/or outreach program of such institutes,
4. strengthen research programs at IRRI.

Appropriate training courses/programs will be developed and implemented as necessary to support IRRI's core and network research programs and to meet its commitments to improve the technical proficiency of national research and extension staffs.

RICE PRODUCTION TRAINING AND RESEARCH PROGRAM (RPTR)[1]

The two major objectives of this program are: Training in Rice Production, and Conducting applied research in farmers fields. The overall training program of IRRI is described on pages   of this report. The applied research program is described as follows:

> There is a tremendous backlog of a new technology in rice that is currently not being adequately utilized. Applied and adaptive research is needed to adequately couple this information to national production program in order to increase farm output and the social welfare of developing countries rural populations in the shortest possible time.

RICE APPLIED RESEARCH

There are several categories of applied research work conducted by the RPTR. A typical research program would consist of:

1. INSART - IRRI New Selections Applied Research Trial
   This trial is conducted under insect protected and unprotected conditions. This research project includes the testing of nine selections and one short duration variety. Also, three medium-early duration varieties and six new selections were included.
2. HART - Herbicide Applied Research Trial
   This trial was on both direct seeded and irrigated rice.
3. NVART - Nitrogen X Variety Applied Research Trial
4. IVART - Insecticide X Variety Applied Research Trial
5. LEM - Levels of Management Applied Research Trial
6. SEART - Stand Establishment Applied Research Trial
7. Production Plots (4 Trials)
8. Growth Stage Plots

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[1] Project Leader: V. E. Ross, Rice Production Specialist and L. D. Haws, Senior Scientist.

9. International Display Plots
10. Varieties Named by Other Countries From IRRI Supplied Materials
11. Spacing Trials

This type of research provides an opportunity for the staff of the RPTR Department to keep up-to-date on the latest production practices and varieties as well as providing the 6-month trainees with training and experience in doing applied research.

RPTR - IRRI-BASED PERSONNEL

IRRI-based RPTR personnel also conduct various types of applied research from time to time in nearby provinces. Most recently, this has involved the INSART and FENSART trials. Data from these variety trials are included as a part of the information used in evaluating new releases. From time to time, fertilizer, herbicide and insecticide trials are also conducted.

APPLIED RESEARCH ON RAINFED AND UPLAND RICE

Beginning in 1971, IRRI conducted 13 different kinds of trials on rainfed and upland rice in four municipalities in Bulacan and one municipality in Nueva Ecija province. In addition, several trials with various upland crops have been conducted each year following the harvest of the transplanted rainfed and upland rice crops in an attempt to determine the feasibility of producing various upland crops following upland and/or rainfed rice. This project was supported by a $90,000 grant from the Rockefeller Foundation. A total of 493 applied research trials have been conducted over the past four years. The findings from these trials have resulted in the discovery of much new and useful production technology. For example:

a) Variety Trials

Indicated that many of IRRI's varieties and selections would essentially double the yield of the varieties grown by most farmers in the area. In 1971, four of IRRI's varieties and selections averaged 4.3 t/ha. as compared to 2.3 t/ha. of INTAN, a favorite variety of farmers in Central Luzon. In addition, a variety trial with upland rice including IR8 and IR5 produced 2.7 and 3 t/ha. respectively as compared to 1.9 and 1.7 for the two best yielding upland rice varieties. This information dispelled the myth that the new short and intermediate high yielding varieties would not do as well as the tall varieties under upland conditions.

b) Nitrogen Trials with IR8 and IR5

Short and medium height varieties. It was discovered that they responded very similar to nitrogen fertilizer under both rainfed and upland conditions, with 90 kg/ha. of nitrogen as the optimum rate.

c) Herbicides

Of the six herbicides tested on upland rice, all provided satisfactory control of weeds. Benthiocarb, Butachlor, C-288, Preforan, A-820, US B 3153. The best control was given by C-288. Under rainfed transplanted conditions, all of the following chemicals gave good control of the three main classes of weeds: 2, 4-D IPE (G); 2,4-D IPE (E. C.); Saturn + 2, 4-D IPE (G); TCE Styrone + 2, 4-D IPE (G) and C290 + 2, $-D IPE (G).

To control weeds in direct seeded rice under rainfed conditions proved more difficult. All of the chemicals that were found effective in the upland trials were either ineffective or were toxic to rice in going from upland to flooded conditions except Butachlor. This material is now the only herbicide that effectively controls weeds in direct seeded rice under rainfed conditions and is not toxic to the rice plants. This chemical gives adequate control only if applied on <u>wet soil</u>, and before weed seeds germinate.

The ability to control weeds in rice when direct seeded under rainfed conditions led to the discovery of the possibility of producing <u>two crops</u> of rice where the practice was to grow only one.

Of 26 million hecates of rice in Southeast Asian countries grown under rainfed conditions, approximately 60% could grow an additional crop of rice. In addition, another 20% of this area which is irrigated from rivers and which produces only one crop, can also produce an additional crop by using this technology.

d) Management Trials

Another trial which provided useful information was the four levels of management ranging from a very low level of inputs used by 70% of the farmers to a high level of management using 100 kg/ha. of Nitrogen and 40 kg/ha. Potassium. Butachlor was used as the control for weeds. Seed and seedling treatment with Furadan plus two applications of one kg/ha. of Furadan plus a folidol spray at heading provided excellent insect control.

During the cropping season in 1971, a six-week drought occurred from the middle of August through the month of September. The trials with the highest management level (level 4) came through this drought with standing water or mud in the paddies while the farmers' plots on the same contour, planted at the same time and using the same variety, were completely devastated by the drought. The interaction of the herbicide gave good control of weeds which reduced competition for nutrients and water, while the high fertilizer application produced a heavy canopy which reduced evaporation from the soil.

e) Insecticide Trials

Insecticide trials indicated that insects, in general, are a much greater problem on rainfed than on upland rice. Carbofuran used as one of the treatments controlled the green leafhopper and tungro virus, providing excellent protection during the tungro epidemic in 1971. This finding was highly important. Some of the plots produced up to six tons of rice/ha. and helped to identify a package of practices that could be recommended to farmers the first year. This enabled the team to move ahead with a pilot extension program in 1972. Luckily, Furadan was used in all plots except in the insecticide trials. There was no harvest in farmers' fields surrounding these trials. The rice crops were completely destroyed in fields around these experiments.

This trial also helped to identify IR20 as the most resistant variety to tungro virus. This lead to it being recommended for the "Masagana 99" program. It ultimately covered an estimated 75 to 80 percent of the rice area in the Philippines.

PILOT EXTENSION PROGRAM

In 1972, one year after the beginning of the applied research on rainfed and upland rice, a pilot extension program was launched to test on a full farm basis the package of practices derived from the previous year's research trials. This pilot program was called "Masagana 99". It was successful in demonstrating that yields could be raised from 35 to 65 cavans/hectare to more than 100 cav/ha. It also identified the constraints that would have to be removed if the program was to be successful as the National Rice Program. In late 1972, the Philippine Government decided to adopt the "Masagana 99" pilot program as their nat-onal rice plan and adopted the "Masagana 99" name. The National Program has been exceedingly successful in changing the Philippines from a large importer of rice to self-sufficiency. Production this year is expected to be 126 million cavans an all time record high.

CURRENT PROGRAM

IRRI-PCAR Cooperative Applied Research Project

Much of the current work of the RPTR is centered around this project. In 1974, the Rockefeller Foundation provided a second grant of $90,000 to IRRI to aid in the institutionalizing of the methodology used in developing and implementing the "Masagana 99" production program. We have chosen the two-crop system of rainfed rice as the project to develop. Apllied research and pilot extension projects are being developed at 32 locations covering the Philippine rainfed areas with special emphasis on solving the various problems of producing an extra crop either of rice or various upland crops in the seven rainfall patterns identified in the Philippines. This objective has been achieved in some areas where a full-blown production program will be developed in cooperation with the national government (NFAC) in 1976.

The research has concentrated on determining the time to establish the direct seeded crop of rice; the best method of establishing the second crop of rice; the testing of promising varieties; and determining the feasibility of producing certain upland crops on light soils for the second crop and a possible third crop of a short duration upland crop on heavy soils.

Bulacan Applied Research and Pilot Extension Work

One RPTR staff member has been located in Bulacan to develop a sufficiently large area of direct seeded rice to demonstrate the importance of a package of practices worked out by the RPTR. About 600 hectares of direct seeded rice have been produced under the supervision of this staff member and BAE technician assigned to this project. The results have been rather spectacular and NFAC is clamoring for the RPTR to assist it in spreading this technology to other areas. In fact, a national program is being planned.

Applied research is also being conducted to determine the best way of establishing the second crop of rice on heavy soils and in producing several different upland crops as a second crop on light soils in San Rafael area.

PLANS FOR THE FUTURE:

In the area of training and applied research, several problems will receive attention over the next five years:

1. There will continue to be a need to conduct the 6-month training program.
2. The lectures on skills, science and communications will be packaged as a kit (tapes and complimentary slides) to be made available to training centers

throughout the world in local languages.

3. Applied research will need to be continued to identify varieties, new and better herbicides and insecticides as well as exploring other ways of reducing the pest problems with special reference to improve the package of practices for producing an extra crop on the rainfed, upland and stream irrigated areas of Southeast Asia.
4. The most urgent need in the next five years will be to work with leaders in developing countries to export the methodology used in developing the "Masagana 99" production program in the Philippines. With the present backlog of technology, rice production can be increased more easily and more quickly by developing sound programs to test and adopt present technology than to depend upon long drawn out research efforts.

ARTICULATION OF THE INTERNATIONAL AND NATIONAL SYSTEMS: THE IRRI OUTREACH PROGRAM[1]

International agricultural research centers provide an innovative approach to the effective use of science in solving the world's food supply problem. Conceptually, they are sharply focused scientific establishments located in developing countries but as well equipped and manned as the best in the more developed world. Their prime objective is to use the genius of science to help a hungry world feed itself.

In my view, International Agricultural Research Centers must have two primary criteria for success. First, they must be centers of excellence. They must bring to bear the world's best scientific talent on the solutions of the practical problems for which they were established to solve. Utilizing this talent they must develop varieties, strains, cultural practices, and farming systems superior to those in existence. In short, they must have or must produce superior products on which improved technology for the developing world can be based.

Secondly, the international centers must serve as stimulating and collaborating forces to improve the quality and output of national research programs. They must do more than merely make available their own products for use by their country cooperators. They must develop collaborative means of improving the scientific expertise, operational efficiency, and output of the national research programs. These things

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[1] N. C. Brady, Director.

ARTICULATION OF THE INTERNATIONAL AND
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they must do, not as interested bystanders or advisers, but to the extent feasible as collaborators in areas of mutual interest.

IRRI's Traditional International Involvement

From its inception, IRRI has responded to this dual role -- as an emerging center of excellence and as a collaborator with rice production countries.[1/] While it was necessary in the early days of the Institute to place heavy emphasis on developing a center of excellence, the international role was not neglected nor could it have been.

Germ Plasm Collection

The original seeds collected for IRRI's germ plasm bank come from existing national stocks or from samples collected by collaborators in cooperating countries. The practice of splitting each sample collected with one part being retained in the country and the other being sent to IRRI set the stage for this mutually beneficial program. In total, more than 33,000 samples have been collected from cooperating countries for this germ plasm bank.

As the seed bank has grown in size, the return flow of samples to national programs has expanded. Last year (1973), nearly 8,000 such samples were requested by and sent to scientists working in national programs. Likewise, seed of lines from IRRI's breeding programs are furnished upon request to country scientists. About 8,000 samples of these lines were sent in 1973.

[1/] McClung, A. Colin 1972, "IRRI's role in Institutional Cooperation in Asia" in Rice Science and Man, Los Baños, Philippines, pp. 19-40.

Publications

Very early in its history (1963), IRRI published a bibliography on the world's rice literature and annually supplements the original publication for use by scientists throughout the world. This service is especially important since much of the rice research literature is published in Japanese, a language not easily translated by researchers in developing countries. Upon request by rice scientists, photocopies of selected articles are made available, a significant service to the staff of national research agencies.

IRRI scientists have written a number of books and special publications on rice and its enemies. Also, the proceedings of important conferences and symposia are published and made available to scientists in cooperating countries.

IRRI also published quarterly the "IRRI Reporter" in which brief summaries are given of not only research findings at IRRI but of cooperative research done with scientists in other countries. The IRRI annual report provides more detailed information on these research accomplishments.

Conferences, Symposia and Workshops

Conferences, symposia, and workshops which provide opportunities for communication among rice workers have been held regularly since the Institute was established. The annual international rice conference, initiated in 1969, has traditionally provided opportunities for scientists and research administrators to review research results from all important rice growing areas. This annual conference is now being used also as a forum for making cooperative plans for future programs.

A series of special symposia has permitted in-depth emphasis on subjects of broad interest to rice scientists. Scientists from both the developing and more developed world are invited to review the latest findings in the subject area of the symposium. We only recently completed a symposium on "Climate and Rice," the eighth such major symposium to be held since the Institute was established. The title and dates of previous symposia and workshops or conferences are given in Table 1.

Training

IRRI's training program is oriented specifically to upgrading the expertise of rice scientists and educators in cooperating countries. Selected in consultation with officials in their home countries, the trainees participate in one of two types of training experience. Those with extension and applied research orientation are involved in special six-month production research training courses. In one such course, they are given practical experience in all phases of rice production; in the other, they are concerned with rice cropping systems. After completing these courses, participants are prepared to give similar training to extension workers in their own countries. Such training imparts needed knowledge and skills, but perhaps more importantly, it provides an attitude of pride in being part of a team which can use science to help farmers produce more food.

Those trainees who are research oriented can participate in short on-the-job research training programs or if the needs dictate, they can take course work at the University of the Philippines at Los Baños to fulfill the requirements for the M.S. or Ph.D. degree. Their thesis research is being done at IRRI, giving them an opportunity to orient this research to the practical problems they will face when they return home.

In cases where it is desirable for the trainee to do some of his graduate program overseas, arrangements are being made to have at least part of the course work taken in an overseas university but the scholar returns to IRRI to do his/her research work on a problem of some relevance to his/her own country. Whether the IRRI scholars and fellows obtain their academic training at UPLB or overseas, they have the advantage of orienting their research to the solution of practical problems. Furthermore, they live in a cultural environment more nearly like their own than would be the case if they did their research in the United States or Europe.

Post-doctoral research experience is provided to a select group of young scientists from rice growing countries. Some are selected from among scientists currently working in national programs with the objective of helping them upgrade their training and experience. Others have only recently completed their Ph.D's and need to sharply focus their attention on rice production problems before returning home.

Since IRRI began its training program in 1962, about 800 man-years of training has been given to scientists and educators from 45 countries. The distribution of the students among the regions is shown in Figure 1. Although most of them have come from South and Southeast Asia, a number were from Africa and Latin America and a few from Europe and North America. At the present time, IRRI is providing about 90 man-years training each year, 25 of which is for non-degree scholars and fellows, 55 for those registered for M.S. and Ph. D. degree training and 10 for post-doctoral fellows.

Three Cooperative Approaches

IRRI's cooperative programs with national research organizations have four primary objectives:

1. To implement location-specific research which cannot be done effectively at IRRI headquarters in the Philippines (we term this collaborative research).
2. To develop international research networks on problems of common interest (termed international testing).
3. To strengthen national research capabilities (outreach services).
4. To strengthen capacity of national programs to utilize research findings in rice production programs.

Any given cooperative project may have more than one of these objectives. In some cases, all may be involved. In achieving these objectives, one of the primary goals is to speed up the development of locally viable production technology.

Collaborative Research

In carrying out IRRI's core program, IRRI scientists often find that major problems cannot be attacked conveniently at our headquarters in Los Baños. For example, some serious insect and disease pests do not occur at that location, and yet it is essential that the resistance of IRRI's varieties and breeding lines be thoroughly tested for resistance to the pests in question. Examples are research on the gall midge insect in India, on the tungro virus disease in Indonesia and on a suspected biotype of the brown planthopper in India.

The tolerance of different rices to toxic soil conditions can also best be ascertained if tests are run in the geographic areas where the problem exists in the field. Tolerances to excess salt, excess acidity, alkalinity and excess iron are examples. Arrangements are being made with scientists in India and Sri Lanka to implement field screening trials to better identify tolerances to these toxic conditions.

In some cases, the collaborative research can be accomplished primarily overseas with little direct input from IRRI scientists other than in the planning stages. The research in question is sufficiently important to the cooperating countries as to justify additional national,financial and personnel inputs without outside assistance. Testing IRRI lines in tungro virus infected parts of Indonesia and in areas with brown hopper pressures in India are examples. In other cases, IRRI scientists are involved, not only to help implement the overseas research, but to carry out supplementary experiments at IRRI headquarters. Research on flood tolerant lines and varieties in Thailand and at IRRI headquarters is an example.

Collaborative research may also be undertaken in cooperation with more than one country through a network approach similar to that discussed in the next section. An example is research being planned on deep water rice, a type of culture for approximately ten percent of the rice area of Asia. The area of deep water rice in the Philippines is insignificant, but large areas are found in Bangladesh, Thailand, Vietnam, India and Indonesia. We are developing a cooperative research program with the Ministry of Agriculture in Thailand to work on deep water rice. Two IRRI scientists located in Thailand will collaborate with their Thai counterparts in expanding and strengthening an ongoing deep water research program there. They will also collaborate with scientists in other countries wherein deep water rice is widely grown.

This past summer, IRRI was pleased to join the Bangladesh Rice Research Institute and FAO in sponsoring a deep water rice research conference in Bangladesh. The conference was held as the disastrous 1973 flood waters were only beginning to recede, giving the participants a field example of the problems faced by cultivators in the deep water areas. Initial plans were laid for a cooperative program involving scientists from each of the major deep water rice growing countries. Further plans will be developed at the 1974 rice research conference to be held in April at IRRI.

If plans can be implemented, IRRI's core work on deep water rice will be implemented through the cooperative program in Thailand and through correlated research under controlled conditions at IRRI headquarters. In turn, this cooperative program will be tied into a regional network involving scientists and national research programs, not only in Thailand but Bangladesh, India, Vietnam and Indonesia as well.

There is a large number of research areas of mutual interest to IRRI scientists and their associates in India. To provide a formal mechanism to encourage and support such collaborative research, a Memorandum of Agreement has been signed with the Indian Council of Agricultural Research. This agreement provides for collaborative research planning and implementation as well as for the exchange of scientific personnel. Each year a work plan will be developed. (The 1974 plan was agreed upon last week). This plan clearly identifies the areas of mutual interest, the division of responsibility in carrying out the needed research, and the areas in which personnel will be exchanged. This pattern of operation has many advantages and is being pursued in a modified form in the Philippines and in Thailand.

While the primary objective of inter-institutional collaborative research is to plan and implement specific areas of research, a secondary objective is the strenthening of national capabilities. In implementing the planned research, both IRRI scientists and their counterparts will improve their capabilities. New techniques will be developed and utilized. Interdisciplinary approaches will be encouraged. This procedure will provide training opportunities in a framework that is satisfying to scientists from IRRI and from the developing countries alike.

International Networks

The second phase of IRRI's outreach program is to assist in the development and implementation of international research networks. These networks provide a mechanism for scientists from different countries to jointly plan and implement research projects which can be carried out more effectively when done in several countries at once, using common objectives and procedures. Up to the present time, four such networks are in existence or are being set up:

1. International Testing Program (ITP)
2. Genetic Evaluation and Utilization (GEU)
3. International Rice Agro-Economic Network (IRAEN)
4. International Cropping Systems Network (ICSN)

Other informal networks exist for research on herbicides and fertilizers.

IRRI's initial objective is to serve as a catalyst for the initiation of these networks. Through routine contacts within rice growing countries, through workshops and conferences, and through special discussions with cooperating scientists, the need for cooperative research and testing programs becomes apparent. Once the general area of mutual interest is identified, scientists from cooperating countries are brought together to set up the general framework for the network and to identify the specific experiments, surveys or studies to be implemented. To minimize travel expenses this is usually done in connection with other conferences or workshops sponsored by IRRI.

In some cases, IRRI or one or more of the cooperating countries may have already run some pilot experiments on the subject research area which serve as a guide. For other projects, a loose cooperative framework may already exist, only a formalization being necessary for the specific experiments in question.

Great care must be taken to obtain full involvement of national research personnel in the planning as well as the implementation of the network. In no case can the impression be given that the network is merely an extension of IRRI's program. To be successful, the network research must be planned and implemented by the country scientists.

IRRI's role in the implementation of the network varies depending on the project area. It may serve only as a catalyst or a focal point of discussion, but is generally much more extensively involved, since some of the research is done in the Philippines by IRRI scientists or overseas by our international staff.

In each of the four projects currently underway, we have assigned an IRRI scientist to serve as network coordinator. He has the responsibility in the case of the genetic (GEU) trials; for example, of collecting seeds of lines and varieties to be tested and of disseminating them among the cooperators. He will facilitate communications among cooperators, and will coordinate the exchange of biological materials, the collection and collation of data and the planning of workshops or conferences. The coordinators visit the countries, review ongoing experiments and program plans with the cooperators, and serve in a liaison capacity.

To the extent funds are available, we encourage scientists from one country to visit experiments in other countries so they can see more celarly how the international network can be useful to them. Also these visits will have some training value as new techniques are demonstrated and innovations evaluated.

The international testing network of the Genetic Evaluation and Utilization (GEU) program has been underway since the early sixties. In cooperation with national research centers, nurseries to screen rice lines and varieties for insect and disease resistance have been set up. For example, more than 300 international blast nurseries have been conducted in 25 countries since 1963. Similar tests for bacterial leaf blight were initiated in 1972 and for sheath blight in 1973. International yield trials were initiated in 1973 and observational nurseries are being established for general evaluation of several hundred of the best selections from both national and international sources.

A marked expansion and intensification of the international testing program is underway (See Figure 2). Included will be international nurseries for not only the major insects and diseases, but for adverse soil and weather conditions as well. Observational nurseries and yield nurseries will be included. The tests are not limited to paddy rice.

Upland rice nurseries are also implemented as part of the program. To plan this enlarged program, a small group of scientists from country programs and IRRI counterparts are meeting at IRRI in late January 1974. They will develop preliminary plans which will be thoroughly reviewed and finalized at the 1974 rice research conference held at IRRI in April. The scientists will build upon past experience, but will develop plans for the international tests which are compatible with national testing programs. Their plans will include mechanisms for monitoring the tests and for visits by scientists from one country to another to observe progress of the research. The enlarged program will be supported by a grant from the UNDP.

The Agro-economic Network is based upon the success of a preliminary cooperative study among economists and agronomists from several countries who were concerned with rice yields in relation to different types of farming. Initially the International Rice Agro-economic Network (IRAEN) will be concerned with an international study of constraints on yields in farmers' fields. It is innovative in that its success depends upon the close collaboration of economists and agronomists who will attempt to measure the relative importance of different constraining factors on rice yields under different environmental conditions in South and Southeast Asia.

A preliminary planning conference involving scientists from Thailand and Indonesia was held at IRRI in early December 1973 to develop planning strategy. A larger conference to which at least one agronomist and one economist from five countries are invited will be held in Bangkok, Thailand in March 1974. At that time, plans will be finalized for the number and type of experiments to be run and the methods to be used.

In the meantime, pilot studies are underway in Thailand and the Philippines to evaluate the proposed methodology for next year's field experiments and studies. IRRI scientists are serving as coordinators and conveners of planning conferences but will not dictate the work to be done nor the methods to be used.

Planning and implementation of the Cropping Systems network is using similar procedures to those being followed for the GEU and IRAEN. Potential research locations are being chosen on the basis of broad agro-climatic regions. A network coordinator has visited most of the countries of Southeast Asia. In consultation with local scientists, potential sites for cropping systems trials have been identified in Indonesia and the Philippines and discussions are underway with scientists from other countries. A cropping systems workshop and planning conference is planned for mid-March at IRRI. To this conference scientists from each of the countries in Southeast Asia are invited. Their general objectives are the same as those for the GEU and IRAEN programs.

The deep water rice research network has already been mentioned. It too will involve national researchers in both the planning and implementation processes.

IRRI scientists have great expectations for the international network approach. It will give country scientists experience in planning as well as implementing research. Also, it illustrates the international nature of science. And it will provide a better understanding by IRRI scientists of the problems faced by farmers and by researchers in the cooperating countries.

Strengthening the Capacity of Country Research Programs (Outreach Services)

Both the collaborative research and international network approaches have as corollary objectives the strengthening of national research capabilities. They are complemented by the outreach services of IRRI which are exemplified by two types of programs: (1) general assistance, and (2) formal cooperating country projects.

General assistance to national research programs has been an integral part of IRRI's activities since the early sixties. The training of country scientists, the frequent overseas visits of IRRI scientists both as consultants and collaborators, the dissemination of publications, the training of scientists and the sponsorship of conferences, workshops and planning meetings are examples of general assistance. Likewise, the dissemination of genetic materials for country breeding programs is one form of this type of assistance which is supported as a part of IRRI's core program and budget.

Formal cooperative country projects provide a second type of general assistance. While these projects may have some elements concerned with collaborative research and international networks, their prime objective is to help the local scientists improve their skills and training and to help the national agency develop a workable research system. Through these projects, IRRI scientists are located in the cooperating country. These scientists function as integral members of the local staff, not merely as IRRI overseas employees. Their operational support comes largely from local sources.

The three major functions of IRRI scientists working in cooperative country programs are:

1. To provide temporary research expertise which permits national research programs to get underway while local staff are receiving formal training outside the country.
2. To provide on-the-job training for their counterparts in national programs.
3. To assist in the development of a viable system of rice research and of a managerial framework within which that research can be implemented.

IRRI first initiated cooperating country projects in 1966. Formal projects were developed involving three parties, the national agency, IRRI, and a donor willing to finance IRRI's involvement in the national research program. Past cooperative relationships with IRRI scientists helped pave the way for these formal projects. In addition to support for research, they contained provisions for consultants, training, foreign travel and the purchase of critical items of equipment, books, and supplies. IRRI staff at headquarters were called on as consultants for these projects.

Since 1966, IRRI has undertaken 12 country projects in Pakistan, Bangladesh, India, Sri Lanka, Indonesia, Vietnam, Egypt, and the Philippines. A summary of the projects, their objectives and accomplishments are described on pages 329-46. While it would be inaccurate to say these projects had all been successful, they have played a major role in the general steady improvement in the research and institutional capabilities of the countries involved.

Strengthening the National Capacity to Utilize Research Findings

For the past three years, IRRI has been involved in a pilot project aimed at more rapidly infusing into a national program the benefits of research. Basically, it involves a series of applied research trials planned and implemented cooperatively with the national research and extension organizations. These in turn become the basis for a pilot action, program operated by the cooperating country and, if this is successful, a nationwide production effort based on the applied research findings.

This procedure has been tried in the Philippines with some success. The applied research trials were concerned first with a "package" technology approach and then with a direct seeding-two crop management system which will permit two crops to be grown in rainfed areas where only one was growing in the past using the conventional cropping systems. The trials were all run on farmers' fields with the aid of IRRI-trained technicians-employees, of the extension service. Observations of these trials were made by innovative officials of the Philippine government who utilized the technology demonstrated thereby to set up the "Masagana-99" national rice production program in the Philippines. This program appears to have been reasonably successful in spite of shortages and high costs of inputs, and of typhoon and flood damage during the past two years.

The Philippine experience is still considered as a pilot operation. It will be expanded this year to further identify the ecological situations under which the proposed two-crop system is viable. Consideration is being given to similar programs in other countries. probably starting in 1976 if the Philippine pilot operation suggests that moving the procedure to other countries has merit.

The Operational Constraints

During the past two years, IRRI scientists and administrators have given considerable thought to steps that might be taken to improve the chances of success in IRRI's international program and particularly in the cooperating country projects. These discussions have led to the identification of at least three major problem areas which tend to limit our ability to succeed. These are:

1. Limitations on IRRI's ability to provide the needed assistance;
2. Limitations on the ability of the national agency to effectively use the assistance;
3. Limitations stemming from the fragmentation and lack of continuity of donor inputs into the national research programs.

IRRI faces several problems in working effectively to improve national research capabilities. First, there is the difficulty stemming from IRRI's playing the dual role of an aggressive "doer" of research on one hand and of a less aggressive "tutor" for research on the other. Some difficulty is experienced in taking steps to strengthen the training, organizational and managerial capabilities of country programs without giving the impression that the external organization is dominating the local scene. Fortunately, in most cases the selection of IRRI staff for the overseas assignments has been such as to minimize the "dual role" difficulty and working relations at the country level are good.

A second limitation on IRRI's current ability to be more helpful to national agencies relates to a greater need for research coordination and management expertise than was originally envisaged. Frequently, the greatest need does not stem from the inadequacy of the local scientists but rather from the inadequacy of the research system of which he is a part. This need for managerial assistance is due both to constraints on the national researchers and to the complexities resulting from the fragmentation of donor assistance, a topic which will be covered later.

The limitations experienced by the national research agencies are well known. In some cases governmental restrictions and inflexibilities provide almost insurmountable roadblocks to the development of viable agricultural research programs irrespective of the external support provided. In others, low staff salaries and inadequate operational support funds give little opportunity for local staff to innovate and reorient programs. In still others, the rate of change needed in the organizational and operational frameworks is more rapid than any but the most innovative adminstrators and political decision makers will permit.

The problems facing national research agencies are due as much to organizational and managerial weaknesses as to inadequacy of the training of scientific personnel or the low quality of the research being conducted. At the same time, the solution to the problem in some cases can be found through research achievement. It has been said, for example, that IR8 and other high-yielding varieties brought about more change in the organizational and managerial frameworks of national rice research programs than all the research coordinators, administrators and other non-research advisors combined. While this may be an overstatement, IRRI is working on the assumption that research accomplishments can influence decision makers and we aim to do all we can to help the country researchers achieve these accomplishments. At the same time, other efforts will be continued to help improve the rice research systems of our cooperators.

The fragmentation and lack of coordination of donor assistance to national rice research programs in some cases provides serious roadblocks to successful achievements. Each donor provides assistance to alleviate the constraints on research as perceived from his institutional point of view. In some cases this point of view must of necessity have some political flavor that relates as much to the objectives of the donor as to those of the cooperating country. While this situation appears to be inevitable where donor assistance is provided by outside national aid agencies, it does not make research coordination very easy.

Fortunately, there are situations in which donor agencies coordinate their activities well, making IRRI's job of assistance easier. Plans are made jointly by representatives of the national agency, the donors and IRRI. Support from each agency is agreed upon and the program is implemented.

A second donor-related constraint is the lack of continuity of funding for the cooperating country projects. These projects are often of two to three years' duration only. While such time limitation is in accord with justifiable donor policies, it is a serious constraint on the employment of the most competent personnel. Also, the seemingly unavoidable delays in approval of project-extensions is bad on staff morale. Furthermore, with the fate of IRRI international staff at stake, it is very difficult to bring about needed changes in projects as they are renewed. Moral commitments to existing staff limits our bargaining power to obtain needed changes in contract provisions.

What of the Future?

Our optimism about the future for IRRI's involvement with national research centers was expressed in a report made at the seminar on national research programs at Bellagio, Italy on March 21, 1974. I quote from this presentation as follows:

"I am personally very optimistic about the future cooperative relations between international research centers and cooperating country agencies. This relationship is helping to move research results from the experimenter's plots to the farmer's field. Furthermore, it is identifying which of the experimenter's results will be most helpful to the farmer.

My optimism is based upon the assumption that certain clear guidelines will be followed in center-country program relationships. These guidelines include the following:

1. There must be a clear delineation of the responsibilities of each center both in terms of science subject matter coverage and of methodology to be used. This delineation must be made by the administration and governing boards of the centers and must be clearly understood by donors and national organizations alike. Centers should not be called upon to perform activities for which they do not have a comparative advantage. For example, they should not be used as a substitute for general assistance type programs formerly carried out by donors.

2. Each special project involving a center and a national program should be directly related to the long term goals of both the center and country programs. To assure this relationship it is desirable to

jointly analyze the long term agricultural research and training goals of the country in question or to develop them if they do not exist. A center should be requested to assist in only those areas of its unique competence and comparative advantage.

3. The quality of center personnel in country projects should, to the extent feasible, be of the same caliber as is found in the center's core program. The nature of his training must fit the scientist's responsibilities in the country in question, but scientists assigned to country programs should not be second rate. If we are to have competent scientists in country programs, longer term commitments must be made to these scientists and they must be given perquisites comparable to those enjoyed by scientists located at center headquarters.

4. A fiscal and personnel management system must be developed at each center to permit the full exploitation of opportunities for collaboration and cooperation with country programs. This involves recognition by core program donors that some scientist and administrator time will be involved in assisting country programs. This time should be recognized as being as legitimate in carrying out the goals of the center as is any other phase of the core program.

To accommodate expanding country-center programs additional scientific and managerial talent must be recruited. This additional help is needed to prevent the erosion of core programs which in many instances are very thinly staffed.

A more sound financial base must be provided for centers to carry out their obligations and opportunities with cooperating countries. Continuity of funding is needed to provide perquisites for special project staff similar to those enjoyed by the long term employees of the centers. Funds are also needed to support exploratory studies and the staff time required for the development of projects prior to their funding by an outside donor.

5. The role of the international centers in providing assistance to national programs must be subject to continuing scrutiny, not only by the center governing bodies but by the Consultative Group as well. Projects dealing with subjects central to the missions of the centers should be developed and initiated by or in cooperation with the centers. If mechanisms independent of the centers are utilized to implement such projects, care must be projects, care must be certain that these mechanisms do not interfere or compete with the respective programs of the centers.

Conclusions

Cooperative relations with national research programs are essential to the international centers' core research programs and to the centers' interest in moving technology closer to the farmer. In turn , centers are providing unique assistance to national programs as they develop their internal capacities to do research and to put research fundings to work on the farmers' fields. The challenge to both centers and national programs is to carry out their symbiotic relationships without endangering their common primary function -- to effectively bring science to bear to the solution of the world's food problems. The challenge for donors is to provide long term funding for quality symbiotic center-country programs which have as one of their prime objectives enhancing country research capabilities."

Table 1. List of international symposia/conferences held at IRRI. 1963-75.

Month/Year	Title	No. of Participants	Publisher
February, 1963	Rice Genetics and Cytogenetics	100	Elsevier Pub. Co.
July, 1963	The Rice Blast Disease	100	Johns Hopkins
August, 1963	Agricultural Engineering Aspects of Rice Production	25	IRRI*
February, 1964	Mineral Nutrition of the Rice Plant	70	Johns Hopkins
September, 1964	Major Insect Pests of Rice	65	Johns Hopkins
March, 1964	Weed Control Short Course	20	IRRI*
April, 1964	Savings and Capital Accumulation in Philippine Agriculture	15	The Phil. Eco. Journal
April, 1967	Virus Diseases of Rice	40	Johns Hopkins
December, 1967	Economics of Rice Production		IRRI*
April, 1968	International Rice Research Project Reviews	40	IRRI*
April, 1969	International Rice Research Conference	40	IRRI*
September,1969	Rice Research & Training in the 1970's	30	IRRI*
December, 1969	Consumption and Marketing	25	IRRI*
December, 1969	Economics of Rice Production	25	IRRI*
April, 1970	International Rice Research Conference	55	IRRI*
April, 1971	International Rice Research Conference	60	IRRI*

(continued/)

*mimeographed copies

Table 1 (cont'd.)

Month/Year	Title	No. of Participants	Publisher
May, 1971	Rice Policy Conference	40	IRRI*
September, 1971	Rice Breeding Symposium	100	IRRI
April, 1972	Rice, Science and Man	200	IRRI
December, 1972	Workshop on Water Management	15	IRRI*
May, 1972	First Task Force Meeting on Integrated Rice Pest Control in Southeast Asia	25	Int'l. Rice Commission Newsletter Vol. 22#3 Sept. 1973
June, 1972	Changes in Rice Farming in Selected Areas of Asia Workshop	20	IRRI
March, 1973	IRRI/UNIDO Conference on Agricultural Machinery Development	80	IRRI*
April, 1973	Multiple Cropping Advisory Committee Meeting	10	IRRI*
April, 1973	International Rice Research Conference	90	IRRI
May, 1973	Changes in Rice Farming Areas of Asia Workshop	25	IRRI
July, 1973	Water Management Seminar	15	IRRI*
April,1974	International Rice Research Conference	115	IRRI*
July, 1974	Political Economy of Rice Workshop	25	IRRI*
September, 1974	Symposium on Climate and Rice	50	IRRI*
March, 1975	Cropping Systems Workshop	90	IRRI*
April, 1975	International Rice Research Conference	95	IRRI*
May, 1975	Agricultural Machinery Workshop	55	IRRI*

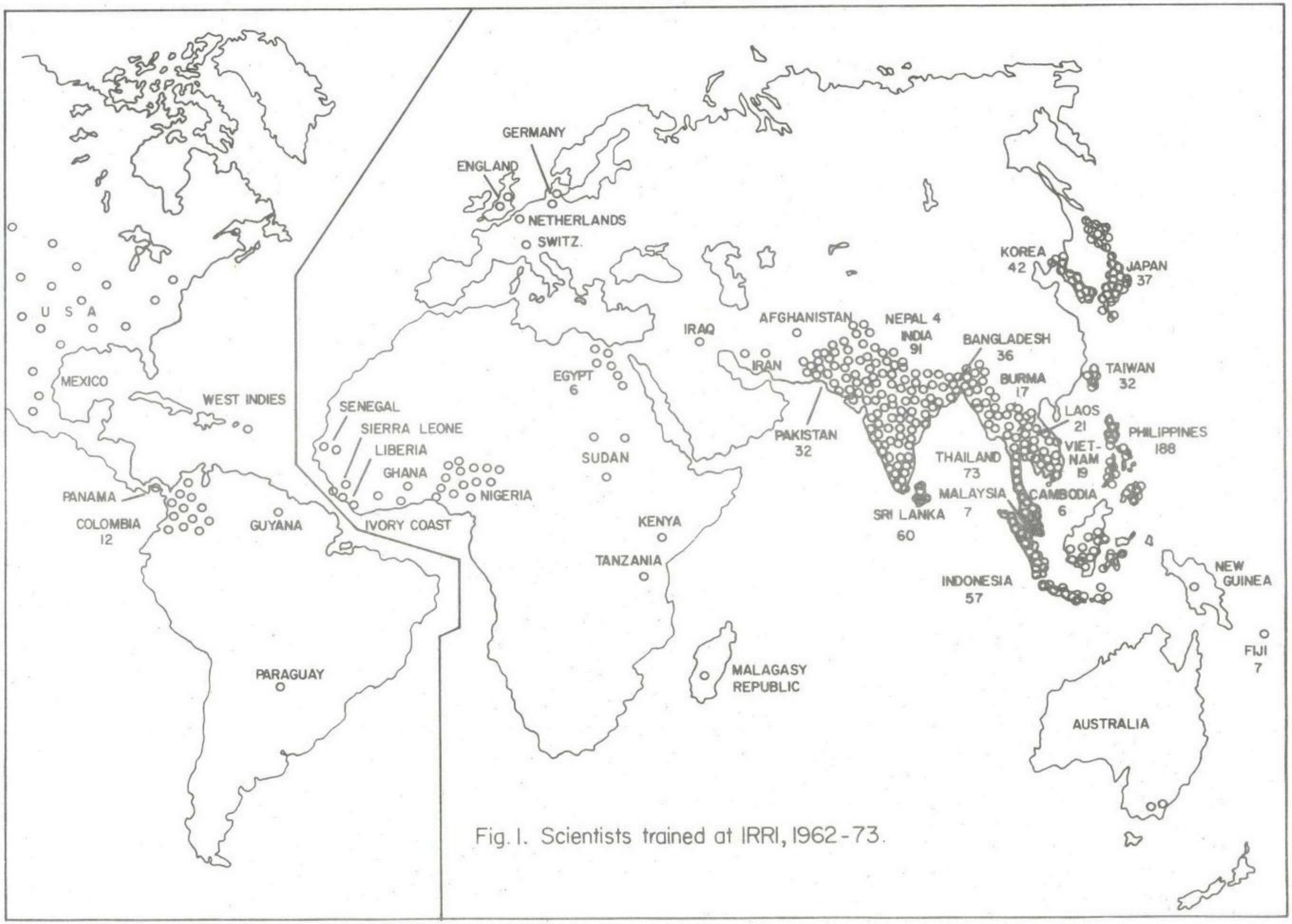
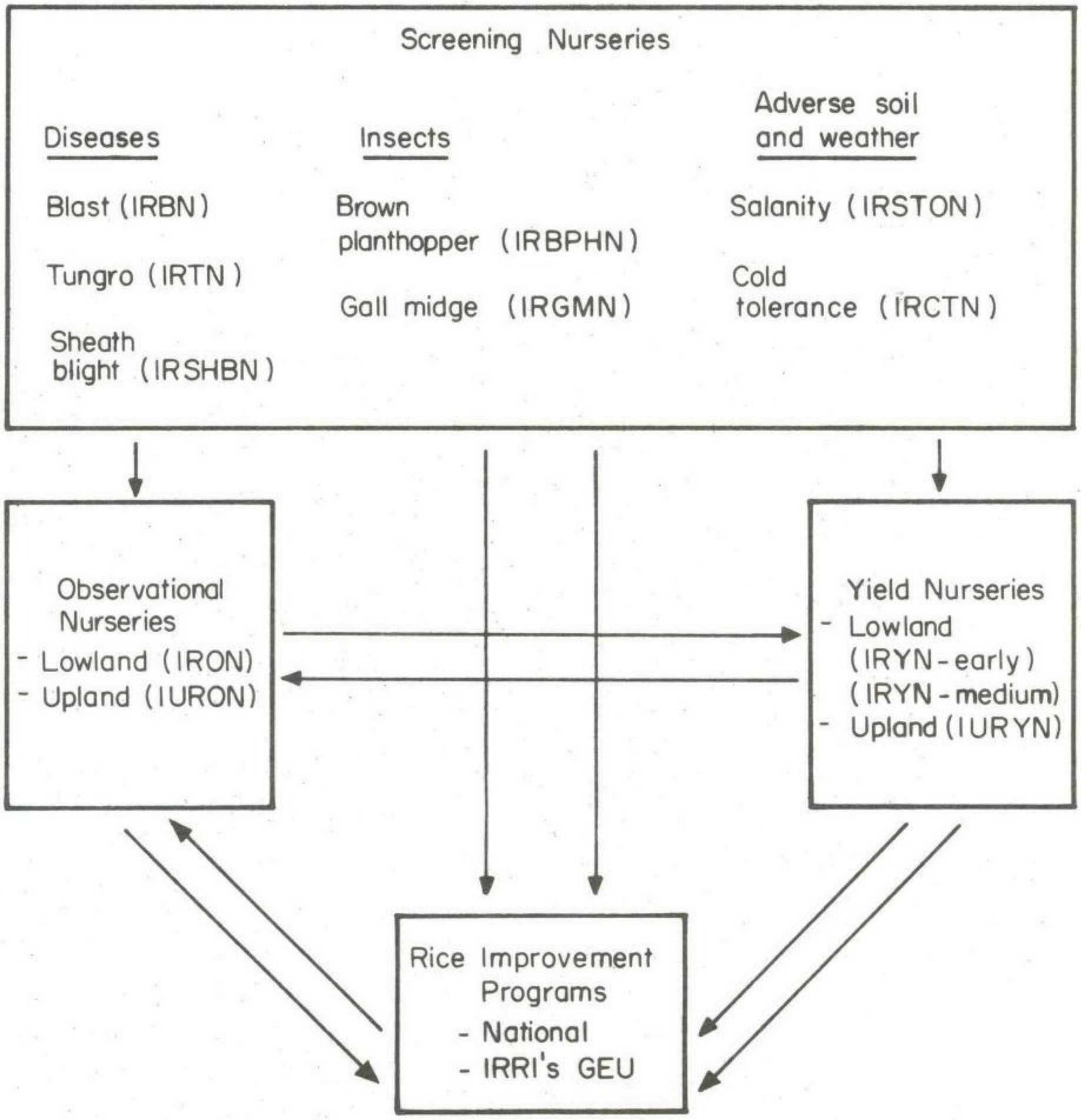


Fig. 1. Scientists trained at IRRI, 1962-73.

Fig. 2. **INTERNATIONAL RICE TESTING PROGRAM**



IRRI'S INTERNATIONAL PROGRAM WITH SPECIAL REFERENCE TO COOPERATIVE COUNTRY PROGRAMS[1]

The fact that IRRI and other international centers are devoted to problems of the developing world gives them a unique opportunity for cooperative work with national programs. In carrying out its research activities IRRI has sought cooperation of national research centers not only for evaluating results of its research but also to determine the direction of its program. The orientation and quality of the program is an important factor in establishing credibility and for the success of cooperative activities. The knowledge and technology that IRRI creates must be of value to national programs and the training it imparts should be relevant to national needs.

As IRRI has attempted over the years to build a strong program at the headquarters, it has recognized that the ultimate goal of increased production can be effectively achieved only by working closely with national research and production programs. How IRRI should work with national programs to ensure utilization of its research and training capacity and to help build national capabilities has been the topic of frequent discussions and the cooperative pattern as we see today is the result of continuous evolution.

National capabilities in rice research and training show a large spectrum of variation and no single model of cooperation is uniformly applicable. Much of IRRI's research efforts are concentrated on major problems affecting rice production on a global

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[1] D. S. Athwal, Associate Director

Paper for TAC Review, Nov. 24-Dec. 14, 1975.

basis. It is essential that important rice growing countries develop strong capability to supplement IRRI's research program and to incorporate new knowledge into production technology especially attuned to their rice growing environment. On the other hand, countries where rice is less important may have to continue to depend heavily on information, genetic material and associated technology developed at IRRI and other national programs. In its cooperative work, therefore, IRRI recognizes the need for facilitating exchange of information and materials not only between IRRI and national programs but also among national programs.

A significant portion of IRRI's off-campus or international activities is an integral part of its core research program. It includes:

1. International Rice Testing Program. IRRI and each national program nominate their most promising genetic materials for global evaluation in yield and screening nurseries. In 1975, IRRI supplied 475 sets of 12 different nurseries to 50 countries in Asia, Africa, and Latin America.

2. International Rice Agro-Economic Network. IRRI is collaborating with scientists in several rice growing countries in Asia to develop methodology to monitor problems that slow down the farm adoption of improved rice varieties and technology through IRAEN.

3. International Cropping Systems Network. Through this network, scientists are testing different cropping patterns in farmers' fields in different countries.

4. Farm Machinery Development Network. IRRI cooperates with a network of national research organizations and manufacturers to help develop appropriate mechanization technology for small farmers.

5. Research Program on Deep Water Rice. Deep water rice is not grown in the Philippines and facilities for field experiments cannot be easily built at IRRI. Therefore IRRI has developed a collaborative project with Thailand to develop varieties and associated technology for rice production under deep water conditions.

As work related to the four international networks and deep water rice program is highly location specific, IRRI must carry out these investigations at other locations in cooperation with different countries to fulfil its mandate. IRRI scientists working in a number of cooperative country projects assist with off campus components of the core program but it is not intended to review here those activities in further details. This paper will largely focus on activities which are carried out as outreach services to national programs. These fall under two main categories -- general cooperative services and specific cooperative country programs. The primary objectives of these outreach services is to make new knowledge and products of research available to national programs and to help improve their capacity for research.

General Cooperative Services

These include holding of seminars, workshops, and conferences in which rice scientists are invited to participate, distribution of published material, supply of genetic material, and training of rice scientists. Such services are generally provided to all major rice growing nations. Much of the funds required for this purpose come from the core budget though specific country projects have additonal budget provisions to cover the cost of these services.

Conferences. Since its beginning, the Institute has organized 33 symposia, workshops, seminars, and conferences in which 1,760 scientists from different countries have participated. These have provided an excellent basis for exchange of information and led to closer cooperation in rice research. The papers presented in some of these meetings have been published as books which continue to serve as important reference volumes for rice workers throughout the world. More recently such meetings have provided opportunities for scientists to jointly review results of cooperative experiments and prepare future plans of work and have provided a significant stimulus to cooperative work.

Publications. The Institute prepared a bibliography of the world's rice literature for the period 1951-60 and its annual supplements and distributed them to national agricultural libraries in rice growing countries. In response to requests from scientists the Institute supplied photocopies of research articles which were not readily available to them. IRRI scientists have written a number of books and special publications. These, along with proceedings of important conferences and symposia, are made available to scientists in national programs. IRRI publishes quarterly the IRRI Reporter which summarizes research findings of IRRI as well as cooperative projects. The IRRI Annual Report provides more detailed information on research accomplishments. Presently 5,300 rice scientists and administrators are on the mailing list for the IRRI Reporter. The mailing list for the Annual Report includes 1,700 individuals.

Training. IRRI's training program is especially designed to upgrade the expertise of rice scientists and educators in national programs. More than 1,000 individuals have attended different courses ranging from short courses of a few months' duration in special techniques and skills to research training leading to the Ph.D. degree. Many of the past IRRI trainees and research scholars are playing leadership roles in national programs.

Distribution of Genetic Material. In 1965 when IRRI breeding lines became available for distribution, seeds of segregating as well as fixed lines were distributed to national research centers. From 1965 through 1973, the Institute supplied 80,000 seed packets to about 100 rice growing countries and territories. Beginning with the establishment of the International Rice Testing Program in 1974, the number of seed samples supplied each year has increased manyfold. For example in 1975, seed samples supplied to cooperating countries numbered more than 103,000. The exchange of genetic material has been greatly systematized under the International Testing Program. Participating countries have access to genetic material not only from IRRI but also from other national programs. IRRI consolidates the results of various tests and supplies them to cooperators. Of special significance are the Plant Pathology Newsletter and the Entomology Newsletter which serve to disseminate information obtained from cooperative screening nurseries. IRRI scientists have the major responsibility for editing and preparing the material for publication of these newsletters.

IRRI has received excellent cooperation from national programs in the collection of rice germ plasm which now consists of 35,000 varieties. As the germ plasm collection has grown in size, the flow of samples to national programs has expanded. IRRI has promptly responded to requests from national scientists by supplying seed samples of local varieties which could not be maintained in the national collection. Important characteristics of 12,000 of the varieties in the collection have been catalogued. Copies of this catalogue have been supplied to over 1,000 research centers and libraries.

The success of general cooperation in the form of distribution of genetic material to different countries can be judged by the number of lines which have been picked up and released for commercial production in different countries. In addition to varieties named by IRRI, more than 30 of the IRRI lines have been released for commercial cultivation in Asia, Africa, and Latin America. Even more significant contribution is the introduction of this genetic material into breeding programs of all major rice growing countries.

The general cooperative work with South Korea and Thailand deserves special mention because it yielded results of considerable interest in relation to breeding for temperate climate and breeding for deep water and flood tolerance. With a small input by IRRI in this cooperative work, results of great significance have been achieved.

The Korean research scholars who came to IRRI for training crossed their japonica varieties with semidwarf indicas and have continuously grown an extra generation of their breeding material each winter at Los Baños. Different scholars in turn grew and advanced their own breeding material while they underwent training in practical rice breeding. This cooperative work resulted in the development of "Tongil," a semidwarf variety adopted to temperate climate. In 1975, one-third of the rice land in Korea (450,000 ha) was planted to this variety. The potential contribution of the genetic material developed through indica-japonica hybridization in creating opportunities for gene transfer among the two varietal groups is of even greater significance.

Although IRRI has never had a country project in Thailand, the Rockefeller Foundation rice specialist located in Thailand worked closely with the Institute. Probably the most significant accomplishment of the cooperative work in Thailand is related to the improvement of deep water rice. This work has demonstrated that the semidwarfing gene can be combined with stem elongation genes of the floating rices with the result that a semidwarf line incorporating the genes for elongation will have the capacity to grow tall if the water depth increases. The cross IR442 between the semidwarf line, $Peta^2$/TN1 and the Thai floating variety, Leb Mue Nahng, has been intensively studied both in Thailand and at IRRI. Performance of selections from this cross have shown that flood tolerance can be incorporated in semidwarf varieties to greatly extend the area of their adaptability.

Specific Cooperative Country Programs

With several symposia completed, many rice scientists trained at IRRI, Institute's staff travel to rice growing countries, and IR8 and related technology in the offing, the stage was set for IRRI to participate more fully with national groups in the development of their programs. Starting in 1966, IRRI became involved in rice research programs in several major rice producing countries. A formal project was developed in each case to assist the country concerned in accelerating its rice research and development activity. Usually three parties were involved in each project -- the national agency, IRRI, and an agency willing to finance IRRI's participation in the national program. The development of IRRI's cooperative projects was greatly stimulated and influenced by the good working relationship which the IRRI scientists had developed with rice scientists in host countries.

The basic philosophy of these projects was to improve the national capacity for rice research. They were in no sense intended to lead to the establishment of branch stations of IRRI. The main features of each project are (a) assignment of one or more IRRI scientists to participate in research on local production problems, (b) assignment of short-term consultants for specific purposes, (c) training of rice scientists, and (d) purchase of essential equipment and library books. The headquarters staff at Los Baños were available as standby consultants to such projects. Funds were provided to enable senior scientists of the host country to attend scientific conferences and to administrators to travel to become acquainted with modern rice programs at IRRI and elsewhere. Occasionally IRRI assisted with improvement of physical facilities and experiment station development if these were essential to the development of any worthwhile research program.

Not only the technical resources of the project were applied to enhance the local research efforts but also the Institute at Los Baños often incorporated in its research program such supplementary investigations as might help in problem-solving research in the host country. IRRI insisted that IRRI's involvement in a country must be a component of the national program and has, in most cases, stimulated the development of a coordinated national program where one did not exist before. The IRRI scientists in country projects worked as members of local teams on one hand and as a link with Los Baños scientists on the other. Their research output is an integral part of the national research effort. Much of it is reported in local progress reports and is not clearly identifiable as a separate contribution. In fact it would be more appropriate to refer to these cooperative projects as cooperative country programs because they were fully integrated with the national programs.

IRRI has participated in cooperative country programs in Pakistan, Bangladesh, India, Sri Lanka, Indonesia, South Vietnam, Egypt, and the Philippines. The duration of these cooperative projects, sources of funds and resident scientists, short-term consultants and training provided are included in Table 1. Additional information on each cooperative program and its progress are given in the Appendix. It is difficult to sort out and quantify

IRRI's accomplishment but the following general statements can be made regarding its contribution.

1. IRRI provided qualified scientists to actively participate in national research programs. In 1974-75 about 25 IRRI scientists worked in seven country programs. Often, IRRI scientists substituted for national scientists when they proceed abroad for training. Many short-term consultants advised on specific phases of the research program.

2. IRRI has stimulated the development of coordinated national programs and multidisciplinary approach to production oriented research. The IRRI team leader has often functioned as a counterpart of the national program coordinator.

3. IRRI helped to identify most pressing problems which require research and to develop long range plans to effectively solve these problems. Preparation of long range plans have been helpful in attracting funds for research in high priority areas in accordance with national needs.

4. IRRI provided services to improve experiment station and laboratory facilities and to purchase library books and essential equipment. IRRI participated in the improvement of facilities for research only when such facilities were grossly inadequate and their improvement was an essential prerequisite to developing a productive cooperative program.

5. The following number of rice scientists from different country programs have received training at IRRI.

Country	Number trained 1962-75	Man-years of Training 1962-75
Bangladesh	47	36.5
Egypt	5	3.2
India	113	101.9
Indonesia	100	63.6
Pakistan	35	23.0
Philippines	211	212.3
Sri Lanka	67	39.6
Vietnam	24	18.0

A large part of the funds required for the training came from cooperative projects. In addition local staff received on-the-job training by working as counterparts of IRRI scientists. Participation in scientific meetings at IRRI also contributed to staff development.

6. The cooperative projects stimulated improvement of linkage between research and extension and farmers' adoption of new varieties and management practices. Many rice production specialists received training at IRRI and returned home to train local extension workers. The minikit technique which involves farmers' participation in evaluation of new selections and proved a powerful extension tool in the Philippines, has been adopted for disseminating new seeds in other countries. IRRI is now working with several countries to help demonstrate on a pilot basis an effective applied research and production program based on its experience in the Philippines with the aim of accelerating utilization of results of research.

From Cooperation to Collaboration

The term "collaboration" is used to refer to a collegial relationship between IRRI and the national program that enables them to work together on problems of mutual interest. The joint studies by IRRI and AICRIP (All-India Coordinated Rice Improvement Project) on the range of variation in the brown planthopper and tungro virus are examples of this kind of collaboration. Simultaneous collaboration with several countries on a regional and global basis to carry out mutually beneficial research is referred to as the regional or international network. The International Rice Testing Program is an example of the network concept.

General cooperative services provided by IRRI to national programs represent one-way flow of information and genetic materials from IRRI to national programs. A cooperative country project is by and large designed to strengthen a specific national program. The ultimate goal of IRRI's outreach activities is to establish effective networks that will facilitate interaction of ideas and flow of information and genetic material among programs.

As national programs develop capabilities and outreach projects phase out, IRRI hopes to collaborate with them on a continuing basis in research on problems which are important not only at the national level but also on the regional and global basis. The current IRRI-AICRIP collaboration is a prototype which can be used for collaboration with other national programs. In 1974 IRRI signed a memorandum of agreement with the Indian Council of Agricultural Research which lays down general guidelines for collaborative relationships. Under this agreement, one

IRRI scientist is located in India as its representative and serves as a continuing link between IRRI on one hand and ICAR/AICRIP on the other. The Ford Foundation has provided a grant for collaborative work and exchange of visits by IRRI and Indian scientists. The arrangement makes it possible to use scientific talent in India for work on problems which are of wider importance.

The concept of strong national programs working together with IRRI will lead to a very much enhanced global capacity to effectively solve problems affecting rice production. Improved national capability also contributes to more effective networks. For example, one-fourth of all nurseries grown in 1975 were handled by Indian scientists. As collaborative research and information networks become more effective, they are expected to stimulate complementary and coordinated research efforts. Also they will permit IRRI to shift its current emphasis on outreach projects to a coordination role in collaborative work with particular reference to international and regional networks.

Major Constraints to Progress of Outreach Projects

In the past, individual donor agencies have tended to provide funds for outreach projects on a fragmentary and short-term basis. This practice has two serious shortcomings. Firstly, it does not give adequate consideration for orderly growth and development of the national research program based on carefully evaluated priorities. National programs should be given adequate assistance in developing long range plans and to establish priorities. Funds available from one or more donors can then be used for strengthening the program in accordance with established priorities rather than on a piecemeal basis encouraged by project funding. Secondly, the lack of any long term commitment of funds by donors prevents IRRI from providing long term opportunities to its outreach staff. Therefore, it has been difficult to build up a corps of dedicated scientists for international work. It is equally important for the national program to have assurance of funding on a long-term basis in order to make real progress in program development and implementation. Joint and long term funding by a group of interested donor agencies on the basis of long range plans will greatly accelerate building of national capabilities.

Lack of adequate experiment station and laboratory facilities are serious constraints to progress. IRRI has in the past undertaken to assist with the development of these facilities under exceptional circumstances because implementation of a productive program was not feasible without such facilities. As IRRI does not have special capability in this area, hopefully other organizations will consider providing assistance to national programs for the development of physical facilities.

The local research and management system often lacks capacity to support the development and implementation of a high quality research program. Its restrictions and inflexibilities combined with lack of incentives can be a serious handicap to research productivity. Inadequate operational support reduces the output of both local and expatriate scientists. There is an urgent need for training and consultancy services in order to help improve effectiveness of the system in rapidly identifying and solving problems that affect production on farmers' fields.

A poor linkage between research and extension delays the utilization of new technology and impact of research on production. A well-organized program of applied research trials on farmers' fields in which research and extension agencies are involved will greatly accelerate dissemination of new technology. Development of training programs that are relevant to the mission of extension workers should receive high priority.

Future Plans

IRRI's strategy in future outreach work will emphasize a shift from cooperation to collaboration. Future plans will involve advance planning, a more rational approach to the development of cooperative projects and a clearer understanding of working relationships with national programs as well as other centers.

In order to use its resources more effectively, IRRI is sharpening the focus of its outreach activities. Tentative plans are being developed regarding its future involvement in outreach work during the next 5 to 10 years. IRRI will have minimum involvement in the development of physical facilities and other development-oriented work and concentrate primarily on helping national programs to increase their capabilities in research and training and on collaborative research.

IRRI has examined its global responsibilities and evaluated the need for cooperative work in those regions or countries which have previously been overlooked. Advance planning will enable IRRI to partially offset the disadvantages of short-term financial support for outreach projects. It will permit retention of staff on a long-term basis by transferring them from one country project that is terminating to another which is getting under way.

In the development of each cooperative country project, long range research plans and requirements for strengthening national programs will receive primary consideration. Each cooperative country project will be staffed with minimum number of expatriate scientists required to do the job with the clear objectives of accomplishing specific tasks within a projected period of time. Working cooperatively with national programs, this approach will enable IRRI to take initiatives in seeking support on the basis of established priorities in program development.

For the next five years or so, IRRI will probably continue to participate in outreach work at about the current level, number of scientists employed are expected to range from 25 to 30. A tentative scheme for IRRI's involvement in outreach and collaborative work is shown in Table 2. Hopefully by the year 1980 major rice growing countries like Bangladesh, Pakistan, and Indonesia will have developed adequate capabilities to implement a high quality program. Others like Vietnam, Laos, Cambodia, Burma, and a number of countries in the Middle East, Africa, and Latin America may continue to seek assistance from IRRI, IITA, and CIAT for a longer time. As outreach projects are phased out, however, IRRI will require additional staff members to coordinate collaborative work on a national, regional and global basis. For example, collaboration with

CIAT in Latin America and with IITA and WARDA in Africa will greatly improve with location of IRRI representatives at these centers.

While several cooperative country projects were phased out during 1974-75, IRRI has received requests for new cooperative projects from a number of countries. The following projects are under active consideration.

Cooperative Country Projects

1. IRRI has been requested by USAID and the Government of Nepal to provide three scientists (rice breeder, agronomist, and economist) for cooperative work on rice and cropping systems. A similar request has been made to CIMMYT for providing staff for corn and wheat research. The project will be funded by a USAID loan to Nepal. The International Agricultural Development Service (IADS) is expected to take responsibility for overall program management and logistic support.

2. Negotiations for implementing a cooperative project in Pakistan have almost been completed. The project will involve locating one IRRI rice breeder to help in developing a strong national GEU program and a rice production specialist to assist with an applied research and production project. The project would be funded by a USAID loan to the Pakistan government.

3. Preliminary discussions indicate that Sri Lanka would like IRRI to participate in a cooperative project that will include assistance in organizing and implementing a strong GEU-type program, research on rice-based cropping system, and in implementing an effective applied research program for evaluating rice varieties and cropping systems.

Regional Outreach Services. IRRI's cooperation in the past has concentrated on South and Southeast Asia. Although much of the rice crop is grown in this region, there are a number of important rice growing countries in the Middle East, West Africa, and Latin America that can greatly benefit by IRRI's involvement along with other international centers. IRRI has carefully evaluated the potential value of its involvement in these regions and the current status is summarized.

1. Middle East. Beginning in 1972, IRRI provided the services of a rice specialist in Egypt under an agreement with the Arid Lands Agricultural Development Program. This project terminated in June, 1975. Activities of ALAD will be taken over by the new international center, ICARDA. IRRI is examining the possibility of developing a project in Egypt which will serve regional needs. Both Egypt and Iran have requested IRRI's assistance. A 2- to 3-man team, including one rice breeder and one agronomist, is considered adequate. In carrying out this work, IRRI anticipates collaboration with ICARDA.

2. West Africa. WARDA has the responsibility of coordinating rice testing work in West Africa. IITA has the regional responsibility for rice research. WARDA has requested IRRI to locate a rice scientist at its headquarters in Monrovia to act as the regional network coordinator. He would serve as a link with WARDA and IITA, help to coordinate international testing program in the region, and facilitate exchange of information and genetic material and collaborative work. IRRI has taken the initiative in developing a tripartite memorandum of agreement with IITA and WARDA that will clearly define relationships and responsibilities of each agency.

3. Latin America. Without any formal agreement, IRRI has collaborated closely with CIAT in disseminating new genetic materials.

Varieties of IRRI origin and lines selected from IRRI material are planted to more than 40% of the irrigated rice land in Latin America. More recently, CIAT has released several varieties developed from crosses made at CIAT. About 20% of the 7 million hectares of rice in Latin America is irrigated and the rest is upland. The problems of upland rice have not received adequate attention by CIAT and IRRI.

At present, the rice program at CIAT is carried out by three scientists. A proposal for IRRI to participate more actively in CIAT's program as well as a memorandum of understanding between the two centers are under consideration. It is tentatively agreed that location of an IRRI scientist at CIAT to work as regional network coordinator for the Latin American region will strengthen IRRI's linkage with CIAT and help in implementing the regional program.

Much of the upland rice is grown in Brazil. Its total rice area is 5 million hectares, out of which 82% is upland. Preliminary discussions among Brazilian authorities, CIAT, and IRRI indicate a mutual desire for undertaking a cooperative project with emphasis on upland rice. Results of research from IRRI's expanded program on upland rice can make a real contribution to the success of such a project.

IRRI's assistance to rice growing countries in regions other than South and Southeast Asia will mainly be provided through a regional network system and in collaboration with other centers. Memoranda of agreement clarifying inter-center relationships are being developed. Also, IRRI will continue to seek collaboration with other international agencies such as FAO and IADS in implementing its outreach programs in Asia, Africa, and Latin America.

Table 1. Cooperative country programs.

Country	Cooperative Activities	Donor	Duration	Resident Scientists (Man-years)[a]	Short-term Consultants (Man-months)[a]	Training[b]		Remarks
						No.	Man-years	
Bangladesh	Rice research and training and development of BRRI	FF	1966-75	13.9	49.5	58	73.2	Will continue with FF & CIDA support
	Research on rice-based cropping systems	IDRC	1974-77	1.0	10.0	2	1.0	
Pakistan	Rice research & training	FF	1966-71	3.7	35.4	24	22.1	A new project is being developed
			1973-75	-	1.6	2	.9	
India	Accelerated rice research and training	USAID FF	1967-73	21.0	10.4	22	20.0	A collaborative project is underway.
Sri Lanka	Research and training in rice research and multiple cropping	FF	1967-74	7.5	13.4	79	56.8	A new project is being developed.
	Rice processing and marketing	FF	1972-76	4.8	11.7	27	8.1	
S. Vietnam	Rice research and training	USAID	1971-75	6.6	22.1	18	7.6	Premature termination due to war.
Egypt	Rice research and training	FF	1972-75	3.1	-	-	-	A new program for regional services is being developed.

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[a] Refers to services provided until termination of the project or through 1975 if project is continuing.

[b] Refers to the training provided through 1975. In case of USAID contracts in Indonesia and Vietnam, funds for training were provided separately as needed and were not included in the contracts.

...continued/

Table 1 (cont'd.)

Country	Cooperative Activities	Donor	Duration	Resident[a/] Scientists (Man-years)	Short-term[a/] Consultants (Man-months)	Training[b/] No.	Training[b/] Man-years	Remarks
Philippines	Incorporation of results of research into the national production program	USAID	1972-75	2.8	-	-	-	Expected to continue.
Indonesia	Support to NRRP	FF	1970-75	4.7	6.8	3	2.4	
	Development of facilities and acceleration of rice research at Maros	Dutch Govt.	1972-77	8.0	-	1	1.0	
	Research on rice and cropping systems at CRIA, Bogor	USAID	1972-76	14.5	6.1	66	39.0	
	Research and station development at Sukamandi	World Bank	1973-79	3.8	12.8	-	-	

Table 2. Tentative scheme for level of IRRI's involvement in outreach/collaborative work.

Region/Country	Project Category	Estimated No. of Scientists through 1975	1976	1977	1980
SOUTH & SOUTHEAST ASIA					
Philippines	Outreach	1	1	1	1
Indonesia	"	12	9	9	3
Bangladesh	"	6	6	6	2
Sri Lanka	"	2	2-3	2-3	2-3
Pakistan	"	-	2	2	2
Nepal	"	-	3	3	3
India	Collaborative	1	1	1	1
Thailand	Collaborative core program on deep water rice	1	1	3	3
Other countries[1]	General assistance/New outreach projects	-	-	-	6
MIDDLE EAST					
Egypt	Regional outreach[2]	-	2	3	3
AFRICA					
IITA-IRRI	Regional core program	-----(IITA Staff)-------			
WARDA (W. Africa)	Regional outreach	-	1	1	1
LATIN AMERICA					
CIAT-IRRI	Regional core program	------ (CIAT Staff) -----			
	Regional outreach	-	1	1	1
Brazil	Outreach (joint IRRI-CIAT)	-	1-2	1-2	1-2
TOTAL		23	30	33	29

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[1] Countries such as Cambodia, Laos, Vietnam, Malaysia, or Burma.

[2] Collaboration with the newly established international center, ICARDA, is anticipated.

PERTINENT INFORMATION ON IRRI'S COOPERATIVE COUNTRY PROGRAMS

Pakistan

In 1966, IRRI with funds from the Ford Foundation entered into an agreement with Pakistan to assist in developing a rice research and production program. A resident scientist was stationed in Lahore near the main rice research station at Kala Shah Kaku to work with local rice scientists and to provide liaison with IRRI.

About 1.5 million hectares of rice are grown in Pakistan. IRRI varieties have probably had their greatest impact in Pakistan where environmental conditions are most favorable for crop production -- plenty of sunshine with good irrigation facilities and no serious disease and insect problem. The IRRI technology was directly transferable to Pakistan. By 1969-70, IR8 was planted over 1/3 of the rice area in Pakistan. During the 3-year period ending 1969-70, rice production increased by about 80% and yield by 50%. In 1971, IR8 and another IRRI line, IR6-156-2 named Mehran 69 in Pakistan were grown on about 60% of the rice area. After these rapid developments leading to increased rice production in Pakistan, the IRRI project ended in October 1971 but the Institute continued to provide assistance on specific problems, such as stem borer control, breeding for tolerance to cold water. Also IRRI scientists travelled to Pakistan to advise in the general areas of rice breeding and applied research.

Rice is becoming an increasingly important crop in Pakistan because of its ability to grow well and give high yield in soils which are waterlogged or have alkalinity and salinity problems. The area under rice has gradually increased because other crops cannot be profitably grown under these conditions. There are a number of limiting factors on which research must be carried out locally. These include soil problems, stem borers, and grain quality. Pakistan is producing the aromatic and long grain basmati rice which sells at a high premium price in the export market. A high-yielding, fertilizer-responsive, and pest-resistant variety of basmati rice is yet to be developed. Post-harvest problems and rice mechanization need attention. There is still a shortage of trained rice scientists in Pakistan. The local procedures connected with the clearance of candidates for training are complex and time consuming and these have prevented the development of a core of competent scientists for rice research.

Beginning September, 1973 IRRI started a cooperative project in support of the rice program without a resident scientist. A 2-year Ford Foundation grant provided funds for training, consultancies, and exchange of seed material, but the available funds have not been fully utilized due to procedural delays and lack of advance planning for training and consultancies. The coordination of the rice program at the national level has considerably weakened. The newly established Pakistan Agricultural Research Council has been entrusted with the responsibility of strengthening coordination. USAID has provided a substantial loan for improvement of research on cereal crops. Negotiations are now underway between the Government of Pakistan and IRRI for a cooperative project that would enable two IRRI scientists to help strengthen the national rice breeding effort and to assist in implementing a pilot applied research and production project.

Bangladesh

The project was first undertaken in March, 1966 and is still continuing. A series of Ford Foundation grants have provided funds for IRRI's participation in the project. Some AID funding supplemented Ford Foundation funds for training. Beginning in 1975, an IDRC grant became available for work on rice-based cropping systems.

Rice is grown in Bangladesh under some of the most difficult environments found anywhere. Moisture status varies from a very low regime in the cool winter season to excessive rain water in much of the region during the warm, humid summer season. The soil fertility is generally low and salinity occurs in some coastal areas. Nearly every major disease and insect pest of rice is found in the country.

In spite of the importance of rice to Bangladesh (then East Pakistan), the rice research efforts faced a precarious situation in the early 1960's. The main experiment station at Dacca was lost in 1962 because the site was selected for the construction of the new national capital. Both field and laboratory facilities were well behind actual needs and many of the trained rice scientists shifted to other fields of endeavor. The country urgently needed the development of a major rice research center to carry out a worthwhile research program.

Most significant contributions of the cooperative project are those concerned with the establishment of the Bangladesh Rice Research Institute (BRRI), development of multidisciplinary and problem-oriented research program and development of manpower to carry out the rice program. At the request of local authorities, IRRI recommended a long term plan to build a rice research center staffed with scientists in different disciplines. The strong disciplinary organization in the old system permitted a group of scientists in one discipline, for example an entomologist, to be responsible for studies on several different crops. This did not encourage the development of a multidisciplinary program for integrated research on problems limiting rice production. The reorganization of research brought about a team approach among scientists concerned with rice. In the beginning the reorganized unit called "Accelerated Rice Research Institute" functioned more or less as a rice program rather than as a separate institute within the Directorate of Agriculture. The formation of the BRRI followed the acquisition in April, 1968 of a site for the rice research center at Joydebpur, about 20 miles from Dacca. Simultaneously with the construction of buildings to house the laboratory, office, library, and service facilities for the institute, a new staffing pattern was established and experiment station development was undertaken. Primary funding for the construction came from the government but a substantial amount of foreign exchange costs was covered by a Ford Foundation grant. In June, 1973 the BRRI was established as an autonomous organization by a special Act of Parliament of the Republic of Bangladesh. Most of the essential facilities have now been completed.

For several years only one IRRI scientist was located in Bangladesh. Beginning June, 1973 the level of IRRI's participation increased rapidly and an aggressive program of training scientists both at IRRI and in U.S.A. was initiated. Currently 3 IRRI scientists (entomologist, agricultural engineer, and rice production specialist) are provided in the Ford Foundation grant and one cropping systems agronomist is provided under the IDRC grant.

IRRI has helped BRRI prepare its long range research plans based on specific objectives. Also IRRI assisted in developing a master plan for improvement of physical facilities at the main research center at Joydebpur and the sub-stations. The external support and local funds required for implementing the program have been determined. Recently BRRI and IRRI have developed a formal memorandum of understanding which lays down guidelines for cooperative relationships as well as privileges and responsibilities of the two organizations in cooperative work. It calls for additional IRRI scientists in the areas of rice breeding (deep water rice) and rice agronomy. This Memorandum gives IRRI an appropriate status as a cooperating agency independent of donor agencies and will facilitate use of funds from different sources in program implementation. The new relationship between BRRI and IRRI has stimulated joint funding of the cooperative country program by several donor agencies.

Many Bangalee scientists have been trained at IRRI and in U.S.A. During 1975, twelve scientists worked for their Ph.D. and master's degrees. The Bangladesh government is giving high priority to agriculture and has gradually increased its support to provide additional facilities and staff. One of the critical needs of BRRI is improvement of operational support for scientists in order to increase their productivity. It is anticipated that during the next five years BRRI will develop into a strong research and training center and IRRI's cooperative activities will gradually phase out. Hopefully the two institutes will have developed by that time a new collegial relationship for collaborative research on problems of mutual interest.

India

In 1967, IRRI entered into an agreement with the U.S. Agency for International Development and the Indian Council of Agricultural Research to participate in the development of rice research. The agreement focused on the All-India Coordinated Rice Improvement Project (AICRIP) which was founded by ICAR in 1965. The AID contract with IRRI provided the services of resident scientists in several fields, training of Indian staff, study tours, short-term consultants, and general assistance in the development of the coordinated program.

Initially the coordinated program in India mainly used the facilities and personnel already existing at the various centers and state research stations throughout the country. The program gradually acquired additional budgetary support for expansion of staff and facilities. The IRRI scientists were located at the newly established headquarters at AICRIP in Hyderabad. The number of scientists ranged from 4 to 6 until June, 1973 when the project was concluded. The IRRI representative, who is a Rockefeller Foundation staff member assigned to IRRI for the rice program in India, is the only one continuing beyond June, 1973. He was designated as the joint coordinator of AICRIP with an Indian scientist working as the coordinator. Also, he acted as team leader for IRRI scientists employed under the USAID contract. IRRI scientists actively participated in the research program by working closely with the Indian scientists.

In addition to the AID contract, the Ford Foundation gave a grant to IRRI to provide the services of a plant pathologist to AICRIP for one year. Also, FF directly supported the development of some physical facilities at the AICRIP headquarters in Hyderabad. The Rockefeller Foundation provided funds directly to AICRIP for the employment of critically needed local staff and for equipment. As the AID-funded IRRI project was phased out, the Indian government strengthened AICRIP by filling new positions created in agronomy, plant pathology, plant physiology, entomology, and breeding.

The coordinated approach as developed in India was able to utilize resources of many different research centers and agricultural universities for a broad and rapid testing program over a wide range of conditions. The excellent leadership provided by the national coordinator resulted in rapid improvement of the program. The quality of research was upgraded by annual workshops held twice a year which played a major role in the planning of the overall research effort. The progress of AICRIP has been excellent. Many new modern varieties were created for use throughout India. Supporting studies in agronomy, entomology, plant pathology, and plant physiology accompanied varietal evaluation.

As research programs in the various states of the country intensified in activity, research was extended to localized problems such as salinity, deep water, and cold tolerance. Also, research was intensified to incorporate a high level of resistance to diseases and insects in widely adapted varieties. The AICRIP is giving support to regional rice stations, through exchange of visits and short in-service training programs. In recent years, the AICRIP has paid particular attention to carrying the results of research to extension workers and farmers. The minikit technique for farmers' participation in evaluating new selections has been extensively used in India.

The Indian rice program is well organized and there is strong research base and local capability to implement a well coordinated program of research. The presence of IRRI scientists is no longer considered necessary. A memorandum of agreement between the Indian Council of Agricultural Research and IRRI was signed in 1974 for collaborative work on a long term basis. Under this agreement the IRRI representative continues to be stationed in India and provides an effective linkage between ICAR and AICRIP on one hand and IRRI on the other. The Ford Foundation made a grant in October, 1974 to facilitate collaborative research on problems of mutual interest and exchange of visits. The basic idea is to develop a continuing relationship that will enable IRRI and AICRIP to work together on significant problems affecting rice production in the Indian subcontinent.

Sri Lanka

Beginning 1967, a senior rice scientist from IRRI was stationed in Sri Lanka under a grant from the Ford Foundation. Most of the country's 0.5 million hectares of rice is grown in the wet zone where rainfall ranges from 200 to 350 cm per year. The production is greatly dependent on rainfall patterns. The dry zone with about 100-150 cm of rain per year is less important in rice production but has the potential for expansion if irrigation systems are developed. Because of the high level of solar radiation, the yield potential on this region is inherently better and soils are also more fertile. In the wet zone, deficiencies in soil fertility and other nutritional problems are a limiting factor in production. Also several diseases and insects limit rice yields in this region.

IR8 and other semidwarf, fertilizer-responsive varieties were introduced to Sri Lanka. They demonstrated that much higher yields can be obtained with these varieties but in view of many local problems, these varieties have not been planted over an appreciable area.

The IRRI scientist during the first two years of the cooperative project was a research agronomist. He was followed by a rice production specialist who spent most of his efforts organizing training programs for extension workers. In-service training of extension workers is one of the most well-developed activities in Sri Lanka. Of the 67 Sri Lankans trained at IRRI, 48 were trained in production type courses (including rice production and multiple cropping). Sri

Lanka has made extensive use of IRRI's rice production training program. Most of the full time trainers now in Sri Lanka are graduates of the IRRI rice production training program. Sri Lanka has institutionalized the training of extension workers by developing a well-equipped training institute at Peradeniya. Another in-service training center has been developed at Maha-Illuppallama. Beginning in 1973, the IRRI project leader has spent half of his time in encouraging multiple cropping research, training and extension.

The rice program in Sri Lanka will greatly benefit from a strong interdisciplinary coordination in research. At present, coordination is mainly confined to variety trials. On the basis of these trials, several semidwarf selections have been released for commercial use and are now planted on more than 40% of the rice area in the country. This is a significant achievement and the extension service played an important role in the spread of these varieties. The minikit technique of disseminating new technology, which proved a powerful extension tool in the Philippines, was successfully adapted by the extension service in Sri Lanka.

IRRI phased out its project on rice production in the end of 1974. The Department of Agriculture is now seeking IRRI's assistance in developing and implementing a more comprehensive rice variety development program and a rice-based cropping system program.

In April, 1972 IRRI participated in a cooperative project with the newly established Paddy Marketing Board of Sri Lanka to help modernize the rice processing industry. The project was funded by the Ford Foundation and it provided the services of a rice processing specialist to the Board. Another staff member (associate engineer) was appointed to the project in December, 1974. The most significant contributions of the project are those concerned with improvement in parboiling, change from the volume to weight measurement which reduced losses during processing, development of plans and facilities for improved storage and milling, training of personnel abroad, and establishment of a local training center. The IRRI rice processing engineer is one of the most experienced specialists in post-harvest technology in Asia. The project in Sri Lanka has given IRRI a valuable experience in rice processing work. At one time IRRI had anticipated that it would have increasing involvement in research and development work related to rice processing and had intended to expand its core program in order to improve its capability to provide services to national programs in post-harvest technology. However, the proposed program expansion did not materialize. The cooperative project in Sri Lanka will phase out in 1976 and IRRI does not expect to participate in another outreach project in rice processing in the foreseeable future due to its limited capability in this area.

Indonesia

In 1969, the Indonesian government invited an international team of scientists to study its agricultural research organization and advise on its modernization. The team recommended the establishment of an Indonesian agricultural research council which would serve as a coordinating body to focus research on problems of national importance. The government accepted the basic features of this plan and initiated a national rice research program in 1970 as a first step towards the implementation of the recommended plan. It is designed to serve a coordinating function similar to that of AICRIP in India with minimum changes in the existing institutions concerned with rice. A senior IRRI scientist was stationed in Indonesia in 1970 with funding by the Ford Foundation. He served as joint coordinator of the National Rice Research Program.

At the same time when plans were being drawn up for the NRRP, the Indonesian government arranged bilateral agreements with the Netherlands for assistance in the areas of entomology and agroclimatology and with Japan for assistance in the areas of plant pathology and physiology, mainly at the Central Research Institute for Agriculture, Bogor. On the average, three or four scientists have been working at CRIA under each of these arrangements.

Working closely with the national program, IRRI played a coordination role in seeking additional foreign assistance where required to strengthen specific aspects of the program. The most important limitation on the development of research program in Indonesia was the lack of trained scientists. This is obvious from the fact that only one or two scientists of CRIA and associated research stations possessed Ph.D. degrees when IRRI started its cooperative work in 1970. Also, experiment station facilities were grossly inadequate. In developing cooperative projects attention was given on providing sufficient number of IRRI scientists to handle research programs as Indonesians proceeded for training abroad.

The Government of the Netherlands made a grant to IRRI for the improvement of facilities at the regional research station at Maros in South Sulawesi and for the development and implementation of a strong regional rice program. An IRRI agronomist and a station development engineer started working at Maros in early 1972. The funds for the improvement of physical facilities were provided by the provincial and national governments. A new research laboratory cum office building and a number of greenhouses and screenhouses have been completed. Land has been acquired and developed for experiments. Several staff members have received training. Beginning in 1974, IRRI concentrated in helping the Indonesians in developing a strong multidisciplinary program of research on rice. Since then three IRRI scientists (one agronomist, one entomologist, and one plant pathologist) have been stationed at Maros to supplement the local research staff in conducting research. As more Indonesians return to Maros after completing their training, the project is expected to gradually phase out over the next 3 to 4 years.

In 1972 IRRI developed a contract with USAID for participation in research on rice and multiple cropping program at CRIA, Bogor. This contract provided five staff members in the areas of rice breeding, rice agronomy, multiple cropping, and statistics. Another contract was signed in the end of 1972 with the Government of Indonesia under a World Bank loan for strengthening research at Sukamandi which will ultimately become the national rice research center. Three IRRI scientists (one plant pathologist, one entomologist, and one breeder) and one station development engineer are now working at Sukamandi. As the Sukamandi station has rapidly developed the work at Bogor and Sukamandi is being gradually integrated.

Agricultural research in Indonesia is undergoing a major reorganization. The entire research on agricultural crops, forestry and animal husbandry has been transferred to the Agency for Research and Development under the Ministry of Agriculture. A World Bank loan is now being negotiated to implement national programs on different commodities. The Ford Foundation grant terminated in April, 1975 and the AID contract will terminate in August, 1976. IRRI's level of future participation in rice and cropping system research at Bogor is not quite clear. It is anticipated that one rice breeder and one cropping system agronomist under the new World Bank loan will continue to work at least for some time with the two national coordinators for rice and non-rice food crops at Bogor. The headquarters of the national coordinators will ultimately be transferred to Sukamandi.

The Indonesian program has been the largest cooperative program of IRRI in recent years. The most significant accomplishments of the cooperative work has been the development of interdisciplinary GEU-type program on rice, research and testing program on cropping systems and regional program of rice research at Maros. IRRI scientists played an important role during critical shortage of local qualified scientists in the early 1970's. About one hundred Indonesians have been trained at IRRI, many of them for master's and Ph.D. degrees. As Indonesian scientists proceeded abroad for training, IRRI scientists maintained an adequate momentum of research. Now the Indonesians are returning after training and are gradually taking over research responsibilities. As they get established in implementing the national program, IRRI's involvement in Indonesia will be phased down.

Vietnam

Under a contract with USAID, IRRI assigned an agronomist and a rice breeder in early 1972 to assist Vietnam's Institute of Agricultural Research in accelerating rice research. One IRRI scientist worked full time at the National Crops Testing and Training Center at Mytho and the other was stationed at the Agricultural Research Institute in Saigon. The efforts of the IRRI team were focused on helping

Vietnam's researchers evaluate IRRI lines and conduct fertility and herbicide experiments. Several new IRRI lines performed well in yield trials and have been released for commercial production in Vietnam. Unfortunately, poor security conditions interfered with the experimental work at Mytho and the IRRI scientist was later moved to Long Xuyen in the Mekong delta.

The unstable conditions in Vietnam were a major constraint to the development of a good rice research program. The short-term crash production programs received more attention under the existing conditions than the long range research programs. IRRI continuously attempted to convince the Vietnamese Ministry of Agriculture for strengthening the research base for achieving increased production on a long-term basis. In January, 1974 a joint IRRI-Vietnam study team recommended the development of a well coordinated national rice program and the identification of strong Vietnamese leadership for coordination and appropriate direction of research to support goals of rice production. The report of the study team was accepted by the Government of Vietnam and was to form the basis for future cooperative work. IRRI helped identify a qualified Vietnamese resident in U.S.A. to assume the responsibility of coordinator, National Rice Program. With the help of the IRRI team the Vietnam Institute of Agriculture developed a 10-year training program to build scientific manpower. Another IRRI scientist was added to the team in the area of cropping systems. Unfortunately, the project came to a sudden end due to the war in April, 1975.

Egypt

In May, 1972 IRRI assigned a rice breeder to work in Egypt under a service agreement with the Arid Lands Agricultural Development Program of the Ford Foundation. He worked as a member of the national team and concentrated on the evaluation of IRRI breeding material with a view to identify fertilizer responsive, long grain indica rice to replace the japonica varieties which were used for commercial production in Egypt. Attention was also paid to establishing appropriate cultural practices for the indica rice. Some IRRI lines gave as high yields as the best japonica varieties but possessed superior grain quality. IR579-48 was grown commercially in 1974 and the area planted to indica varieties is expected to expand rapidly. Having completed its initial objectives, the project terminated in May, 1975.

Philippines

Since August, 1972 an IRRI rice production specialist is working with the National Food and Agriculture Council of the Philippines under a contract with USAID. The major objective of the contract is to help NFAC incorporate the results of research carried out at IRRI and by other local agencies into the national production program. The emphasis has been on training of extension workers, preparation of information material and production plans, and conduct of applied research on farmers' fields.

The IRRI crop production specialist operates through the NFAC-sponsored inter-agency project -- the Unified Rice Applied Research Training and Information Project (URARTIP), which provides technical support to the national rice production program called "Masagana 99" (bountiful harvest). It involves the use of tungro-resistant high yielding varieties, supervised production credit, a fixed minimum support price to the farmer, and use of recommended amounts of fertilizers and insecticides. The national program was patterned after a pilot applied research and production project implemented by IRRI in cooperation with the Philippine Bureau of Agricultural Extension in Central Luzon. Masagana 99 has been widely acclaimed as a highly successful and effective program which has brought back the Philippines close to self sufficiency in rice. The cooperative project in the Philippines is expected to continue for the foreseeable future.

COOPERATIVE COUNTRY PROGRAM IN INDONESIA

COOPERATIVE COUNTRY PROGRAM IN INDONESIA[1]

I. Background

The Ministry of Agriculture submitted a request for funds from the Ford Foundation in early 1970 for the services of a senior scientist, consultants, salary supplements for Indonesian rice research workers, training, and equipment and supplies. The Ford Foundation made a grant to IRRI in mid-1970 in line with the Ministry's request.

Dr. Shastry was employed by IRRI as a consultant in June-July 1970 to make recommendations for a rice research program. He realized that one of Indonesia's largest problems was the dearth of trained research workers. In order to more fully utilize effectively these few scientists available, he recommended the establishment of the National Rice Research Program (NRP). The emphasis was to be placed on a coordinated program to avoid duplication of work and to tackle only those research projects of highest priority. The NRRP was to be supported by three task teams, one for production and protection, the second for economics and the third for extension and training; each team was to be headed by one person. These three task teams were to be further subdivided into ten working groups. The production and protection group was to be supported by research workers in breeding, entomology, pathology, and agronomy and physiology, the

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[1] Prepared by Robert I. Jackson

latter two disciplines forming one group. The economics team was to be composed of teams in economics, marketing and processing and the extension and training team supported by groups in education, training and extension. Through a series of meetings, the teams and groups were to develop a coordinated rice research program for high priority research. During the first meetings of the NRRP, none of the members were given any guidelines nor research project(s) to defend and each thought that his research should be supported by the NRRP. This resulted in no change in the system and the research workers became disappointed and disillusioned in the NRRP mainly because of the lack of extra funds for their research.

Just as significant as the lack of added financial assistance from the NRRP for research has been the fact that the NRRP has never been formally established by government decree. Had such decree been issued, it would have given some impetus to the Program and perhaps fostered some leadership.

In mid-1972 an <u>ad hoc</u> committee held a series of meetings to determine the priorities for the research projects as criteria for inclusion in the NRRP. Once these were completed, they were never circulated to the members of the NRRP.

The NRRP has now existed, at least as an idea, for four and a half years. Two coordinators have been named for the Program at this time but neither has spent the time required to coordinate the Program. The first coordinator was named in April 1971, nearly one year after the conception of the Program. Both of them at best have spent considerably less than 25 percent of their time as coordinators.

Another recommendation made by the consultant was for the setting up of a body composed of top level civil servants to examine and to approve of the research to be carried out under the aegis of the Program. At least this body was formally established and it held one meeting. Unfortunately, instead of the top level policy and decision makers attending, persons of much lower stature were included. Some of the people hardly knew what the NRRP was nor much of its concept. Foreign donors providing assistance to Indonesia were to serve on this body in an _ex officio_ capacity, but this too never came about.

In Indonesia, a program can be financed only to the extent of its secretariat function and not for research projects and the execution of the work. At best then, the NRRP can obtain funds for holding meetings, publishing research findings and the day-to-day operation of a small office. If it can be no more than a coordinating body without some control over funds for research work, it cannot be very effective. Perhaps one way to overcome this difficulty is to change the name from a Program to Project and thus avoid this budgetary restriction. In order for it to become a Project, it could be incorporated into an existing research unit. At the same time some type of formal recognition should be given.

II. The Ford Foundation Grant

Funds from the Grant were used by IRRI to employ a senior scientist who became the joint coordinator of the NRRP. Since there has been no full time coordinator, not as much could be accomplished with the NRRP as was originally envisaged. It wasn't until the agreement between the Ministry of Agriculture, on behalf of the Government of Indonesia, and IRRI was signed in late December 1972 that IRRI's senior scientist was formally recognized as the joint coordinator.

The reason for including a provision of funds in the first Grant for salary supplement for the Indonesian rice researchers was that many of them were spending a large proportion of their time on outside jobs to earn sufficient income to exist. It was believed that one way to increase their effectiveness and the amount of research work done was to add to their basic salaries. It was never possible during these first two years of the Grant to work out a satisfactory arrangement for these income supplements. Fortunately as time has gone along, the Government has been able to increase the take home pay of the research workers through higher salaries and increased honoraria. Both of these have had a decided effect on the improvement of the morale and reduction in the moonlighting. Since these funds were not used in the first two years of the Grant, no provision was made in the next two-year grant for this budgetary item.

It has already been mentioned that Dr. Shastry served as an IRRI consultant to Indonesia. Funds for this and a few other early consultancies were provided from the Grant. More recently consultants from IRRI have been financed by other projects and little use of this budgetary item has been made in the last two years. The same has held true for purchasing supplies and equipment for the IRRI/Indonesian projects. The equipment necessary to make amylose determinations was purchased before money was available from other sources. Prior to setting up the quality laboratory, grain samples were sent to IRRI. With an expanded breeding program getting underway in Indonesia, it was determined that it would be more practical to do the laboratory analyses within the country.

One of the big contributions which has been derived from this source of support has been the opportunity to allow the wives and up to two children to accompany those participants who have gone abroad for a Ph.D. degree program. This has given a great boost to the morale of these candidates and their families. Funds were used for in-country training and for a few participants trained abroad when funds were not available from alternate sources.

III. The Dutch Grant

The Netherlands Government agreed in the first instance for a grant to IRRI for $500,000 over a period of five years to support rice research in Indonesia. In line with one of the recommendations of the Cummings-Sutardi Report for the decentralization of agricultural research, it was decided to support the development of a new branch station at Maros, South Sulawesi. The provincial government had delineated an area of 150 hectares for this station, approximately 110 hectares were irrigated and the remaining 40 were to be used as a building site and an area for research on upland crops. A proposal was submitted to the Netherlands Government requesting $200,000 for the period October 1971 through September 1973. This money was used for the development of the Maros station including the services of two experts and purchase of equipment and supplies. There were sufficient funds in the first grant to continue the project up to August 1974. The Netherlands Government was requested to provide $443,000 for the second phase for the period August 1974 through July 1977, an increase of $143,000 over the original $500,000. This second release of funds is being used to hire three agricultural experts to train part of the Maros staff and to purchase additional equipment and supplies.

The progress at this station has been very good. The biggest drawback has been the slowness on the Government's part to purchase the 150 hectares about half of which has been obtained. The construction of the laboratory/office buildings, workshop, seed storage and greenhouse has been completed pretty much as scheduled. Much of the credit for this is given to the development engineer provided by IRRI under the grant. The equipment has been installed in the laboratoreis and is being used by the staff. One man is completing his requirements for an Ir. degree. There are plans to send one for a Ph.D. and another for an M. S. in February this year.

Research work is underway and the three IRRI staff members will be of great assistance in training the staff and developing a sound research program. The three disciplines of these scientists are agronomy, entomology and plant pathology. One of the important diseases in South Sulawesi is tungro and it has been found to be an excellent area to screen both Indonesian and IRRI material for resistance. The IRRI entomologist at Maros has worked closely with the Indonesian staff and experts from Bogor, as well as with the Maros staff, in conducting these screening trials. The agronomist has spent most of his time in the past working with the staff in research administration and staff development; it is expected that he will have more time to devote to field research in the future. The plant pathologist is expected sometime within the next month or so.

IV. AID Contract

The USAID Mission in Jakarta finalized a project with the Ministry of Agriculture in June 1971 and a contract was entered into by AID and IRRI in February 1972 in which IRRI was to provide a total of five scientists in rice breeding, rice agronomy, secondary crop breeding, multiple crop agronomy, and statistics/economics. The contract also had funds to purchase equipment and supplies including automobiles. There was no provision of funds in the contract for training as all this money was retained by the USAID/ Jakarta office.

The first four experts arrived in Indonesia during August-September 1972. The Indonesian Government is obliged to provide staff housing for the IRRI team members. Even though the construction of the houses began in April 1972 it was thirteen months before they were completed and ready for occupancy. In the meantime, four of the team members and their families were placed in temporary quarters and this was demoralizing for them.

With the approval of USAID, laboratory and field equipment, office supplies and vehicles have been purchased under this contract. Most of these items have been received and are in use.

Ten persons are abroad for advanced training from USAID funds in the disciplines of breeding, agronomy, entomology, and agricultural education. Three or four of them are expected to return during this year. These and the others can and should give much impetus to the research program in Indonesia.

The rice breeder has done an excellent job in assisting in the selection, testing and evaluation of several crosses made in Indonesia and at IRRI. Multi-resistance to insects and diseases, cold tolerance, high protein, cooking quality, high yield potential, and short maturity are some of the characteristics which have been under study. It was through his encouragement that the two most recent varieties, Pelita I/1 and I/2 were released. He anticipates the release of one or two more varieties this year.

The rice agronomist position is now vacant after being filled for two years. During his tour the agronomist conducted trials with sulfur coated urea and water management. There is still a need for the services of an agronomist and hopefully this position will be filled in the near future.

The secondary crop breeder has been working principally on soybeans, peanuts and mungbeans. New introductions of these crops have been made and screened for disease and insect resistance. Some of the lines which have been found to have resistance have been used as parents in the hybridization program. It is the plan to use improved varieties from this project in the multiple cropping program.

The multiple cropping research has developed from an ad hoc status in the Agronomy section into a cropping systems project, one of the four at the Central Research Institute for Agriculture. Research workers from other disciplines, such as entomology, physiology and economics, have been assigned to the project and a coordinated, interdisciplinary research effort has been developed. This project has been enhanced by training personnel in multiple cropping at IRRI. Presently there are fifteen experiments involving basic and applied studies on intensive cropping systems underway. Research has been initiated on farmers' fields in problem areas in South Sumatra and the north coast of Java to develop cropping systems that will allow one or two extra crops per year.

The statistician/economist has had the added responsibility of spending about one-third of his time in administration. Much of this is related to small details which has to be done by someone but is not directly productive to research findings. In spite of this he has been able to initiate research at the Maros and Sukamandi stations on the influence of HYV's and technological changes associated with their use.

From the standpoint of administering this contract, there are restraints which cause delay, added inflexibility and more administrative detail than with the two grants already discussed. Without these restraints we have moved ahead faster and accomplished more at Maros than at Bogor, the headquarters for the AID/IRRI team. Research workers balk at these restraining details and the net effect is a lowering of morale.

V. Sukamandi Contract

The World Bank became interested in seed production in Indonesia in the late 1960's. An IDA credit was made to finance a seed production center and a supporting research station. The Sukamandi Station has been developed from funds from the Ministry of Agriculture. The loan credit has been used for a contract with IRRI to provide foreign experts, training and to purchase a limited amount of equipment and supplies, and vehicles. This contract was signed at the end of December 1972 and up to the present time less than 1.5 man-years of foreign experts services have been used when provision was made for up to 12 man-years. In the contract it is stated that the Ministry will provide furnished housing with electricity, potable water, local counterpart staff and laboratory and office accommodation. Since these have not been provided in a timely fashion, recruitment has been delayed. The counterpart staff is still short and as yet no one has been sent abroad for training.

The restraints are not as great in this contract so far as IRRI's personnel policies are concerned in comparison to the AID CONTRACT. However, IRRI has had little control over the housing, supply of potable water and hiring of the counterpart staff. Consequently without flexibility, funds and control, it has not been possible to achieve the goals and objectives as defined in the original contract. Plans are now underway to extend the contract for two years to make up for this loss in time. A recent regulation has made it extremely difficult to provide the automobiles, agreed to in the contract, for any of the experts to be recruited.

Vi. Agricultural Machinery Sub-contract

This small project is an extension of IRRI's program to design agricultural machinery for the small rice producer. It was the original intent of this sub-contract to provide funds and a means for testing the IRRI-designed equipment under Indonesian conditions. So far the two-row seeder, power tiller, axial flow thresher, table thresher and bellows pumps have been tried.

Recently there has been a keen interest in some of the local manufacturers and distributors to build and market the power tiller, axial flow thresher and row seeder. It appears that this program is now at the stage of takeoff and that rapid progress and expansion will soon take place. There is a definite need for this equipment when one considers the cropping systems programs along with the shorter maturing rice varieties which can be cultivated successfully twice a year. The Government is opening large areas outside Java for its transmigration program where the transmigrants are expected to cultivate up to five hectares of land. This can only be done satisfactorily with additional power and machinery.

VII. Brief Summary of Accomplishments

IRRI has provided 24 man-years of foreign experts service during the past four and a half years associated with the two grant and two contract projects. In addition, nearly every senior scientist at IRRI has served as a consultant to the Indonesian Program by making at least one visit to the country.

This foreign expertise has helped the Ministry of Agriculture in the development of new crop varieties (screening for disease and insect resistance), improved cultural practices, setting up a statistical center, and the development of two branch stations.

At the beginning of IRRI's involvement in the Indonesian Program, there was only one staff member at CRIA who had a Ph.D. degree. There are now 13 men abroad for academic training, most of them candidates for a Ph.D. Approximately 50 have been given non-degree or short course training in multiple cropping, rice production, rice breeding, field experimentation, rice quality testing, and physiology.

Laboratory, field, office equipment and supplies have been purchased and put into use. To support the projects, 21 vehicles have been bought.

VIII. Future Plans and Comments

During the April 1974 meeting at IRRI, a working paper on Indonesia's rice research was discussed, primarily in the light of the NRRP. The foreign donors providing assistance to Indonesia for rice research showed concern over the NRRP and the USAID had determined that its grant program should be converted into a loan by August 1976. During the past eight months, the USAID has prepared a loan proposal for financing rice research in Indonesia for a five-year period, the foreign cost component now stands at $5.4 million. Four foreign experts would be provided, one for Sukamandi plus three at Bogor. Included are $935,000 for training, $2.4 million for equipment and supplies, and $1 million for local costs for buildings and houses.

The Dutch bilateral program now calls for four foreign experts, all to be at Bogor. There is a small amount alloted for non-academic training as well as for a limited amount of equipment.

The Japanese are preparing a new proposal for assistance as their current project terminates in October 1975. Currently they are providing four experts and are considering increasing this to eight. Funds would be available also for non-academic training and commodities.

The Dutch grant for Maros provides for three experts for about three more years. The Sukamandi contract, as amended to present plans, will furnish four agriculturists. In the World Bank's new loan proposal for assistance to agricultural research in secondary crops, the services of three or four experts will be required.

From these various programs 26 or 27 experts will be provided. To make the services of these individuals effective, good counterparts must be available. It is difficult to find this many, that is one for each expert, and of course even more difficult to find more than one. In addition to this problem, each of the programs calls for sending persons abroad for training. This makes the problem of counterparts even more critical. Nearly all of the counterparts going abroad for this training require up to six months of intensive English language training and this is effect takes them out of service for this additional time.

Considering past experience of donor assistance in Indonesia, it is questionable how much more can be effectively absorbed in the way of technical assistance and commodities. The shortage of local manpower in numbers, in quality of research management skills are the governing factors. There is only so much change in form and size an organization can undergo before the systems of power, communication and directional control begin to breakdown. All of the foreign assistance currently planned for research on food crops might exceed the absorptive capacity and initiate pressure for institutional changes which cannot be made under the current situation. The system has only so much capacity for growth and development and increased assistance may not accomplish the goals and objectives of a sound research program.

THAILAND RICE RESEARCH PROGRAM[1]

Although rice research has been in progress for the past 60 years, 1950 marked a determined effort by the Thai government to increase production and improve grain quality through research efforts. Staff numbers and training have continually increased and resulted in more than 200 technical workers located at 21 rice experiment stations throughout the country at the present time.

It should be emphasized that a wide diversity of research is required for the country since climate, soils, diseases and insects vary greatly from the South to the Central Plain, North and Northeastern regions. For example, major constraints in the South include an extended monsoon season, high incidence of disease, lack of good water control and infertile soil whereas in the Northeast farmers are confronted with drought, extremely infertile sandy soil, rice gall midge and a short monsoon season with limited rainfall. Furthermore, many of the North and Northeastern people consume glutinous rice as a basic part of their diet whereas in Central Plain and South non-glutinous type grain is used almost exclusively. In the Central Plain, a large part is devoted to floating rice and traditional tall types which are photo-sensitive and capable of coping with semi-deep to

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[1] Ben R. Jackson, Rice Breeder

deep water. Good milling and cooking quality is a major requirement for the release of a variety in all regions but especially so far the Central Plain.[2]

MAJOR PROGRESS IN DEVELOPING HIGH YIELDING VARIETIES:

During the past seven years, Thai rice scientists have developed seven hybrid varieties, all of which are responsive to fertilizer and have non-sensitivity to photoperiod. These varieties were developed to help fulfill the needs of specific areas where problems such as gall midge, brown planthopper, yellow-orange leaf virus (Tungro) and bacterial leaf blight and semi-deep water exist.

RESEARCH WORK CURRENTLY UNDERWAY:

Major emphasis is being devoted to the following:

1. Rainfed Lowland Rice (varieties, agronomy).
2. Deep Water Rice (varieties, agronomy, physiology).
3. Development of Photoperiod-Sensitive semi-dwarf forms.
4. Identification of well-adapted local forms with higher grain protein content and wide adaptability.
5. Improvement of cooking quality.
6. Incorporation of multiple resistance to diseases and insects of major importance.
7. Improvement of upland varieties for the hill and mountainous areas.
8. Maintenance of local genetic stock collections.

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[2] Most of this paper is concerned with varietal improvement since this has been a major focus of attention. However, it should be emphasized that practically all important areas of research are being actively pursued in cooperating divisions of the Department of Agriculture and and to some extent by other organizations.

PROPOSED WORK DURING THE NEXT FIVE YEARS:

All of these projects will require continued efforts during the next five years. As we identify genotypes which are superior in such characteristics as drought tolerance, protein content, deep water tolerance, salinity, and acid sulfate soil tolerance and improved grain quality, attempts will be made to combine such characters into improved varieties with high yield potential. For example, plans are underway to combine tolerance to salinity with ability to survive deep water and submergence since most coastal areas where salinity is a problem also suffer from semi-deep water. Similarly, genetic stocks which have high grain protein content will be crossed with improved varieties to permit greater fertilizer responsiveness and subsequently high yield along with improved nutritive value.

THE INVOLVEMENT OF THE IRRI IN THAILAND RICE RESEARCH PROGRAM:

Even though the formal involvement of the IRRI in Thailand's rice research program is very recent, close informal participation and cooperation has been underway since the founding of the institute. Thailand has provided the services of three prestigious persons to serve as members of the board of trustees at IRRI including M.C. Chakrabandhu, a charter member, followed by Dr. Sala Dasananda who served during the years 1965-1969 and Dr. Bhakdi Lusanandana, a current member.

One of the IRRI's major contributions to Thailand has been in the area of training. Since the establishment of the institute more than 100 Thai Civil servants have received training ranging from short term to the graduate level. Most of these were from the Rice Division of the Ministry but a few were also from Kasetsart University. With very few exceptions all former trainees have returned to their respective tasks and are using the knowledge and experience gained while at the IRRI.

The annual international meetings and symposia have also provided an excellent opportunity for Thai scientists to exchance views with colleagues from other countries as well those at the institute.

Cooperative experiments began in 1964 with the introduction of experimental lines, bulk hybrid populations and advanced lines for yield testing. This was expanded to include field screening tests of IRRI breeding material for resistance to tungro virus during 1967-1969 when the disease was extremely heavy in Thailand but testing in the Philippines had to be restricted to the laboratory. International blast tests have been grown on a cooperative basis for many years. Prsently, Thailand is cooperating with IRRI in the GEU program by growing one or more sets of the international tests currently offered.

One of the past cooperative tests which deserves special mention concerned the evaluation of different sources of rock phosphate. This was a joint Thai-IRRI-TVA research project to determine the usefulness of rock phosphate as a substitute for super phosphate. The results of a 3-year study at the Klong Luang Rice Experiment Station clearly showed that not all sources of rock phosphate were equally effective but some were as good as super phosphate under the acid sulfate soil conditions. The results of this work have stimulated Thai scientists to search for local sources of this material and to expand their research to other regions where phosphorous deficient soils severely limit rice production.

IRRI breeding lines have provided valuable sources of diseases and insect resistance for use in crosses. The varieties RD1, RD2 and RD3 contain either IR8 or Taichung (Native)1 as the donor of the semi-dwarf characteristic and many other IRRI varieties and lines are presently involved in hybrid populations under selection and evaluation.

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