International Rice Research Institute

Annual Report for 1984



International Rice Research Institute
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Annual Report for 1984

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Contents

TRUSTEES	vi
PERSONNEL	vii
ABOUT THIS REPORT	xiii
RESEARCH HIGHLIGHTS	1
GENETIC EVALUATION AND UTILIZATION (GEU) PROGRAM	7
Genetic resources program	7
Agronomic and physiological characteristics	17
Grain quality and nutritional value	35
Disease resistance	45
Insect resistance	65
Drought tolerance	85
Adverse soils tolerance	101
Deep water and flood tolerance	111
Adverse temperature tolerance	115
Innovative breeding methods	125
Computerized data management	139
International Rice Testing Program	143
Integrated GEU program	155
CONTROL AND MANAGEMENT OF RICE PESTS	175
Diseases	175
Insects	189
Weeds	217
IRRIGATION WATER MANAGEMENT	231
SOIL AND CROP MANAGEMENT	245
Soil characterization	245
Management of soil and fertilizer nitrogen	457
Nitrogen fixation and azolla management	273

Management of other nutrients 293
International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) 305
Rice crop cultural practices 315
Tillage and management of soil physical conditions 319
CLIMATIC ENVIRONMENT AND RICE 331
CONSTRAINTS ON RICE YIELDS 343
CONSEQUENCES OF NEW TECHNOLOGY 361
CROPPING SYSTEMS PROGRAM 371
Analysis of the physical and biological environment 371
Analysis of the social and economic environment 377
Pest control in rice-based cropping systems 383
Design and evaluation of cropping patterns 395
Selecting and testing varieties for rice-based cropping patterns 399
Agronomic management in rice-based cropping systems 411
Preproduction testing and technology transfer 433
Asian Rice Farming Systems Network 441
MACHINERY DEVELOPMENT AND TESTING 451
ASSOCIATED TRAINING PROGRAMS 463
COOPERATIVE RESEARCH 475
INFORMATION RESOURCES, EXPERIMENTAL FARM, AND SERVICE LABORATORIES 480
PUBLICATIONS AND SEMINARS 484
FINANCES 498
STAFF CHANGES 499
WEATHER SUMMARY 502

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About this report

This 23d annual report includes research conducted during 1984. After carefully summarizing their work, scientists submitted more than 1,800 pages of documentation for this report. Further condensation produced this volume, necessarily abbreviated in style as well as detail.

Although scientists' names do not appear in the text, chapter and section headings identify departments responsible for the work reported. Scientists also report through Research Highlights, the International Rice Research Newsletter (IRRN), the institute's research paper series (IRPS), and conference proceedings, books, and technical journals.

Each year, the institute intensifies its cooperative work with national and international agencies, based on the priorities expressed at work plan meetings. Although every section of this report makes specific mention of this collaboration, it is best described in the Cooperative Research section, p. 475. Other sections on cooperative work include those in the International Rice Testing Program (IRTP), p. 143; the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER), p. 305; the Asian Rice Farming Systems Network (ARFSN), p. 441; the Machinery Development and Testing Program of Industrial Extension, p. 451; and the Associated Training Programs, p. 463.

The amount of detail presented requires many abbreviations, which may disconcert readers. We therefore spelled out all names and terms on first use in each section and used abbreviations thereafter.

This report refers to three fundamental types of rice culture. Upland culture means rice grown without irrigation in unbunded fields. Rainfed culture means rice grown without irrigation but in fields that are bunded to impound water. Irrigated culture means rice grown with irrigation in bunded fields. The adjectives upland and lowland describe rice and rice-growing soils.

The report is on a metric basis and uses the International System of Units (SI), with a few exceptions. Monetary units are usually in U.S. dollars ($) but sometimes in Philippine pesos (exchange rate ₱14 = $1). Control or check normally means an untreated control. Grain yield is calculated as rough rice at 14% moisture, and protein content as a percentage of brown rice at 14% moisture. Yield refers to grain yield unless otherwise noted. Most fertilizer amounts are converted from various formulations (P_2O_5, K_2O, etc.) to N, P, K, Zn, etc.

Pedigrees are indicated by a slant bar (/) rather than by a multiplication sign (×). For example, PTB33 × IR30 is written PTB33/IR30. The sequence of crosses is illustrated by the number of slant bars. (PTB33 × IR30) × IR36 is written PTB33/IR30//IR36. Fourth and further crosses are designated /4/, /5/ and so on. Backcrosses are indicated by a superscript numeral.

Unless otherwise noted, scoring of morphological characters and of damage attributed to rice pests and physiochemical stresses is based on scales in Standard Evaluation System for Rice (SES), 2d ed., 1980. Copies are available from the IRTP, IRRI.

A single asterisk (*) means difference at the 5% level of significance, and a double asterisk (**) means significant difference at the 1% level. Unless otherwise stated, separation of means in table columns is by Duncan's multiple range test at the 5% level.

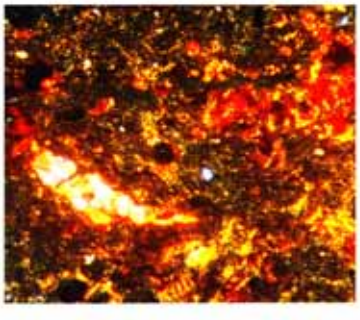
This report normally uses generic names for chemicals. Use of a commercial or brand name does not constitute endorsement.

A thumb index on the back cover provides access to each section. To use it, bend the book slightly and follow the margin index to the page with the black-edge marker.









The success of IRRI research and collaborative programs, whether basic or adaptive, depends upon the pride and skill of our researchers, and cooperators in national agricultural systems.



Research highlights

NEW DIRECTIONS

In 1984, as we approach our 25th anniversary, it is important that we evaluate past achievements and look forward to the new directions the current global agricultural situation demands.

When we began, our efforts concentrated upon improving yields and production in the irrigated lowlands of South and Southeast Asia. Through collaborative work with national research systems, short-statured, fertilizer-responsive, pest-resistant varieties were developed, introduced, and widely adopted. The real price of rice to consumers fell and some rice-importing nations became exporters. Confidence in rice research increased, and through training and collaborative research, we helped establish a secure foundation for continued improvement of rice production and management.

Our first and most important challenge in coming years is to defend the gains already made. Although many modern rices have resistance to insects and diseases such as brown planthopper, stem borer, tungro, and bacterial blight, pests continue to evolve and change. Our entomologists, pathologists, and breeders must monitor insect biotype development and disease virulence patterns to keep in the development pipeline new breeding lines with a wide spectrum of resistance genes for the time when a new pest causes economic losses.



*Ripple bugs (*Microvelia*) attack brown planthopper larvae when they fall from rice plants into field water.*

In 1984, we carefully watched planthopper evolution in Indonesian and Philippine fields and observed changes in green leafhopper populations. Virulence patterns of bacterial blight in some countries are substantially different from 5 years ago. Research on tungro, with the help of an electron microscope, has identified different shaped virus particles and particle combinations and related them to disease intensity.

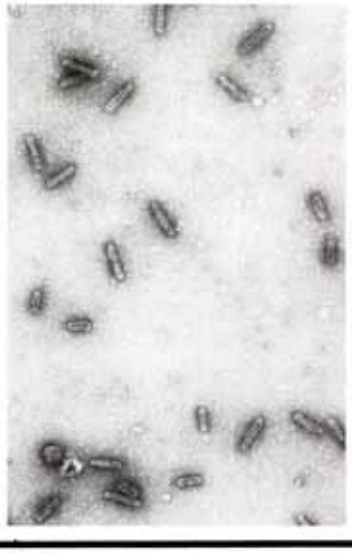
Rices with wider genetic sources of pest resistance and more tolerance to soil and environmental stresses will remain essential to stable and increased yields. Expanding the rice germplasm collection, including the wild rice collection, will broaden the pool from which genes for resistance may be extracted.

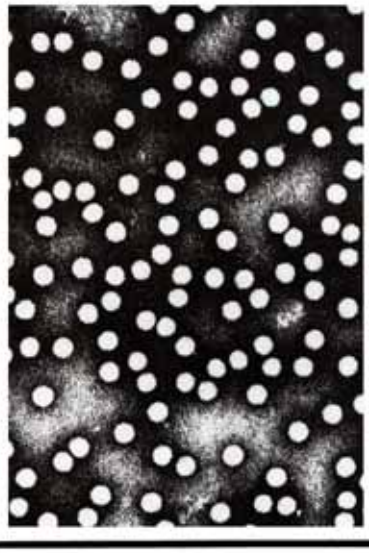
Soil stresses such as salinity, aluminum and iron toxicity, and phosphorus deficiency limit yields or prevent useful cropping on large land areas around the world. Rice, often used as a reclamation crop in poor soils, has shown substantial potential for tolerating adverse soils. Soil chemical and soil physical

research are essential to understand tolerance mechanisms and growth patterns that will help researchers develop varieties for areas where rices cannot now survive.

The development and use of low-cost technologies such as organic manuring and cultural methods to encourage growth and multiplication of nitrogen-fixing organisms are receiving increasing attention. These will complement the use of inorganic fertilizers to increase soil nutrients and reduce investments in purchased inputs. To improve the efficiency with which fertilizers maintain and increase yields, we must optimize water management to decrease nitrogen volatilization and







Field infected with tungro virus (top). Through electron microscopy, we have identified two tungro virus particles: bacilliform particles (left) and spherical particles (right).

encourage the use of fertilizer deep-placement and injection machines, and correct timing of applications.

For those countries that have reached self-sufficiency in rice, research into the nutritional value of the rice grain and consumer grain quality preferences is increasingly important. In 1984, we conducted preliminary marketing surveys to identify rice types that consumers prefer and worked with researchers in the United Kingdom and Denmark to quantify the nutritional value of rice varieties and effects of milling on different types of rice grains.

As we work to defend those gains already achieved for favorable rice growing areas, we also must intensify our efforts to find better adapted varieties and management methods for adverse environments and give greater attention to social and equity issues.

We are continuing our efforts to more precisely classify world rice environments. *Terminology for rice growing environments,* published in 1984, is the first step in developing a universal language for rice cultural types and environments around the world. More than 50 rice workers contributed time and ideas to the booklet. We will continue to incorporate additional data and work to fine-tune the terminology.

Breeding and management for adverse environments, in which more than half of the world's farmers must survive, are challenging problems to address. In most harsh environments, farms are small, management practices may degrade what are already poor soils, and the economy and market infrastructure are underdeveloped. We are working to develop drought- and submergence-tolerant varieties; simple, low-cost input management practices; and simple machines that will increase yields and cropping intensity while reducing human drudgery.

In these environments, homegrown inputs such as nitrogen-fixing green manure crops and ecologically advantageous cropping patterns may be especially important. Cropping systems projects in disadvantaged areas are answering questions about modern technology adoption and its consequences for farmers, families, and laborers, and are establishing a basis for extrapolating new technology to other impoverished areas.

Similarly, we need studies to identify the effect of modernization on the availability of work traditionally performed by women and other landless laborers. Technologies for increasing the income of women farmers and laborers will receive attention under the Asian Rice Farming Systems Network. Research to understand market infrastructure also will contribute to the introduction of better farming methods.



Azolla green manure is used on large areas of rice in Vietnam.



Always, our research must respond to the specific needs of our clients — the national research systems, farmers, and consumers of the rice world.

Three groups of rice-growing nations can be identified. Group I countries have almost no gap between current and potential production and yield. Harvests average more than 4 t/ha. Research for these areas will attempt to raise the yield ceiling, achieve greater yield stability through improved soil and plant health care, intensify cropping, and develop input-output pricing policies that stimulate production and consumption.

In Group II countries, there are technological and socioeconomic constraints to improving yields, which average 2-4 t/ha. These countries require increased support from the major IRRI networks: the International Rice Testing Program, the International Network on Soil Fertility and Fertilizer Evaluation for Rice, and the Asian Rice Farming Systems Network. For Group II countries, such as Burma and Thailand, that export rice, technology will grow in importance.

Many Group III countries, with yields below 2 t/ha, have a large, untapped production reservoir. Some have harsh environments, poor soils, and severe socioeconomic constraints. The first research step for these nations will be multidisciplinary constraints analysis to identify ecological, technological, economic, institutional, and sociopolitical constraints that cause the yield gap. A carefully designed malady-remedy analysis will help formulate short- and long-term research and development strategies. We have recently begun a cooperative program with the Malagasy Republic, using this strategy.

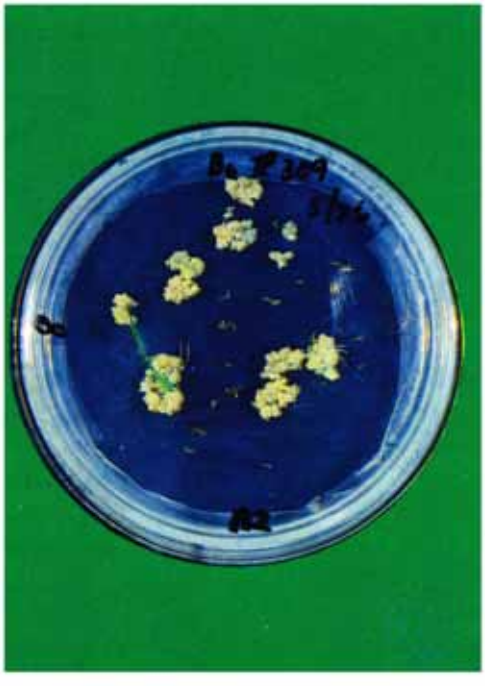
IRRI research programs can be divided into three categories: *maintenance research,* to defend gains already made; *downstream research,* to solve immediate field problems through applied and adaptive research; and *upstream research,* to harness the latest advances in science and technology for solving downstream problems and raising the yield ceiling to a new plateau of stability.

With sophisticated tools such as the electron microscope, the phytotron, interactive computer programs, and satellite imagery, we will seek to understand the intricacies of virus disease development and transmission, climatic influence on rice growth, the social impacts of new technologies, and the interactions of land use patterns and pest populations.

New techniques in biotechnology are helping us to move valuable genes across sexual barriers. For example, by culturing embryos of seeds from a cross of *O. sativa* and the wild rice *O. officinalis,* we successfully grew F_1 hybrid plants that had genes and exhibited traits of both parents. Tissue, anther, and somatic cell culture may speed the development of new rices that perform well in complex adverse environments, such as those where almost every rice crop needs drought and submergence tolerance and may need traits such as photoperiod sensitivity. The new techniques also may reduce for farmers the cost of proven technology such as hybrid rice production.

Anther culture can reduce breeding time for new cultivars, increase selection efficiency, and save space and labor in experimental fields.







S. H. Escudero III, Philippine minister of agriculture and food, addressing the biannual IRRI-Philippines Technology Transfer Workshop.

Essential to our work will be strong cooperation and collaboration with universities and research institutes that have expertise in fundamental studies, state-of-the art instrumentation, and interest in applying their strengths to solving practical problems in rice production. These associations will allow the newest advances in genetic engineering to be applied to rice research.

The finest of agricultural science is useless if the results remain inaccessible to extension workers and farmers. Communication of knowledge and skills will remain essential to all our programs. We communicate through degree and nondegree training programs, subject-matter conferences, publications, and person-to-person contact with researchers and extension workers around the world.

Transferring developed and proven training programs and methodologies from IRRI to national programs will place training closer to trainees and permit IRRI to develop new courses. Copublication with book publishers and national programs helps spread information to diverse, non-English speaking audiences. Interactive, computer-aided instruction also will help bridge the language gap. We are continuing to broaden our communications activities and adjust them to the needs of our national cooperators.

These techniques, in combination with constant fine-tuning of cooperative and research programs and the growing inventory of opportunities for increased rice yields and production, will guide our new directions as they have guided our past successes. In agriculture, there is no time to relax. We must continually meet new challenges of plant and soil health care and consumer and market needs. Eternal vigilance and a dynamic response to changing needs therefore are IRRI's guiding principles.

Genetic evaluation and utilization (GEU) program

Genetic resources program

International Rice Germplasm Center, Statistics Department, Tissue Culture Facility, and Communication and Publications Department

FIELD COLLECTION **8**
INSTITUTIONAL EXCHANGES **8**
INVENTORY, CHARACTERIZATION, AND DATA PROCESSING **9**
SEED INCREASE, REJUVENATION, AND DISTRIBUTION **9**
SEED PRESERVATION **9**
RESCUE OF NONVIABLE SEEDS BY TISSUE CULTURE **10**
ENZYMATIC POLYMORPHISM IN RICE GERMPLASM **10**
TRAINING OF GENETIC CONSERVATIONISTS **10**
TECHNICAL ASSISTANCE TO OTHER GENEBANKS **11**
DIFFUSION AND ADOPTION OF GENETIC MATERIALS, 1965-84 **11**
- Diffusion of parental materials **11**
- Breeding objectives **12**
- New varieties **13**
- Widely grown varieties **15**

FIELD COLLECTION

International Rice Germplasm Center

Field collection expanded and accelerated in 1984 as four Asian countries and Malagasy joined the germplasm conservation program. The program netted 549 traditional varieties and 18 samples of wild rices during 6 collection missions.

Field activities in 7 countries in 1984 gathered 3,740 cultivars (Table 1). The collection, begun in 1971, nears 40,000 seed samples of which IBPGR funding accounted for 13,130.

In early 1984, IRRI-IBPGR mobilized a cooperative project for conserving rice germplasm in the Malagasy Democratic Republic. The IRRI-IBPGR field collector helped form a national collection program and field collection began on the Antananarivo floodplain. Field operations in May netted 85 lowland varieties and 13 upland land races that are potential sources of tolerance for low temperature and adverse soils.

Operations in Bangladesh during the aus season possibly saved the collection of 103 varieties from permanent loss in floods that followed. IRGC now has seeds of almost 5,500 Bangladesh varieties. High priority is to collect wild species.

The second phase of collection in Bhutan covered remote interior regions and upland sites under shifting cultivation. Numerous old land races may be sources of tolerance for low temperature and drought. IRRI and IBPGR helped implement broad-based field canvassing in Bhutan in 1984 and gathered 66 varieties. Future input will help train local researchers collect for and maintain the national collection.

Traditional variety collection in Sri Lanka was essentially completed in early 1984. With the field collector's help, the Central Agricultural Research Institute collected 108 varieties in 8 districts, which represent promising sources of tolerance for drought and submergence and adaptation to unfavorable soils.

In addition, 10 populations of 4 wild *Oryza* species (*O. rufipogon, O. nivara, O. officinalis,* and *O. granulata*) and 4 hybrid swarms between *O. sativa* and its wild relatives were sampled. IRGC now maintains 2,200 Sri Lankan accessions. Intensive wild rice collection was recommended for 1985.

Table 1. Indigenous rice varieties collected with IRRI-IBPGR assistance in collaborating countries during 1984.

Country	Indigenous varieties collected (no.) with IRRI's	
	Direct participation	Indirect participation
Bangladesh	103	–
Bhutan	66	–
Indonesia	174	15
Malagasy	98	123
Philippines	–	57
Sri Lanka	108	–
Thailand	–	2996
Total	549	3191

In Indonesia, collections from Aceh Province and Nias Island included 30 upland types plus 144 varieties with potential for tolerance for drought, temporary submergence, low temperature, and saline soils. Four populations of *O. officinalis* were sampled.

The Philippine Bureau of Plant Industry sampled the saline-affected areas of Cagayan Province and obtained 55 samples.

In early May, 31 field collectors met in Chiang Mai, Thailand, for lectures on the principles of genetic conservation and a practical strategy for germplasm collection. In late 1984, three teams canvassed the northern and central regions of Thailand and netted 2,873 cultivars and 123 wild rices.

During 1984 Pakistan Agricultural Research Council staff collected 63 seed samples in the NWFP area (not included in Table 1). Central Rice Research Institute (India) staff and ORSTOM (France) staff jointly explored areas in Karnataka, Maharashtra, Gujarat, and Madhya Pradesh and collected 43 *O. nivara,* and *O. rufipogon* wild rices.

INSTITUTIONAL EXCHANGES

International Rice Germplasm Center

National and state and regional international centers deposited 4,817 rice accessions and wild species in the IRGC in 1984. Major donors were

- Bangladesh Rice Research Institute — 103 varieties.
- Bhutan Department of Agriculture — 66 varieties.

- Chinese Academy of Agricultural Sciences and Guangdong Provincial Academy of Agricultural Sciences — 999 cultivars and 20 wild rices.
- Bihar Agricultural Research Institute of India — 55 varieties.
- Central Research Institute for Food Crops of Indonesia — 174 varieties. A foreign service volunteer collected another 15 varieties.
- National Institute of Genetics of Japan — 613 wild species of *Oryza*.
- National Agricultural Research Center of Pakistan — 19 varieties.
- Bureau of Plant Industry of the Philippines — 55 varieties.
- Department of Agriculture of Sri Lanka — 108 varieties.
- Rice Research Institute, Prae Rice Research Center and the Tribal Research Center of Thailand — 877 varieties.
- IRAT (France) — 1,192 *O. sativa* varieties, 62 *O. glaberrima* varieties, and 1 strain of *O. barthii*.
- WARDA (Africa) — 51 varieties from Senegal and 30 varieties from Guinea-Conakry.

New seeds replaced 1,139 accessions that became nonviable during storage.

The International Rice Testing Program provided 631 promising entries from various international nurseries.

Many land races were collected from remote areas with chronic climatic, biotic, edaphic, or hydrologic constraints. IRGC has 9,761 accessions reputed to have tolerance for such contraints.

INVENTORY, CHARACTERIZATION, AND DATA PROCESSING

International Rice Germplasm Center and Statistics Department

IRGC holdings in 1984 reached 64,744 accessions of *O. sativa*, 2,888 accessions of *O. glaberrima*, 1,878 wild taxa, and 695 genetic testers and mutants. About 5,400 recently received seed samples await planting and seed increase.

For initial seed increase and characterization, 1,399 plots were planted in dry season (DS) and 6,523 in wet season (WS). Recording of 32 traits in the field was completed for 6,523 accessions. Laboratory measurements of 13 traits were made on 2,124 accessions, and 52,292 accessions are now completely recorded. Measurements on 10,613 accessions are not complete.

The Statistics Department routinely furnished every seed-requesting GEU scientist with a computer printout of requested accessions and pertinent information that was designed to facilitate the recording of new evaluation data.

SEED INCREASE, REJUVENATION, AND DISTRIBUTION

International Rice Germplasm Center

Seed increase plots were on the IRRI upland farm and on rented fields in Dayap, Laguna Province. A total of 19,528 plots occupying 24.5 ha had 3 types of plantings: initial seed increase of new accessions, characterization of recently received accessions, and seed rejuvenation of old accessions. Another 2.5 ha of IRRI farm was planted to *O. glaberrima* accessions and wild species, and used for special seed increase for genetic engineers, and as seedlots for monitoring seed viability during storage.

Seed production in WS at Dayap was somewhat reduced by typhoon and brown planthopper damage. Nevertheless, the rented site produced more and healthier seeds than the IRRI farm.

Wild rice characterization and seed increase were handicapped by shortage of screened nursery beds in the Pili Drive area. New nursery beds and a headhouse were designed to allow seed multiplication of wild rices and temperate-zone varieties frequently requested by genetic engineers in developed countries.

Seed distribution to rice researchers remained a major IRGC service. The volume of seed samples provided to IRRI GEU scientists and foreign researchers has stabilized during the last 9 years: 31,780 samples to IRRI staff and 7,170 samples to scientists abroad. Seed requests for evaluation and breeding experiments totaled 307 within IRRI and 180 in foreign countries.

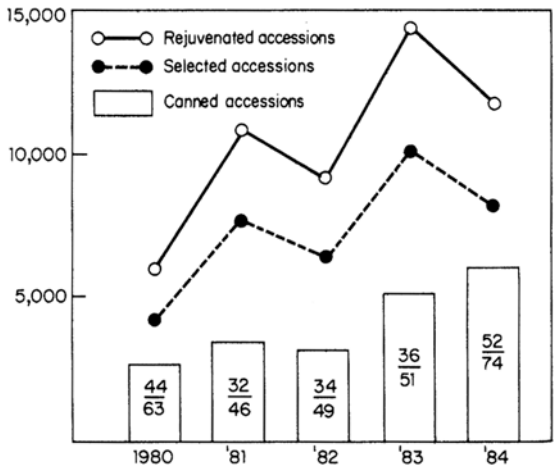
SEED PRESERVATION

International Rice Germplasm Center

Addition of rejuvenation fields outside IRRI enabled IRGC to vacuum-can 6,000 rejuvenated

accessions in 1984, compared to 5,125 in 1983. The proportion of canned accessions to seed lots of new accessions with sufficient seed for selection and canning also rose from the average of 50% during 1981-83 to 74% in 1984 (Fig. 1). By year-end, canned accessions reached 20,417.

In 1984 5,541 packages were shipped to the U.S. National Seed Storage Lab in Ft. Collins, Colorado, for duplicate storage.



1. Progress in canning rice accessions for medium- and long-term storage. In columns, the upper numbers indicate percent of canned accessions from rejuvenated seedlots; the lower numbers, percent of canned accessions from selected seedlots.

RESCUE OF NONVIABLE SEEDS BY TISSUE CULTURE

International Rice Germplasm Center and Tissue Culture Facility

Stored seeds lose viability sooner than expected, and proportionately more nonviable accessions are those from temperate regions.

Using 75 accessions with both low viability (2% mean germinability) and low seed stock, IRGC staff cultured dehulled seeds (caryopses) in an artificial medium to revive them. The cultures were incubated for 10-25 d in a dark room with 26-28° C temperature. Seedlings of 11 accessions were eventually grown to maturity in the phytotron glasshouse. Such a technique could revive some old seed stocks no longer preserved elsewhere.

ENZYMATIC POLYMORPHISM IN RICE GERMPLASM

International Rice Germplasm Center

Of 1,688 Asian rice varieties studied during 1983-84, 120 varieties were drawn as samples to represent the population's enzymatic diversity and were analyzed for 6 more presumed loci. A principal component analysis of 38 independent variables was made for 59 alleles at 21 loci. The distribution of the varieties on two planes indicated the existence of six groups: four major ones and two minor.

Group I (the largest group, 53.1% of total) consists of the typical indica varieties: traditional indicas of the tropics, transplanted-aman varieties of Bangladesh and northeast India, cere (tjereh) varieties of Indonesia, and the hsien (sen) varieties of south and central China.

Group II (the third largest group, 7.3%) comprises varieties grown from Iran to the foothills of the Himalaya extending up to Assam (India). It includes the aus and boro varieties of Bangladesh and northeast India.

Group III, a minor group, contains the early-maturing and photoperiod-insensitive rices among the deep water varieties of Bangladesh.

Group IV, the smallest group, includes the 11-mo and deep water rayada varieties of Bangladesh.

Group V (the fourth largest group, 6.9%) consists of varieties grown along the Himalaya range from Iran to Burma. It includes the Sadri and Basmati types.

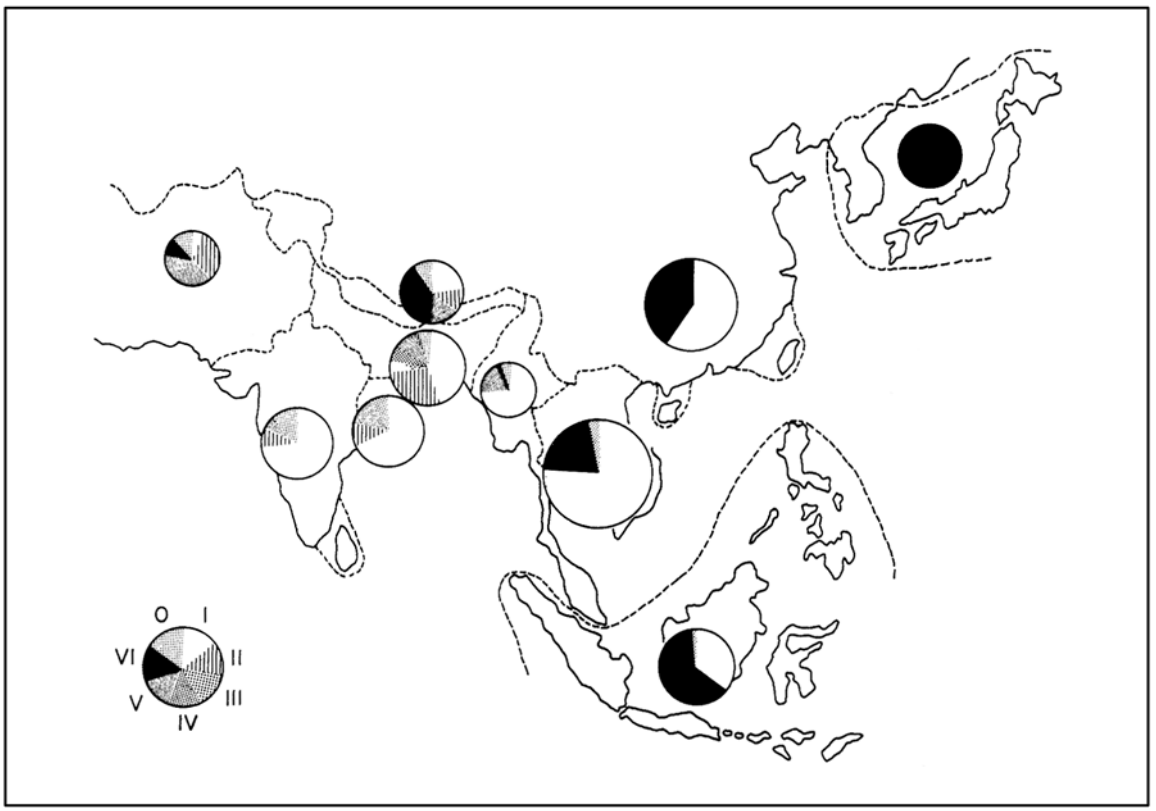
Group VI (the second largest group, 26.5%) corresponds to the typical sinica (japonica) race of China, Japan, and Korea, but also includes the bulu varieties (javanica race) of Indonesia, many upland rices of SE Asia, and rices grown at high elevations in India and Nepal.

Eighty-nine varieties (5.3%) could not be classified. Figure 2 shows the geographic distribution of the six groups.

TRAINING OF GENETIC CONSERVATIONISTS

International Rice Germplasm Center

In-service training ranging from 1 to 11 mo was provided to 5 scientists involved in genebank management or seed science. The trainees came from China, Pakistan, and Vietnam.



2. Distribution in Asia of 6 rice varietal groups defined through analysis of the enzyme polymorphism scored at 21 loci. Groups are designated I to VI (see text); class 0 corresponds to varieties not easily classifiable.

A new 12-mo certificate course on rice genetic resources management is planned for late 1985, in cooperation with IBPGR, UPLB, and Universita degli Studi della Tuscia of Italy.

TECHNICAL ASSISTANCE TO OTHER GENEBANKS

International Rice Germplasm Center

During 1984, IRGC aided genebanks at AVRDC and in China, Ethiopia, Fiji, India, and Liberia, primarily on refrigeration and seed drying equipment.

DIFFUSION AND ADOPTION OF GENETIC MATERIALS, 1965-84

Communication and Publications Department

In 1984 IRRI updated a 1975 study on changes in rice breeding in Asia. Through personal interviews, hybridizations were randomly selected from the crossbreeding records of 1965-67, 1970-71, 1974-75, 1980, and 1983-84. The diffusion of specific varieties and types of varieties was then plotted for the 20-yr period.

The 1975 and 1984 studies used the same methodology to determine breeding objectives. Each breeder described why each cross was made and reasons for use of each parent (i.e., yield potential, early maturity, insect resistance). Data were also gathered on plant type (tall, semidwarf, etc.) and parental origins.

Data were gathered from 44 rice breeders at 23 research centers in Bangladesh, India, Indonesia, Korea, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand. Twenty-two of the same stations were surveyed in 1975.

Diffusion of parental materials. Asian plant breeders rapidly adopted the early IRRI semidwarf varieties as parents to develop their own semidwarfs. The percentage of semidwarf parents in

Table 2. Percentages of rices of different plant height used as parents in 578 randomly selected crosses and as individual parents (1,308) at 19 agricultural experiment stations and universities in 7 Asian nations, 1965-84.

Plant height	Rices used (%)				
	1965-67[a]	1970-71[b]	1974-75[c]	1980-81[d]	1983-84[e]
	In crosses				
Tall	74	57	45	40	49
Intermediate	51	39	35	38	33
Semidwarf	61	86	84	85	83
Floating or deep water	2	1	2	6	2
	As individual parents				
Tall	40	30	24	23	25
Intermediate	31	22	17	19	16
Semidwarf	28	48	58	55	58
Floating or deep water	1	—	1	3	1

[a]277 rice varieties and lines used in 119 crosses. [b]351 rices used in 147 crosses. [c]191 rices used in 89 crosses. [d]205 rices used in 94 crosses. [e]284 rices used in 129 crosses.

crosses rose from 61 in 1965-67 to 84 in 1984 (Table 2). The percentage of crosses involving a tall variety dropped in 1975, then increased in 1984.

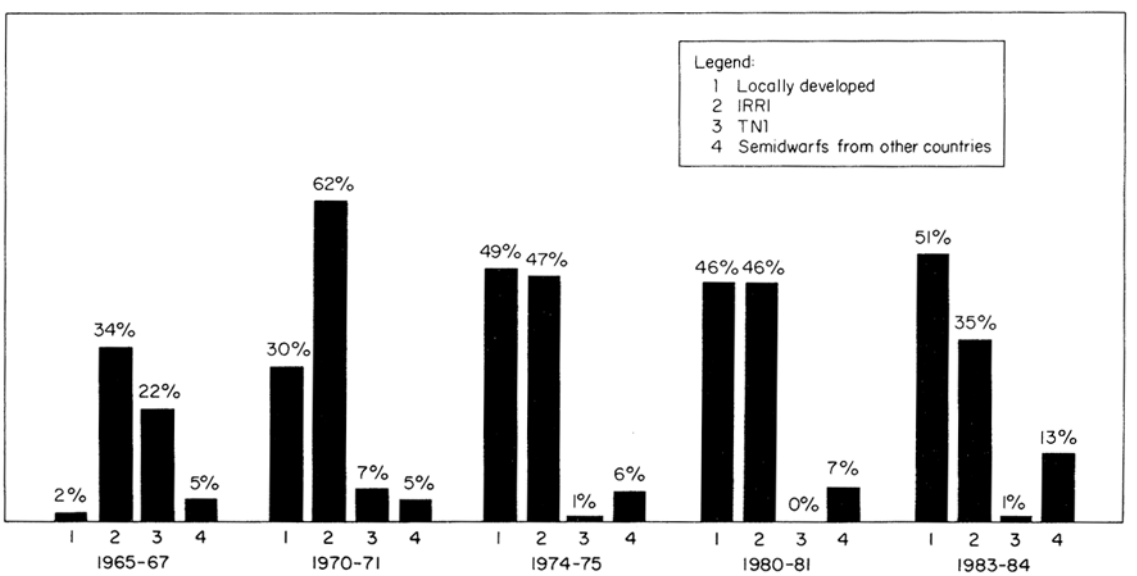
Breeders increasingly crossed semidwarfs with other semidwarfs over the first 10 yr. By 1975, semidwarf use increased to 58%, remaining so through 1984. Direct use of IRRI varieties in Asian crosses peaked at 62% in 1970 (Fig. 3), then leveled off from 1975 to 1984 concurrent with use of locally developed semidwarfs.

Because 36% of crosses analyzed were made in India, parental materials used in Indian crosses were compared with those elsewhere. Indian breeders crossed local semidwarfs more and introduced semidwarfs less than breeders in other national programs throughout the 20-yr period.

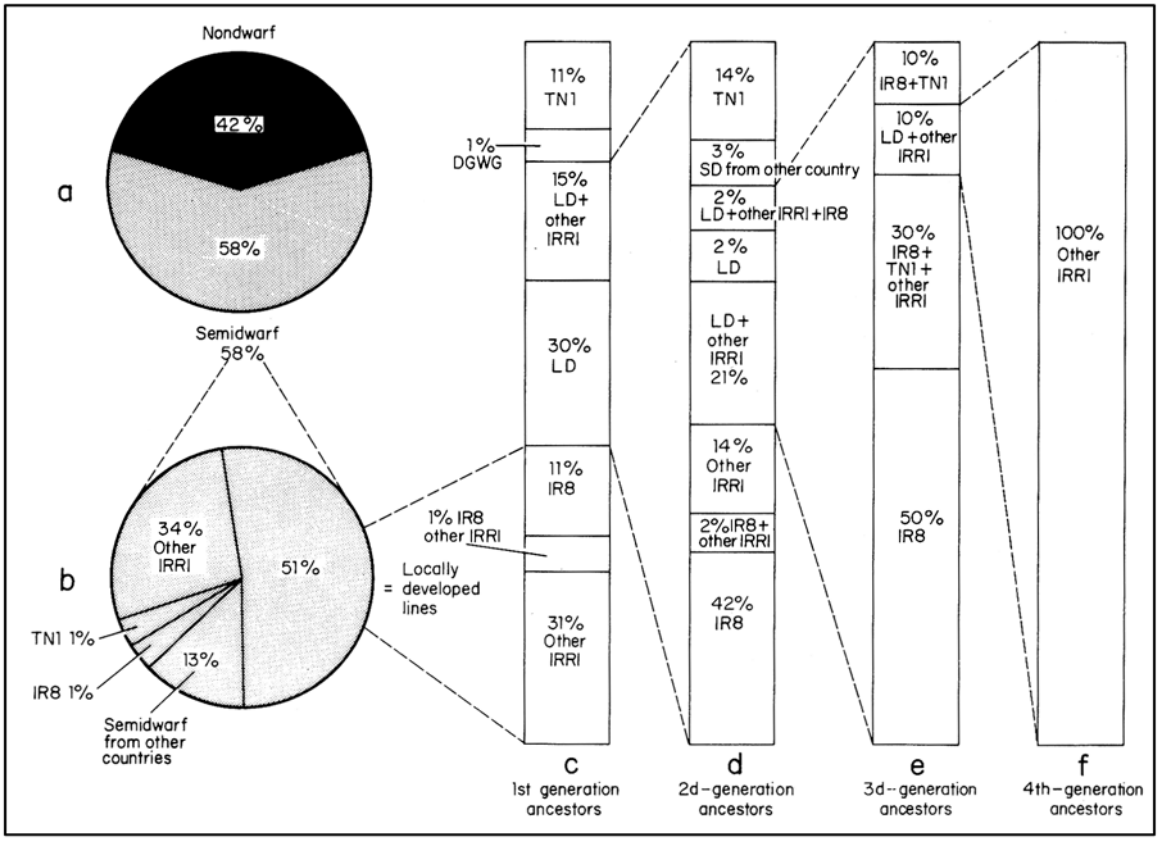
Taichung Native 1 (TN1) was used in 22% of the mid-1960 crosses; IR8, in 20%. By 1970, IR8 and other IRRI cultivars had largely replaced TN1. But by 1975 IR8, like its predecessor, had virtually disappeared from Asian breeding. In 1984, IR50 was the most popular IRRI parent, used in 10% of the crosses; IR36 was used in 9%.

In 1984, the most intensively used local semidwarfs as parents were OR59-6 and IET1444 (Rasi) from India. The pedigrees of all local semidwarfs used in 1983-84 crosses were traced back four generations. An IRRI variety or experimental line was a *direct* parent of 58% (Fig. 4,c), and 45% were progeny of still earlier crosses involving a local semidwarf. Tracing ancestry of those local semidwarfs back a second generation showed 81% were progeny of IRRI varieties (Fig. 4,d).

Breeding objectives. The relative breeding objectives from 1975 to 1984 were similar. High yield



3. Sources of 1,308 rice cultivars used in 578 hybridizations from 1965 to 1984 at 14 research stations in 7 Asian nations.



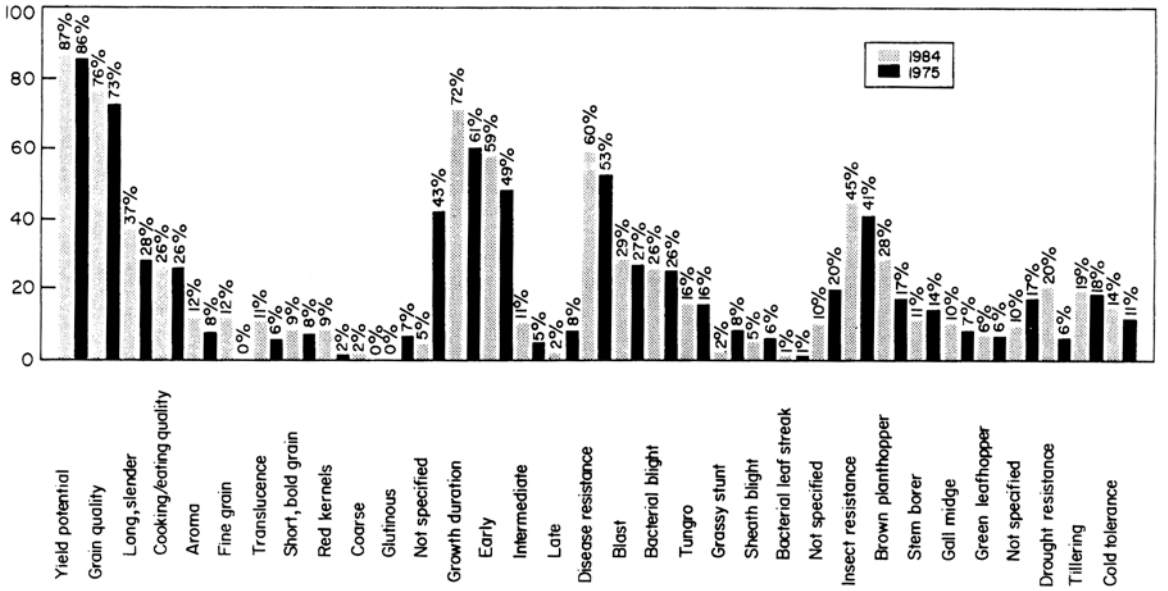
4. a. Plant height of 284 parents used in 129 crosses made in 1983-84. b. Origin of 164 semidwarf parents used in 129 crosses. c. Sources of the dwarfing genes in the direct ancestry of 84 locally developed (LD) semidwarf rices used as parents. d. Sources of the dwarf genes in the ancestors of 37 LD semidwarf rices. e. Sources of the dwarfing genes in 10 LD semidwarf rices. f. Sources of the dwarfing genes in the ancestors of local semidwarfs.

remained the main breeding objective for 86 to 87% of crosses (Fig. 5). Grain quality remained the second most common objective, followed by growth duration (usually early) and drought resistance.

To determine why breeders used specific parents, parents for each objective (yield potential, grain quality, etc.) were classified by plant type (semidwarf, intermediate-statured, tall, deep water). Eighty-five percent of semidwarf crosses in 1975 were to transfer yield potential; in 1984 breeders used semidwarfs proportionately more for other traits (Table 3). In 1975, grain quality was an objective for 65% of tall variety crosses and 40% of semidwarf uses. In 1984, breeders tended to use semidwarfs as parental sources of locally preferable grain. Trends for growth duration and disease and insect resistance were similar.

Similar analysis was used to determine why breeders used locally developed and IRRI semidwarfs. The 1984 sample showed 164 semidwarf parents used: 51% were locally developed, 35% were from IRRI, and 14% were from other national programs. Sixty-seven percent of the time that a breeder crossed a local semidwarf, he hoped to transmit a preferred grain type into progeny vs 22% for IRRI semidwarfs (Fig. 6,b). But insect resistance was an objective for 69% of the IRRI semidwarf uses (Fig. 6,e).

New varieties. Rice breeders in 9 nations listed new varieties released by 21 agricultural research centers over the past 3 yr. Genetic data sheets were prepared on each new variety, and recent releases were compared with the varieties released by the same stations in 1975 (Table 4). Releases shifted to

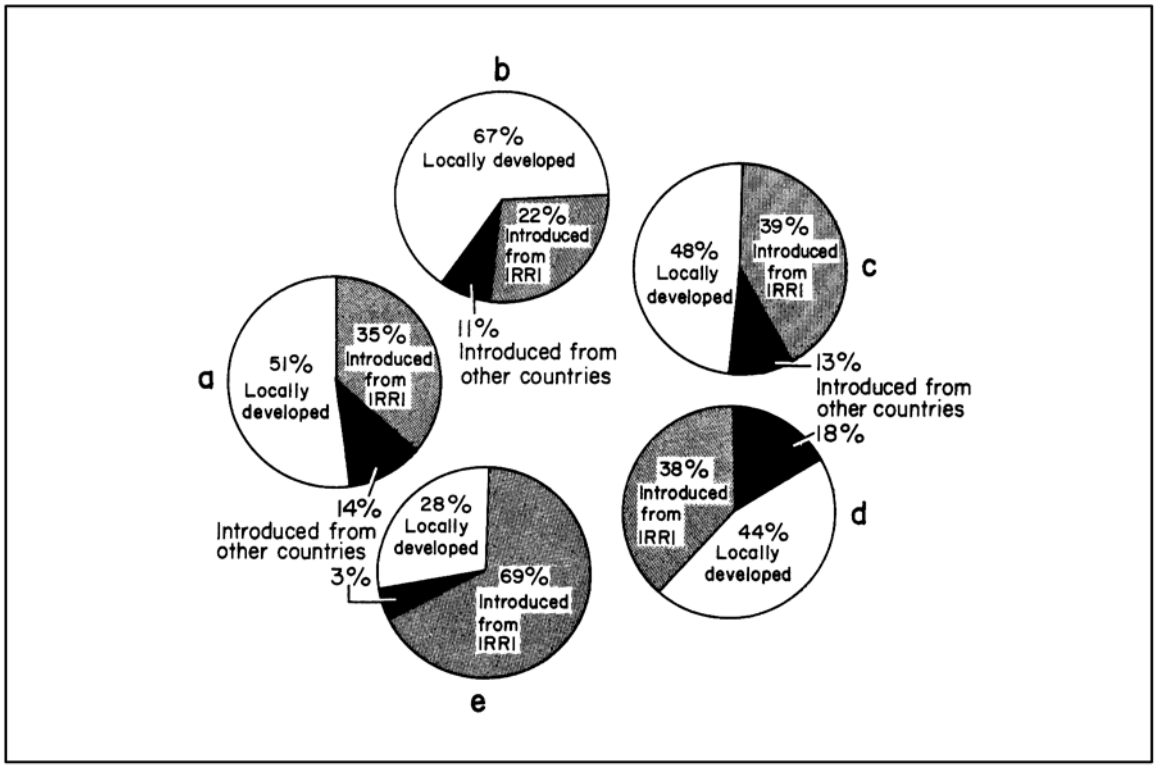


5. Breeding objectives for 1975 and 1984.

Table 3. Varietal types used to meet major breeding objectives, 1975 and 1984.[a]

Breeding objective	Use (%) as parents							
	Semidwarf		Intermediate		Tall		Floating or deep water	
	1975	1984	1975	1984	1975	1984	1975	1984
Yield potential	85	51	51	42	5	15	10	0
Grain quality	40	54	60	61	65	45	20	0
Growth duration	34	42	36	31	31	10	80	100
Disease resistance	36	47	64	53	25	28	20	0
Insect resistance	30	41	15	27	19	17	–	0
Drought tolerance	2	5	4	13	5	12	0	100
Tillering	10	10	17	9	4	5	–	0
Cold tolerance	1	7	17	11	11	3	–	0
Seedling vigor	4	2	17	2	4	4	–	0
Adaptability	2	9	13	2	2	7	–	0
Adverse soils tolerance	3	3	19	11	9	3	–	0
Photoperiod sensitivity/insensitivity	4	1	2	6	5	5	90	100
Heavy grains or panicle weight	2	2	4	0	–	11	–	0
Straw yield	–	0	–	2	–	0	–	0
Short, erect leaves	–	0	–	11	–	0	–	0
Nonshattering	–		–		5		–	
Threshability	–	0	–	0	–	0	–	0
Alternate gene source	–		2		1		–	
Protein content	–		–		–		–	
Yield stability	–		–		–		–	
Deep water tolerance	–		4		5		100	
Dry sowing	–	1	–	2	–	0	–	0
Genetic diversity	–	2	–	0	–	0	–	0
Floods/elongation capacity	–	1	–	11	–	10	–	100
Others	3	1	11	11	8	12	–	0
Pigmentation	–	1	–	0	–	0	–	0

[a]Source of data = 201 semidwarf, 47 intermediate, 85 tall, and 10 floating parents in 161 randomly selected crosses made in 1974-75 at 27 agricultural experiment stations, 10 Asian nations; and 164 semidwarf, 45 intermediate, 73 tall, and 2 floating parents in 129 randomly selected crosses made in 1983 at 23 agricultural experiment stations, 9 Asian nations.



6. Sources of semidwarf parents used for different breeding objectives. a. Origin of 164 semidwarf parents. b. Origin of 70 semidwarf parents used for grain quality. c. Origin of 70 semidwarf parents used for growth duration. d. Origin of 55 semidwarf parents used for disease resistance. e. Origin of 41 semidwarf parents used for insect resistance. 1984.

Table 4. Characteristics of newest varieties[a] released by research stations in 1975 and 1984.

Characteristic	Varieties (%)							
	Tall		Intermediate		Semidwarf		All	
	1975	84	1975	84	1975	84	1975	84
Plant height	6	16	25	33	69	51	–	–
Origin								
Locally developed	100	90	100	71	80	82	86	80
Introduced from IRRI	0	0	0	19	20	9	14	11
Introduced from other countries	0	10	0	10	0	9	0	9
Method of development								
Hybrid	50	80	89	85	96	100	91	92
Mutant	0	10	11	5	4	0	8	3
Pureline selection	50	10	0	10	0	0	3	5

[a]36 varieties from 27 agricultural research stations in 10 Asian countries in 1975; 65 varieties from 21 stations in 9 Asian countries in 1984.

taller varieties over the decade. Several breeders — particularly in southern India and Sri Lanka — were shifting to intermediate-statured varieties mainly for higher yield of straw, used for cattle fodder and fuel. In those regions, cash value of rice straw was as high as that of grain.

Widely grown varieties. Breeders named the 3 most widely grown varieties within the regions

Table 5. Characteristics of the 3 most widely grown varieties[a] cited by farmers in 9 countries in 1975 and 1984.

Characteristic	Varieties (%) widely grown									
	Tall		Intermediate		Semidwarf		Floating		All	
	1975	84	1975	84	1975	84	1975	84	1975	84
Plant height	35	22	17	13	45	63	3	2	–	–
Origin										
Locally developed	97	64	13	100	44	52	100	100	59	65
Introduced from IRRI	0	0	37	0	54	43	0	0	31	25
Introduced from other country	3	36	50	0	2	5	0	0	10	10
Method of development										
Unimproved	36	43	0	0	0	0	67	100	15	10
Pureline selection	49	14	0	0	2	0	33	0	19	3
Mutant	0	0	0	0	2	3	0	0	1	2
Hybrid	15	43	81	100	96	97	0	0	62	85

[a] A total of 95 rices at 27 agricultural research centers in 1975 and 68 at 22 stations in 1984.

served by 22 research centers. Genetic data showed that the 68 rices comprised 47 distinct varieties and most were semidwarfs (Table 5).

The 1975 study cited 10 of the same rices as widely grown in 2 or more regions. In 1984, only 7 were grown in more than one region and 65% were locally developed. The most popular IRRI variety was IR36, grown extensively in four regions. The most popular locally developed variety was Jaya (five regions).

Genetic evaluation and utilization (GEU) program

Agronomic and physiological characteristics

Agronomy Department, Upland Rice Breeding, International Rice Germplasm Center, Plant Breeding Department, International Rice Testing Program, and Plant Physiology Department

MAXIMUM YIELD EXPERIMENT **18**
- IRRI **18**
- Farmer's field **18**
- Lodging **18**

YIELD PERFORMANCE AND NITROGEN RESPONSE OF VARIETIES AND SELECTIONS **20**
- Irrigated rice **20**
  - IRRI **20**
  - Farmer's field **21**
  - BPI stations **21**
- Rainfed rice **22**
  - Farmer's field **22**

IMPROVING YIELD POTENTIAL AND STABILITY IN UPLAND RICE **22**

SOURCES OF SEMIDWARFISM **22**

SELECTION FOR PHOTOPERIOD SENSITIVITY **25**

IDENTIFYING RAINFED RICES FOR LATE TRANSPLANTING **26**

SELECTING UPLAND RICES THAT SUPPRESS WEEDS **27**

RICE RATOONING **29**
- Dormant buds **29**
- Bud development **29**
- Regeneration time **30**
- Culm thickness **30**
- Temperature **30**
- Light intensity **31**
- Growth regulators **31**
- Seedlings per hill **32**
- Root system of main and ratoon crops **32**
- Time of ratoon crop harvest **32**

SELECTING DEEP WATER RICES WITH RATOONING ABILITY **32**

PHYSIOLOGICAL BASES OF HETEROSIS **33**
- Dry matter production **33**
- Yield at different spacings **33**
- Roots of F_1 hybrids **33**

MAXIMUM YIELD EXPERIMENT

Agronomy Department

IRRI. Ten rices of early, medium, and late maturities received varying N rates. First, urea supergranules were deep-placed, then prilled urea was topdressed as required. Planting dates were staggered for uniform ripening at two IRRI sites.

In dry season (DS), IR21820-154-3-2-2-3 yielded highest (7.1 t/ha) followed by IR29723-143-3-2-1 (6.7 t/ha), both at the lowest N rate at the old site (Fig. 1). At the new site, IR29723-143-3-2-1 yielded 6.6 t/ha. Early-maturing IR31847-67-2-1-1-2 and IR58 yielded comparably at lowest N rate. Yields were generally lower in 1983 DS because of late planting (March) and less solar radiation during ripening. Moreover, heavy rains during ripening completely lodged most rices, particularly at higher N doses.

The late-maturing IR29723-143-3-2-1 consistently yielded highest at both sites at all N rates in wet season (WS) (Fig. 2). IR58 and IR36 yielded highest among early and medium-maturing rices at the new site. Tungro affected IR42 and especially IR8. Sheath blight, narrow brown leaf spot, and bacterial leaf streak also affected susceptible rices.

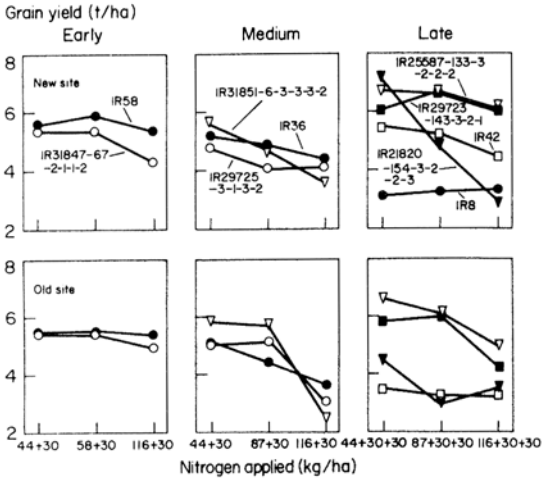
In both seasons, maximum yields usually came from lowest N.

Farmer's field. Yields in a Nueva Ecija field were low in DS, except for IR29723-143-3-2-1 which yielded highest (6.8 t/ha) at the lowest N rate (Fig. 3). Under humid conditions, bacterial leaf streak and bacterial blight attacked the test rices.

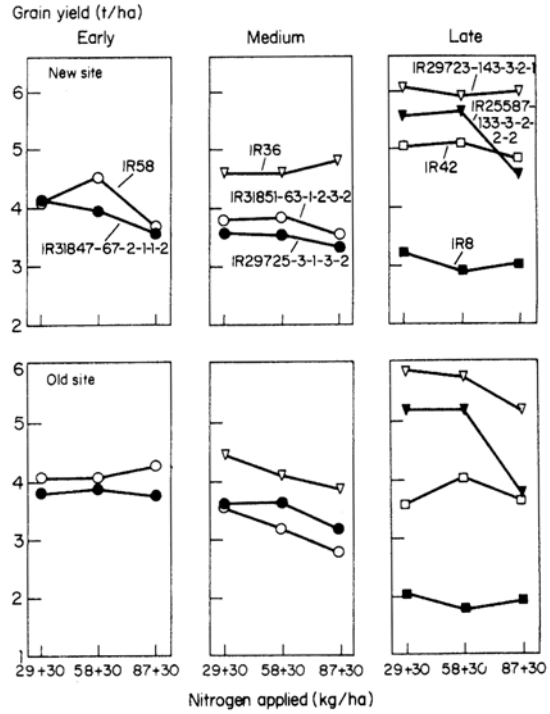
In WS, late-maturing rices yielded higher than medium and early ones. IR29723-143-3-2-1 produced 5.7 t/ha at the lowest N rate.

Lodging. In 1984 DS and WS, crop lodging was observed. Crop culm strength (bending resistance) and yields were determined at IRRI. To assess culm strength, a push gauge attached to a 60-cm rigid bar was used to bend 3 plants to 30° above the water level.

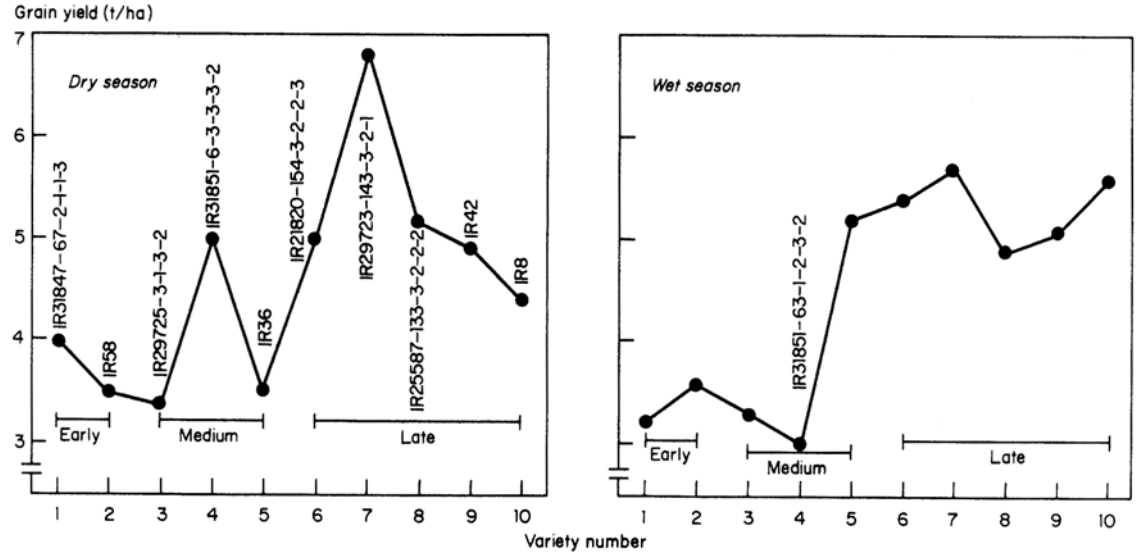
Lodging was severest in DS because of three heavy rains during ripening. N rates were apparently higher in DS than WS. Percentage lodging increased (Fig. 4a) and bending resistance decreased (Fig. 4b) with increased N rates in the medium-maturity group. This reduced yields (Fig. 4c). Low yields of most late maturity entries were attributed to diseases; however, IR29723-143-3-2-1 had the highest grain yield at the lower N rates.



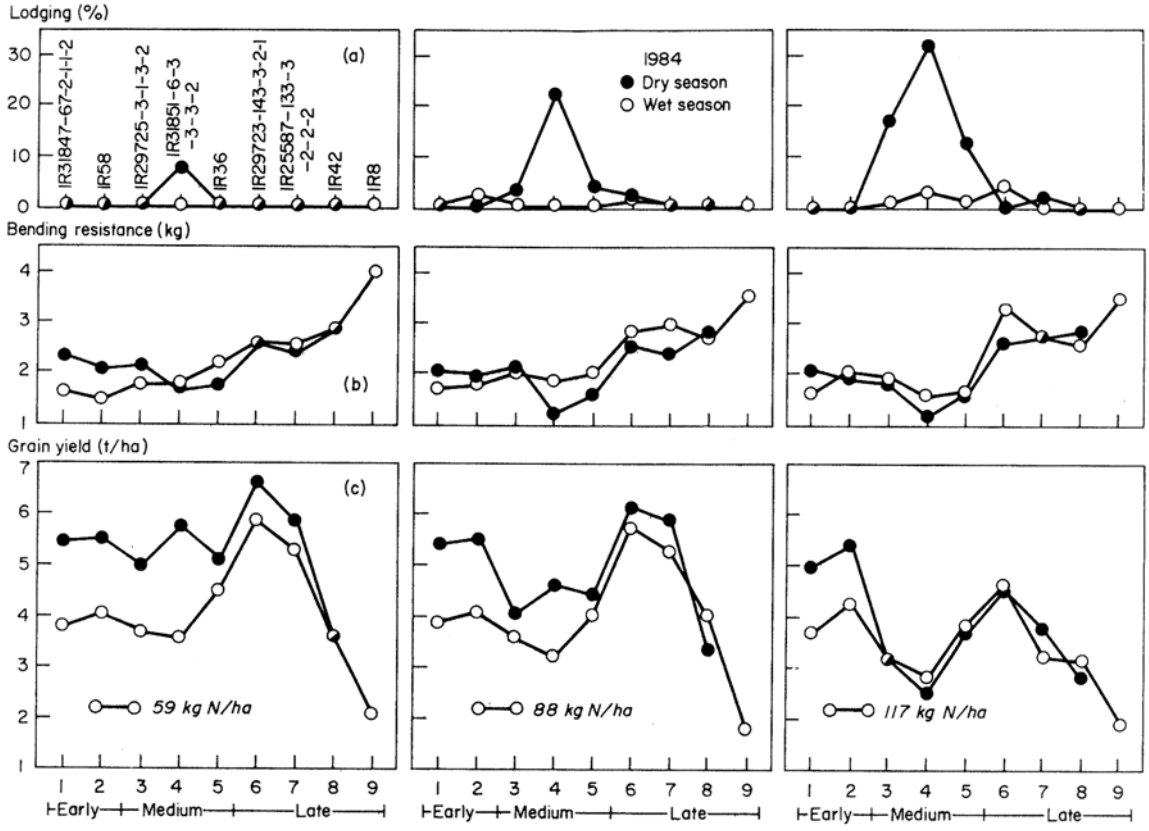
1. Nitrogen response and grain yield of early-, medium-, and late-maturing rices at 2 sites. IRRI, maximum yield experiment, 1984 DS.



2. Nitrogen response and grain yield of early-, medium-, and late-maturing rices at 2 sites. IRRI, maximum yield experiment, 1984 WS.



3. Yields of rices in maximum yield experiment in a farmer's field. Talavera, Nueva Ecija, Philippines, 1984.



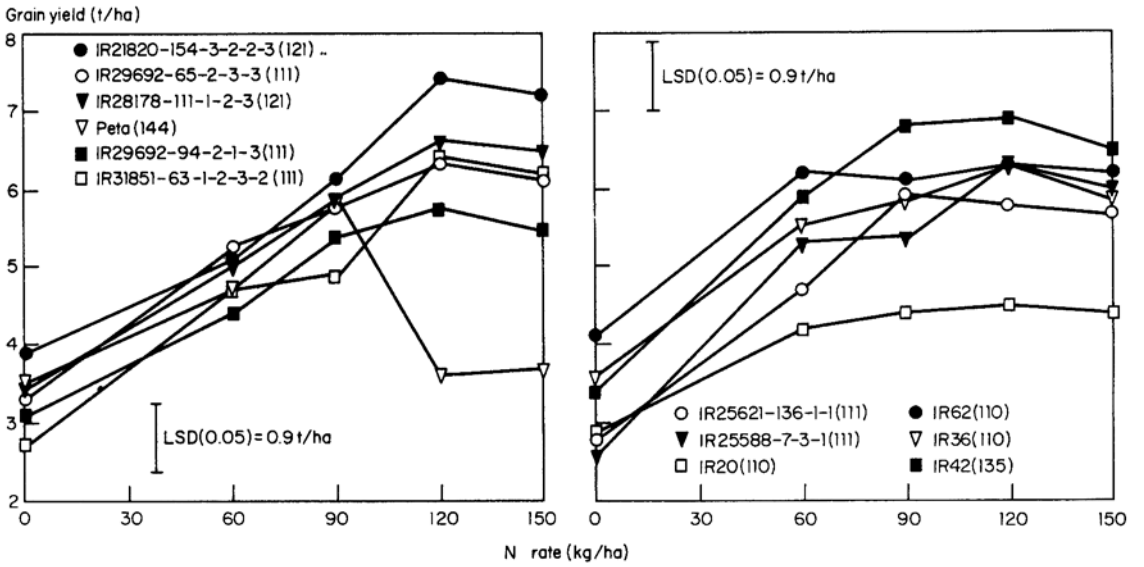
4. Observed lodging (a), bending resistance (b), and grain yields (c) of varieties representing the three maturity groups. Bending resistance and percentage lodging are mean of values taken from tillering to ripening. For DS: N application 1 (N1) = 74 kg N/ha (early and medium), 104 kg N/ha (late); N2 = 88 kg N/ha (early), 117 kg N/ha (medium), 147 kg N/ha (late); N3 = 146 kg N/ha (early and medium), 176 kg N/ha (late). IR8 was removed at later growth stage because of tungro. IRRI, old site.

YIELD PERFORMANCE AND NITROGEN RESPONSE OF VARIETIES AND SELECTIONS

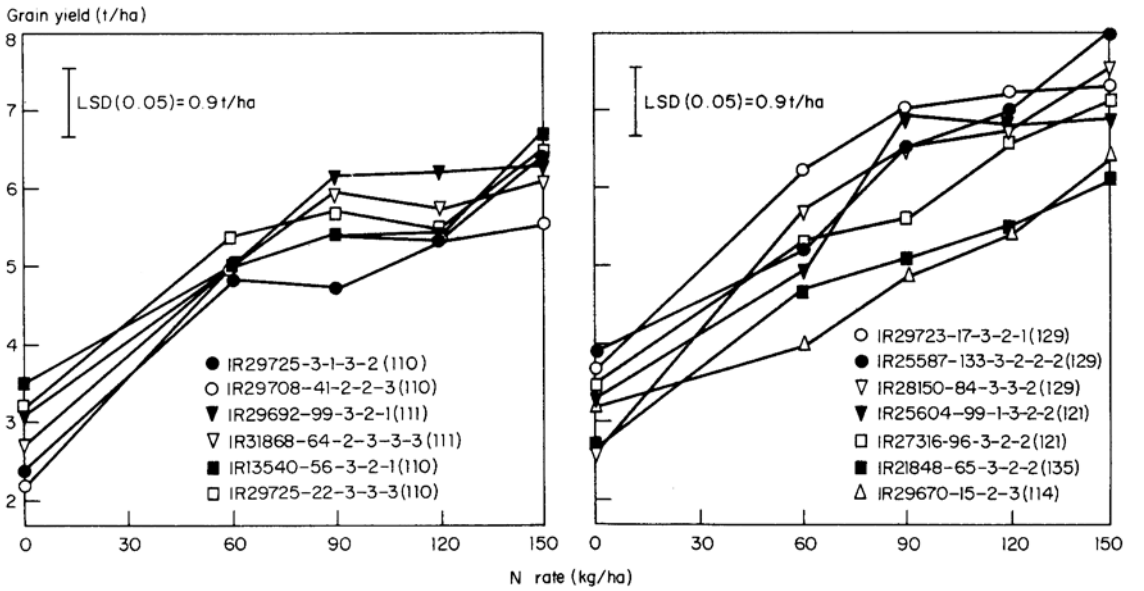
Agronomy Department

Irrigated rice. Yield performance of IR varieties and promising breeding lines were evaluated at IRRI, a farmer's field in Laguna, and at the BPI stations in Nueva Ecija, Bicol, and Iloilo. Rices were tested at varying N rates with WS application lower than of DS.

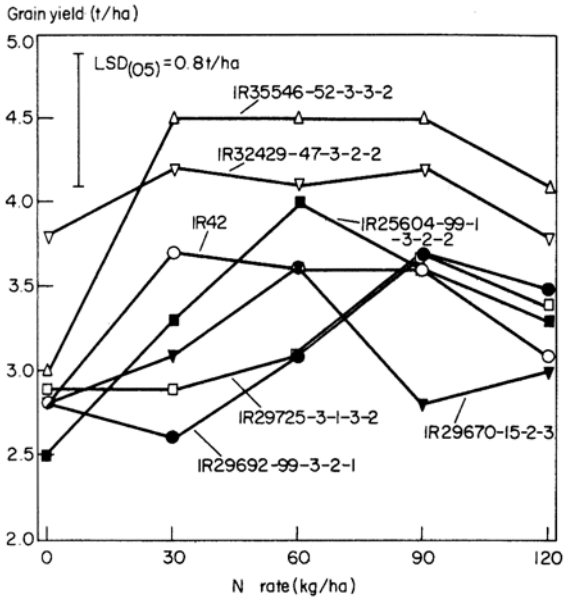
IRRI. During DS, 22 promising IR breeding lines and 6 varieties were tested at 5 N levels. IR8,



5. Yield performance of 12 rices (whose maximum yield was reached) at 5 N levels. IRRI, 1984 DS. Numbers in parentheses refer to duration from seeding to harvest. LSD is for comparison of 2 N means for each variety or line.



6. Yield performance of rices (highest N rate probably is not enough to give maximum yield) at 5 N levels. IRRI, 1984 DS. Numbers in parentheses refer to duration from seeding to harvest. LSD is for comparison of 2 N means for each variety or line.



7. Grain yield of 7 rices responding to applied N fertilizer. N-response experiment, IRRI, 1984 WS. LSD is for comparison of 2 N means for each variety or line.

however, was severely damaged by tungro and ragged stunt virus, while IR31917-31-3-2 and IR29723-143-3-2-1 had missing data; although results are not included, IR29723-143-3-2-1 appeared promising at all N rates.

Figure 5 shows 12 rices that reached their maximum yield at 120 kg N/ha (except Peta with maximum yield at 90 kg N/ha). On the other hand, even with 150 kg N/ha, yields of 13 rices increased (Fig. 6). This suggests a need for a higher N rate for these test rices to achieve maximum yield. IR25587-133-3-2-2-2 yielded highest at 8.0 t/ha. Except for IR21848-65-3-2-2, rices maturing later will yield higher when more N fertilizer is applied. This holds also for rices whose maximum yields were attained with less than 150 kg N/ha.

In WS, lodging was common at high N rates; thus yields were generally low. Of 28 rices tested, only 7 positively responded to N fertilizer (Fig. 7). Without fertilizer N, IR31868-64-2-3-3-3 produced 4.3 t/ha. However, it did not respond significantly to added N.

Farmer's field. In DS, grain yields from the farmer's field were generally higher than that at IRRI farm (Table 1). IR29723-143-3-2-1 outyielded other test rices both in plots with fertilizer N (8.1 t/ha) and without added N (6.0 t/ha).

During WS, yields from farmer's field were again higher than that at IRRI (Table 2).

BPI stations. At Maligaya, during DS, breeding line IR29723-143-3-2-1 outyielded all entries with 8.1 t/ha at 120 kg N/ha. Without fertilizer N, this line produced 5.7 t/ha and its sister line IR29723-17-3-2-1 had 4.7 t/ha, higher than the IR42 yield. At low N rate (60-90 kg N/ha) both lines, along with IR20, gave 7.0 t/ha or more.

In Bicol, IR28150-84-3-3-2 produced the highest yields in both fertilized (7.1 t/ha) and no fertilizer N (4.5 t/ha) plots during DS. At low N rate (60 kg N/ha), sister lines IR29723-143-3-2-1 and IR29723-17-3-2-1 yielded well along with IR21820-154-3-2-2-3 and IR25587-133-3-2-2-2. The same breeding lines had relatively good yields at zero fertilizer N.

Table 1. Yields of IR varieties and promising breeding lines at 5 N levels (0-150 kg N/ha) on irrigated plots at IRRI and farmer's field, 1984 DS.[a]

Variety or line	Duration (d)	Farmer's yield (t/ha)				Duration (d)	IRRI yield (t/ha)				
		0	50	100	150		0	60	90	120	150
IR8	130	4.6	4.8	5.6	5.9	135	2.4[bc]	3.9[b]	4.3[bc]	3.9[bc]	4.8[b]
IR36	117	3.4	3.8	4.8	5.1	110	3.6	5.5	5.8	6.3	5.9
IR42	145	4.9	5.5	6.1	6.1	135	3.4	5.9	6.8	6.9	6.5
IR13525-43-2-3-1-3-2 (IR62)	117	4.3	5.7	5.8	6.5	110	4.1	6.2	6.1	6.3	6.2
IR21820-154-3-2-2-3	127	5.2	5.6	5.9	4.8	121	3.9	5.1	6.1	7.4	7.2
IR21848-65-3-2-2	127	4.4	4.8	7.0	5.3	135	2.7	4.7	5.1	5.5	6.1
IR29723-17-3-2-1	127	5.3	5.7	5.7	6.5	129	3.7	6.2	7.0	7.2	7.3
IR29723-143-3-2-1	138	6.0	6.3	8.1	7.5	135	3.8	6.4[d]	6.7	6.6[d]	8.1[d]
			Farmer's		*IRRI*						
Comparison			LSD .05		LSD .05						
2N means at same N or diff. V			1.24		0.9						

[a]Av of 3 replications. Each treatment includes 30 kg N/ha topdressed 5-7 d before panicle initiation. [b]One replication missing because of tungro (RTV) and ragged stunt virus (RSV). [c]Infected with RTV and RSV. [d]Av of 2 replications only.

Table 2. Yields of IR varieties and promising breeding lines at 5 N levels (0-120 kg N/ha) on irrigated farms at IRRI and farmer's field, 1984 WS.[a]

Variety or line	Duration (d)	Farmer's yield (t/ha)				Duration (d)	IRRI yield (t/ha)				
		0	40	80	120		0	30	60	90	120
IR8	124	3.8	4.6	4.6	4.0	126	1.6[b]	1.6[b]	1.7[b]	2.1[b]	1.7[b]
IR36	111	3.3	4.0	4.1	4.2	109	3.6	3.8	3.8	3.9	3.6
IR42	130	4.1	4.2	4.6	4.8	134	2.8	3.7	3.6	3.6	3.1
IR28150-84-3-3-2	123	5.0	4.8	4.8	5.0	129	4.0	4.3	4.2	3.6[c]	3.8[d]
IR28228-12-3-1-1-2	124	4.6	5.4	5.3	4.8	129	4.1	4.5	4.5	3.4[e]	2.9[e]
IR29723-88-2-3-3	130	4.3	4.6	5.7	5.3	129	3.4	3.7	3.4[d]	3.2[c]	3.2[d]
IR9723-143-3-2-1	130	5.1	5.4	5.3	5.7	134	3.8	3.9	4.1	3.9[d]	3.3[e]
IR32453-20-3-2-2	130	4.0	5.0	5.3	4.9		[f]	[f]	[f]	[f]	[f]
			Farmer's		*IRRI*						
Comparison			LSD .05		LSD .05						
2N means at same or diff. V.			0.58		0.8						

[a]Av of 3 replications. Each treatment includes 20 kg N/ha topdressed 5-7 d before panicle initiation. [b]Infected with tungro and ragged stunt virus. [c]Lodged in 2 replications. [d]Lodged in 1 replication. [e]Lodged in 3 replications. [f]= not tested.

Yields were generally higher in the Visayas station than at Maligaya and Bicol. Many rices produced 7.0 t/ha or more, with IR29723-17-3-2-1 yielding 8.5 t/ha at 120 kg N/ha. IR27316-96-3-2-2 consistently produced more than 7.0 t/ha with added N. Without fertilizer N, yields of 5.9 t/ha were obtained from IR21820-154-3-2-2-3 and IR28150-84-3-3-2.

Responses to varying levels of N during DS are shown in Table 3.

WS yields were considerably low in all 3 BPI stations (Table 4). IR8 and IR42 showed some tungro infection.

Because of unusually heavy and prolonged rain during late booting to spikelet-filling stages, most rices lodged, particularly with added N fertilizer at Maligaya. Infection of bacterial diseases was heavy. Thus, no significant positive response was noted.

However, in Bicol, application of 30 kg N/ha gave the highest yield in most rices. Beyond 30 kg N/ha, yields generally declined. IR29723-17-3-2-1 and IR31868-64-2-3-3-3 were notable at zero fertilizer N by yielding more than 5.0 t/ha.

IR25587-133-3-2-2-2 gave the highest yield of 6.8 t/ha at 60 kg N/ha in the Visayas during WS.

Rainfed rice. *Farmer's field.* Yields of test rices at the rainfed farmer's field were low compared to when grown in the irrigated field (Fig. 8). Yield of IR28150-84-3-3-2 at high N rate in the rainfed site was similar to that of IR36 in the irrigated field. IR42 was infected by tungro.

IMPROVING YIELD POTENTIAL AND STABILITY IN UPLAND RICE

Upland Rice Breeding

Since the 1970s, IRRI upland rice breeders have been striving toward a plant type that combines intermediate plant stature, gently droopy leaves, moderately high tillering, extensive roots, and high tissue tolerance to water stress at the vegetative stage — traits that will contribute to increased yield potential in upland rice. Breeders have tried to modestly upgrade yield capability while retaining yield stability of traditional types by incorporating various tolerances to adverse environmental factors into the improved plant types.

Multisite trials in the Philippines were in relatively high soil fertility but drought-prone fields. Data indicate it is feasible to improve yield capacity while providing stability in the desired plant type (Table 5). Testing should be extended to other sites with adverse soil factors (high acidity, low N and P), and high blast incidence.

SOURCES OF SEMIDWARFISM

International Rice Germplasm Center

We continued to search for new sources of semidwarf plant height for diversifying the genetic base of modern varieties (MVs). Eleven new sources were evaluated by concurrent planting and comparison with IR36, F_1 plants, and F_2 progenies.

Table 3. Yields of IRRI varieties and promising lines at 6 N levels[a] (0-180 kg/ha) in irrigated plots. Maligaya Rice Research and Training Center, Bicol Experiment Station, and Visayas Experiment Station. 1984 DS.

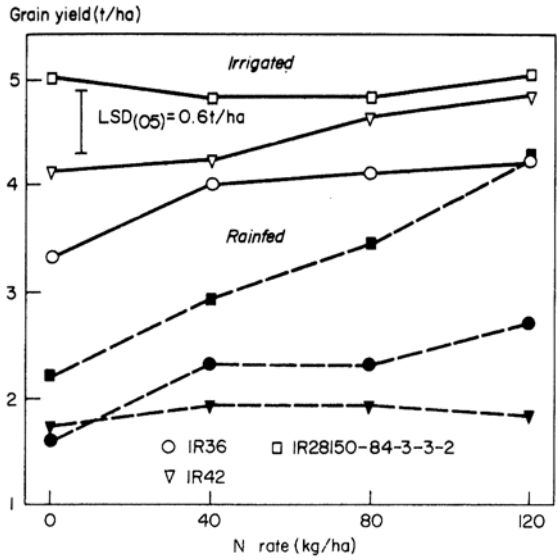
Variety or line	Duration[b] (d)	Yield[c] (t/ha)					
		0	60	90	120	150	180
		Maligaya					
IR8	128	3.5 d	4.3 bcd	5.3 ab	4.7 bc	6.0 a	4.1 cd
IR20	117	4.1 c	5.8 b	7.0 a	6.9 ab	6.6 ab	6.5 ab
IR36	114	3.9 c	5.9 b	6.9 ab	6.7 ab	7.1 a	6.8 ab
IR42	136	4.5 b	5.0 b	6.8 a	6.7 a	6.7 a	7.0 a
IR13525-43-2-3-1-3-2 (IR62)	107	3.6 c	5.3 b	6.0 ab	5.9 ab	6.9 a	6.8 a
IR21820-154-3-2-2-3	123	4.1 b	5.9 a	6.7 a	6.9 a	6.6 a	6.6 a
IR21848-65-3-2-2	126	4.1 b	5.9 b	6.5 ab	6.2 b	7.3 a	6.9 ab
IR25587-133-3-2-2-2	120	3.5 b	6.4 a	5.9 a	6.6 a	6.2 a	6.4 a
IR25588-7-3-1	104	2.8 d	4.6 c	5.0 bc	5.9 ab	6.5 a	6.3 a
IR27316-96-3-2-2	121	3.8 b	6.1 a	6.4 a	6.4 a	7.1 a	6.8 a
IR28150-84-3-3-2	124	3.6 c	5.7 b	6.1 ab	6.5 ab	7.0 a	6.3 ab
IR29692-65-2-3-3	106	2.7 c	4.2 b	5.9 a	5.5 a	5.7 a	6.0 a
IR29692-99-3-2-1	104	2.9 d	4.3 c	5.1 bc	5.7 ab	6.4 a	6.6 a
IR29708-41-2-2-3	106	2.6 c	4.1 b	4.6 b	5.0 ab	6.1 a	5.9 a
IR29723-17-3-2-1	123	4.7 c	6.1 b	7.3 a	7.5 a	7.4 a	6.1 b
IR29723-143-3-2-1	128	5.7 b	7.3 a	7.9 a	8.1 a	7.7 a	7.6 a
IR29725-3-1-3-2	107	2.4 c	3.7 b	4.8 a	4.8 a	5.0 a	5.5 a
Peta	142	4.4 a	3.5 a	3.4 a	1.1 b	1.7 b	0.9 b
		Bicol					
IR8	128	2.1 b	2.8 ab	2.9 a	2.1 b	2.4 ab	2.2 ab
IR20	117	3.5 c	4.7 b	5.5 ab	5.3 ab	5.7 a	5.1 ab
IR36	114	3.6 c	4.6 b	5.1 ab	5.2 ab	5.8 a	5.8 a
IR42	136	2.4 c	3.9 ab	4.6 a	3.9 ab	2.9 c	3.2 bc
IR13525-43-2-3-1-3-2 (IR62)	107	3.3 b	5.7 a	5.3 a	5.4 a	5.6 a	5.8 a
IR21820-154-3-2-2-3	123	3.9 d	6.6 a	6.0 ab	6.0 ab	5.5 bc	5.0 c
IR21848-65-3-2-2	126	3.3 c	5.5 ab	5.1 b	5.4 ab	5.6 ab	6.2 a
IR25587-133-3-2-2-2	120	4.1 b	6.0 a	6.0 a	5.8 a	6.4 a	6.0 a
IR25588-7-3-1	104	2.3 c	4.3 b	4.5 b	4.7 ab	5.5 a	4.8 ab
IR27316-96-3-2-2	121	3.7 d	5.2 c	6.4 a	6.3 a	6.2 ab	5.4 bc
IR28150-84-3-3-2	124	4.5 c	5.9 b	7.1 a	6.2 b	7.1 a	6.1 b
IR29692-65-2-3-3	106	3.1 b	4.2 a	4.2 a	4.9 a	4.9 a	4.9 a
IR29692-99-3-2-1	104	2.6 d	4.3 bc	3.9 c	4.8 ab	4.1 bc	5.2 a
IR29708-41-2-2-3	106	2.9 c	4.0 b	5.4 a	6.2 a	4.2 b	5.9 a
IR29723-17-3-2-1	123	4.1 b	6.2 a	6.3 a	6.1 a	6.5 a	6.2 a
IR29723-143-3-2-1	128	4.0 c	6.4 a	6.3 a	6.0 ab	6.2 ab	5.4 b
IR29725-3-1-3-2	107	3.1 c	4.6 ab	5.0 a	4.7 ab	4.5 b	5.4 a
Peta	142						
		Visayas					
IR8	128	4.0 b	4.5 ab	5.4 a	5.6 a	5.6 a	5.6 a
IR20	117	4.1 b	5.3 a	5.9 a	6.3 a	6.2 a	6.1 a
IR36	114	4.2 b	6.3 a	6.6 a	6.6 a	6.5 a	6.6 a
IR42	136	3.9 c	5.6 b	6.6 ab	7.5 a	5.7 b	5.6 b
IR13525-43-2-3-1-3-2 (IR62)	107	3.9 c	5.5 b	6.7 a	6.1 ab	7.0 a	5.5 b
IR21820-154-3-2-2-3	123	5.9 c	6.3 bc	7.5 a	7.6 a	7.1 ab	7.1 ab
IR21848-65-3-2-2	126	3.9 c	4.7 bc	5.4 b	5.7 ab	5.7 ab	6.7 ab
IR25587-133-3-2-2-2	120	3.0 b	5.9 a	6.3 a	6.7 a	6.9 a	6.0 a
IR25588-7-3-1	104	2.8 c	4.4 b	6.0 a	6.1 a	6.4 a	6.4 a
IR27316-96-3-2-2	121	5.0 b	7.1 a	7.1 a	7.6 a	7.1 a	7.1 a
IR28150-84-3-3-2	124	5.9 b	6.6 ab	7.5 a	7.6 a	7.3 a	7.1 a
IR29692-65-2-3-3	106	2.3 d	4.3 c	5.5 b	6.2 ab	6.7 a	6.2 ab
IR29692-99-3-2-1	104	4.7 b	5.9 a	6.4 a	6.5 a	6.4 a	6.0 a
IR29708-41-2-2-3	106	2.5 c	5.2 b	5.7 ab	6.7 a	6.6 a	6.5 a
IR29723-17-3-2-1	123	4.8 d	6.3 c	7.5 ab	8.5 a	6.8 bc	6.6 bc
IR29723-143-3-2-1	128	4.6 c	6.3 b	6.8 ab	7.2 ab	7.6 ab	7.9 a
IR29725-3-1-3-2	107	2.5 c	4.7 b	5.1 ab	5.9 a	6.2 a	5.9 a
Peta	142	3.8 ab	4.5 a	4.0 ab	3.4 ab	3.4 ab	3.1 b

[a]Includes 30 kg N/ha topdressed 5-7 d before panicle initiation of each variety or line. [b]Av of 3 locations. [c]Separation of means in a row by Duncan's multiple range test at the 5% level.

Table 4. Yields of IRRI varieties and promising lines at 6 N levels[a] (0-150 kg/ha) in irrigated plots. Maligaya Rice Research and Training Center, Bicol Experiment Station, and Visayas Experiment Station, 1984 WS.

Variety or line	Duration[b] (d)	Yield[c] (t/ha)					
		0	30	60	90	120	150
				Maligaya			
IR8[d]	126	1.6 g	1.7 f	1.8 hi	1.6 g	1.4 i	1.3 hi
IR20	124	3.3 cde	3.9 a-e	2.9 fg	2.8 ef	3.1 c-g	2.9 b-f
IR36	116	4.2 a-d	4.1 a-d	4.1 a-e	3.3 b-f	2.9 d-g	2.3 fg
IR42[d]	131	3.2 def	3.0 e	3.1 efg	2.9 ef	2.7 e-h	3.1 a-f
IR25587-133-3-2-2-2	134	3.7 b-e	3.8 a-e	3.4 d-g	2.9 ef	2.3 gh	2.1 fgh
IR28150-84-3-3-2	127	3.8 b-e	3.4 cde	3.9 b-f	3.7 a-e	3.3 c-g	3.4 a-e
IR28228-12-3-1-1-2	126	3.6 b-e	4.6 ab	4.7 ab	4.2 ab	4.0 abc	3.5 a-d
IR29692-65-2-3-3	105	4.5 ab	4.3 abc	3.8 b-f	3.7 a-e	4.3 ab	4.0 a
IR29692-99-3-2-1	105	2.3 fg	3.2 de	2.5 gh	3.1 def	2.6 fgh	2.1 fgh
IR29723-17-3-2-1	126	3.4 cde	3.7 b-e	3.7 b-f	3.2 c-f	2.4 gh	2.8 b-f
IR29723-88-2-3-3	133	3.4 cde	3.5 cde	3.5 d-g	2.8 ef	1.8 hi	2.5 def
IR29723-143-3-2-1	133	4.3 abc	4.3 abc	3.5 d-g	3.1 def	2.8 d-g	2.4 ef
IR29725-3-1-3-2	108	3.0 ef	3.2 de	3.0 fg	2.6 f	3.0 d-g	2.4 ef
IR31802-48-2-2-2	114	3.2 def	3.4 cde	3.2 d-g	2.6 f	2.4 gh	2.2 fgh
IR31851-63-1-2-3-2	105	3.2 def	3.4 cde	3.7 b-f	2.8 ef	3.3 c-g	3.7 ab
IR31868-64-2-3-3-3	115	4.8 a	4.8 a	4.6 abc	4.4 a	3.2 c-g	2.6 c-f
IR32429-47-3-2-2	104	3.3 cde	4.0 a-e	4.1 a-e	3.9 a-d	4.0 abc	3.6 abc
Peta	134	1.9 g	0.9 f	1.0 i	0.8 g	0.5 j	0.7 i
				Bicol			
IR20	124	3.4 ab	4.4 a	3.9 ab	3.5 ab	3.1 b	2.8 b
IR36	116	3.9 abc	4.9 a	4.6 ab	3.5 bc	3.4 bc	3.1 c
IR25587-133-3-2-2-2	134	4.1 ab	4.8 a	4.2 ab	3.4 bc	2.6 c	3.2 bc
IR28150-84-3-3-2	127	4.6 ab	5.2 a	4.8[e] ab	4.0 b	3.8 b	3.5 b
IR28228-12-3-1-1-2	126	4.8 ab	5.1 a	4.7 ab	3.6 bc	3.9 abc	3.3 c
IR29692-65-2-3-3	105	4.4 a	4.7 a	4.4 a	2.8 b	3.0 b	2.8 b
IR29692-99-3-2-1	105	3.6 a	4.6 a	4.8 a	4.5 a	3.9 a	4.8 a
IR29723-17-3-2-1	126	5.2 a	5.2 a	4.8 a	4.1 ab	3.3 b	3.6 b
IR29723-88-2-3-3	133	4.2 ab	4.8 a	4.5 a	4.7 a	3.2 bc	2.9 c
IR29723-143-3-2-1	133	4.3 b	5.5 a	3.8 b	4.2 b	3.4 b	3.4 b
IR29725-3-1-3-2	108	4.2 ab	5.1 a	4.8 a	4.7 a	4.1 ab	3.4 b
IR31802-48-2-2-2	114	3.6 b	5.2 a	3.8 b	3.7 b	4.4 ab	3.4 b
IR31851-63-1-2-3-2	105	4.4 ab	5.0 a	4.7 ab	4.7 ab	4.4 ab	3.7 b
IR31868-64-2-3-3-3	115	5.1 ab	5.4 a	5.0 ab	4.2 abc	3.9 bc	3.4 c
IR32429-47-3-2-2	104	4.6 a	5.0 a	5.4 a	5.2 a	4.4 a	4.2 a
Peta	134	1.4 a	1.5 a	1.0 a	1.0 a	0.7 a	1.1 a
				Visayas			
IR8	126	2.3 a	2.7 a	3.0 a	2.5 a	2.9 a	2.5 a
IR20	124	4.6 b	4.7 b	5.1 ab	5.6 ab	5.8 a	5.2 ab
IR36	116	4.0 bc	5.0 ab	5.1 a	4.8 ab	4.1 abc	3.2 c
IR42	131	2.7 a	3.0 a	3.6 a	2.6 a	2.7 a	3.0 a
IR25587-133-3-2-2-2	134	4.6 c	5.6 bc	6.8 a	6.6 ab	6.3 ab	4.9 c
IR28150-84-3-3-2	127	5.4 a	5.4 a	5.6 a	5.6 a	5.4 a	4.9 a
IR28228-12-3-1-1-2	126	5.2 a	5.4 a	5.5 a	5.5 a	5.3 a	4.9 a
IR29692-65-2-3-3	105	4.3 a	5.1 a	5.1 a	4.9 a	4.7 a	4.2 a
IR29692-99-3-2-1	105	4.2 a	4.9 a	5.1 a	5.1 a	5.3 a	4.6 a
IR29723-17-3-2-1	126	4.5 a	5.1 a	5.4 a	5.6 a	5.1 a	5.0 a
IR29723-88-2-3-3	133	4.2 b	5.5 a	5.8 a	6.0 a	5.6 a	5.4 a
IR29723-143-3-2-1	133	4.9 b	6.4 a	6.6 a	6.6 a	6.7 a	6.5 a
IR29725-3-1-3-2	108	4.0 ab	4.3 ab	4.5 ab	4.9 a	4.8 a	3.7 b
IR31802-48-2-2-2	114	3.7 c	5.2 ab	5.8 a	6.1 a	5.2 ab	4.7 b
IR31851-63-1-2-3-2	105	3.5 b	4.9 a	5.2 a	5.1 a	5.0 a	4.7 a
IR31868-64-2-3-3-3	115	4.5 b	5.5 ab	5.9 a	5.9 a	5.8 a	5.3 ab
IR32429-47-3-2-2	104	3.6 b	4.4 ab	4.8 a	4.9 a	4.9 a	4.8 a
Peta	134	2.9 a	1.6 b	1.3 b	1.4 b	1.2 b	1.2 b

[a]Includes 20 kg N/ha topdressed 5-7 d before panicle initiation of each variety or line. [b]Av of 2 locations. [c]Separation of means in a column in Maligaya and in a row in Bicol and Visayas by Duncan's multiple range test at the 5% level. [d]Not included in statistical analysis for Bicol because of severe tungro damage. [e]Mean of 2 replications only.



8. Grain yield comparison of 3 IRRI rices at 4 N levels (0-120 kg N/ha) in irrigated and rainfed farms. N-response experiment, Laguna, Philippines, 1984 WS. LSD is for comparison of 2 N means for each variety or line on the irrigated farm.

The new semidwarfs were classified under two gene systems:

1. Identical with sd_1 locus: F_1 and F_2 plants were semidwarfs, with effect of modifying genes detected in the F_2 distribution. In this group are M302, Calmochi 202, and M401 from USA; Chai-yeh-ching, Tung-ting-wan hsien 1, Kwang-er-ai 5, and China 1039 mutant from China; Pulut Unggul from Indonesia; and Dwarf Jenugudu and Dwarf J. Sanna from India.
2. Sharing a compound locus with sd_1: F_1 plants were semidwarf; almost all F_2 plants were semidwarfs with less than 1% intermediate-tall or tall. Dwarf B. Theega fell into this category.

Genetic monitoring for new semidwarf sources will continue.

SELECTION FOR PHOTOPERIOD SENSITIVITY

Plant Breeding Department

Many rainfed lowland areas could benefit from improved plant types that are photoperiod sensitive. Photoperiod sensitivity was studied in random F_5 families of three rice crosses. Plants not flowering in the February planting were identified as strongly sensitive. The degree of photoperiod sensitivity was determined by seeding at two dates in WS, and calculating the number of days difference in heading dates divided by the number of days difference in seeding dates. A value close to 0 indicates insensitivity and close to 1 indicates sensitivity.

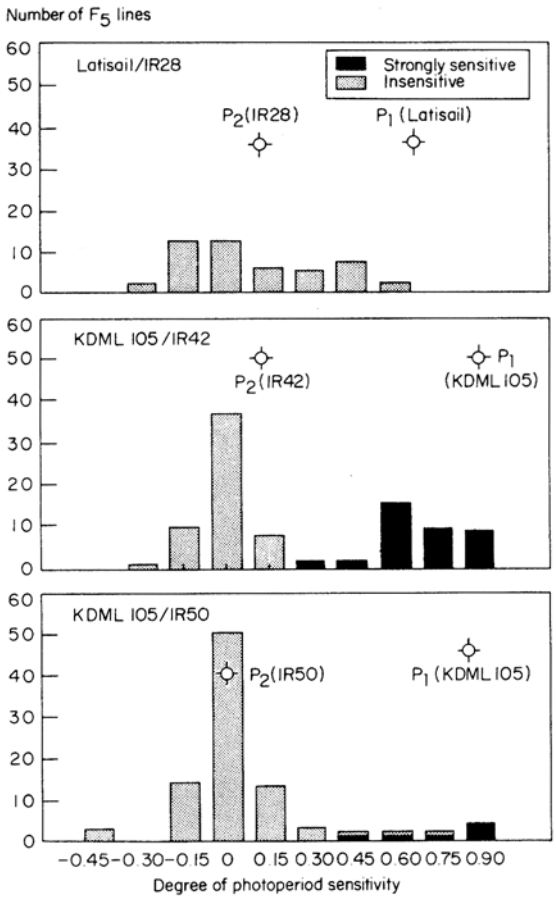
Distribution of sensitivity of the three F_5 crosses is shown in Figure 9. The cross Latisail/IR28 produced no clear segregation pattern. With Khao Dawk Mali 105/IR42, approximately equal numbers of sensitive and insensitive families were recovered, implying control by a single gene pair. With Khao Dawk Mali 105/IR50, however, very few sensitive recombinants were recovered. Therefore the genetic background of the insensitive parent may influence the expression of this trait. IR50 is of much shorter duration than IR42.

Latisail/IR28 showed no clear relation between plant height and sensitivity. In the Khao Dawk

Table 5. Yields of varietal types in favorable years and dry years at IRRI and Santo Tomas, Batangas, Philippines, 1981-84.[a]

Varietal type	Plant ht (cm)	Yield t/ha				
		Favorable years		Dry years		
		1983 (ST)	1984 (ST)	1981 (ST)	1983 (UF)	1984 (UF)
Semidwarf						
IR43	77	3.4	2.7	0.1	2.0	1.3
IR6115-1-1-1	80	3.6	2.7	0.2	1.5	1.9
Intermediate type						
IR5420-1-1-2	101	3.4	2.8	0.1	2.1	1.7
IR10147-113-5	115	3.1	2.8	–	1.6	1.3
IR12979-24-1	115	2.7	2.8	0.9	1.9	1.2
Traditional upland						
Kinandang Patong	142	1.7	2.2	0.2	1.3	0.7

[a] ST = Santo Tomas, Batangas; UF = IRRI upland farm.



9. Distribution of degree of photoperiod sensitivity in 3 rice crosses. Dark bars mean the plants did not flower during the February seeding. IRRI, 1984.

Mali 105 crosses with IR varieties, however, sensitivity was strongly associated with plant height. Only one sensitive family less than 140 cm tall was recovered. This indicates that semidwarf photoperiod-sensitive plants may be difficult to recover in crosses with some parents. Breeding program experience, however, does not often indicate difficulty in combining photoperiod sensitivity and semidwarfism.

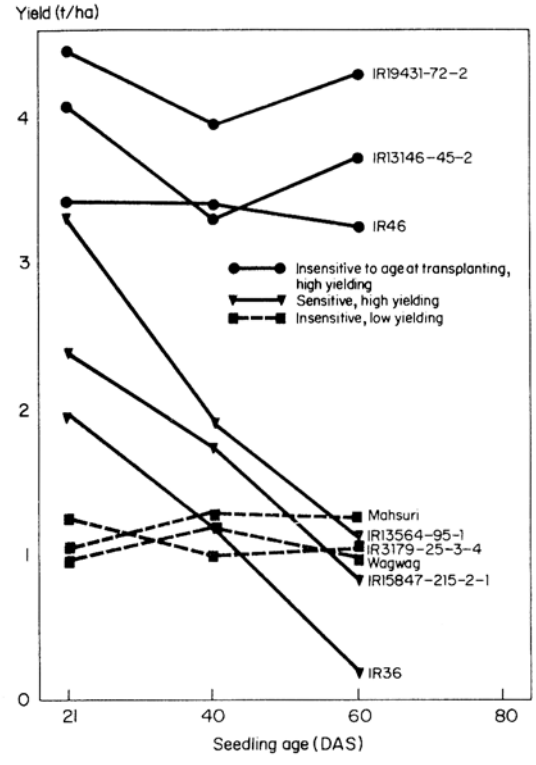
IDENTIFYING RAINFED RICES FOR LATE TRANSPLANTING

International Rice Testing Program

Most farmers in rainfed lowland areas in Asia use aged seedlings (30-60 d old) because water is not available in fields at planting time. They usually grow one crop using a photoperiod-sensitive, low-yielding variety. Yields are poor when early and medium-duration MVs are transplanted late. MVs insensitive to late transplanting could improve yields.

The growth and yield of 29 cultivars from the 1984 International Rainfed Rice Shallow Water Yield Nursery (IRRSWYN) were tested in 3 seedling age treatments (transplanted 21, 40, or 60 d after seeding). Plots were shallow flooded until 14 days after transplanting (DT), then irrigated to maintain a wet surface without standing water.

Three groups of genotypes were tested for sensitiveness to transplanting age: insensitive, high yielding; sensitive, high yielding; and insensitive, low yielding (Fig. 10). High yielding entries (3.2 to 4.2 t/ha) insensitive to transplanting age were IR19431-72-2, IR13146-45-2, IR19083-22-2-2, and IR46.



10. Relationship between grain yield and age of seedlings at transplanting time for selected entries from the IRRSWYN, IRRI, 1984.

IR36 and several other MVs yielded much less as transplanting was delayed. The sensitive traditional variety Wagwag and the moderately sensitive Mahsuri were not affected by late transplanting but were low yielding. Mahsuri, widely grown in Asian rainfed lowland rice areas, yielded only 1.2 t/ha.

Only 4 entries yielded more than 3.0 t/ha when transplanting was delayed until 60 DAS. Their yields with late transplanting were >90% of the corresponding yield with 21-d-old seedlings. The early and medium-duration varieties yielded high relative to very early-maturing varieties. No very early maturing genotypes had high yields when transplanted late. Some genotypes yielding poorly due to late transplanting had fewer panicles (Table 6).

SELECTING UPLAND RICES THAT SUPPRESS WEEDS

International Rice Testing Program and Agronomy Department

Weeds are the most serious problem in upland rice production. Only with early and thorough weed control can upland rice compete well with common weed species. Most upland rice farmers spend several hundred hours per hectare in hand weeding. They require upland rice cultivars which suppress weeds.

A set of 27 elite upland rices from the International Upland Rice Yield Nursery (IURYN) were compared for weed suppression abilities. The trials had moderate and higher weed management levels

Table 6. Grain yield, panicles, and days to flowering of 29 IRRSWYN varieties or lines planted at 21, 40, and 60 days after seeding. IRRI, 1984.

Designation	Yield (t/ha)			Panicles (no./m²)			Days to flowering
	21	40	60	21	40	60	
IR19431-72-2	4.4	3.9	4.3	238	221	258	90
IR13146-45-2	4.1	3.3	3.7	249	223	274	90
IR19083-22-2-2	3.6	4.0	3.3	217	209	277	93
IR46	3.4	3.4	3.2	261	226	242	86
IR19256-88-1	3.3	3.4	2.9	235	233	237	95
IR14753-86-2	2.9	3.2	2.7	241	219	242	89
IR13358-16-3-2	2.5	3.5	2.6	232	215	236	97
IR10781-143-2-3	2.6	2.5	2.5	252	222	213	97
BR51-74-6/J1	2.1	3.3	2.2	248	212	252	96
RP1045-25-2-1	2.4	2.6	2.2	220	228	220	95
BR11	2.4	3.2	2.1	233	208	227	87
IR9852-22-3	2.7	2.1	2.0	267	196	222	86
Cisadane	2.4	2.1	2.0	238	210	231	97
IR5853-198-1-2	2.4	2.4	1.9	263	255	222	84
IR5873-9-1	1.8	2.1	1.9	234	226	197	87
BR4	2.3	3.0	1.8	233	225	251	95
IR4819-77-3-2	1.9	1.8	1.7	259	219	218	86
IR4829-89-2	2.2	1.9	1.5	248	231	191	86
Mahsuri	1.0	1.3	1.2	228	238	217	97
IR4744-295-2-3	2.1	2.3	1.2	262	278	165	82
IR13257-46-1E-P1	2.2	1.1	1.1	210	165	204	90
IR13564-95-1	3.3	1.9	1.1	253	243	227	89
IR8608-82-1-3-1-3	1.8	1.2	1.1	223	222	217	79
IR3179-25-3-4	1.3	1.0	1.0	230	164	201	79
Wagwag (Local check)	1.0	1.2	1.0	179	211	168	104
IR15847-215-2-1	2.4	1.7	0.8	234	272	218	86
IR13260-100-1E-P2	1.8	0.9	0.7	231	166	149	78
IR9698-16-3-3-2	1.8	0.4	0.4	251	162	194	79
IR36 (Local check)	2.0	1.2	0.2	248	221	124	78

Table 7. Weed weight and grain yields for some elite IURYN cultivars tested for weed suppression ability under 2 weed management levels. IRRI, 1983 and 1984 WS.

Designation	Mean plant height (cm)	Weed weight (t/ha)							Grain yield (t/ha)					
		1983			1984			2-yr mean	1983[a]			1984		
		2 HW	3 HW	Av	1 HW	2 HW	Av		2 HW	3 HW	Av	1 HW	2 HW	Av
B3622E-Tb-5-4-4	135	1.7	0.5	1.1	1.1	0.2	0.6	0.8	1.5	2.5	2.0	3.0	2.8	2.9
Salumpikit	131	0.4	1.7	1.0	1.0	0.3	0.6	0.8	0.3	0.4	0.3	1.1	1.6	1.3
C894-21	121	1.1	0.5	0.8	1.5	0.3	0.9	0.9	0.9	1.6	1.2	1.5	2.7	2.1
UPL Ri-7	109	1.7	0.5	1.1	1.5	0.3	0.9	1.0	1.1	2.3	1.7	2.6	3.4	3.0
IR6023-10-1-1	117	1.8	0.8	1.3	1.3	0.3	0.8	1.1	2.0	2.4	2.2	2.4	2.6	2.5
C732-14	130	1.5	0.5	1.0	1.9	0.3	1.1	1.1	0.7	1.0	0.8	1.4	1.9	1.7
UPL Ri-5	117	1.7	0.7	1.2	1.5	0.5	1.0	1.1	1.3	2.0	1.7	1.9	2.8	2.3
IR12721-24-3-1	131	2.7	0.4	1.5	1.6	0.4	1.0	1.3	0.9	1.7	1.3	2.6	2.2	2.4
BR319-1	106	2.6	0.7	1.7	1.4	0.4	0.9	1.3	1.4	3.0	2.2	2.0	2.7	2.4
B3623G-Tb-48	121	1.8	0.8	1.3	2.4	0.4	1.4	1.3	1.5	1.8	1.7	1.7	2.7	2.2
UPL Ri-3	120	1.7	0.8	1.2	2.7	0.3	1.5	1.4	1.1	1.2	1.1	1.8	1.7	1.8
B2992b-Tb-73-4-2-3-3-3-2	124	2.4	0.4	1.4	3.0	0.3	1.7	1.5	1.1	1.8	1.4	1.8	2.3	2.0
IR3179-25-3-4	106	2.0	0.6	1.3	2.9	0.6	1.7	1.5	2.1	2.9	2.5	2.1	2.8	2.5
BP1 Ri-6	107	2.1	1.0	1.5	3.6	0.4	2.0	1.8	1.6	1.8	1.5	1.5	2.9	2.0
IR5931-110-1	105	3.1	0.8	2.0	2.7	0.7	1.7	1.8	0.4	1.8	1.1	2.0	3.1	2.6
C4-1-5[b]	126	1.7	0.5	1.1	5.5	1.8	3.6	2.4	0.9	1.8	1.4	0.4	1.2	0.8
IR43	83	4.1	1.5	2.8	3.3	0.8	2.1	2.4	0.8	2.4	1.6	1.6	3.0	2.3
IRAT 104[b]	118	2.6	0.8	1.7	5.4	0.9	3.2	2.4	1.3	2.4	1.9	0.4	2.0	1.2
IRAT 140[b]	114	2.7	1.3	2.0	4.1	1.8	2.9	2.5	1.4	3.0	2.2	0.4	1.3	0.9
IRAT 112[b]	113	3.3	1.2	2.3	5.7	1.6	3.7	3.0	1.9	3.1	2.5	0.2	1.0	0.6
CR156-5021-207	82	5.6	2.4	4.0	3.3	1.0	2.2	3.1	0.1	1.1	0.6	1.4	2.3	1.9
IR9782-111-2-1-2	73	5.8	2.6	4.2	4.1	0.7	2.4	3.3	0.4	1.8	0.8	1.2	2.2	1.7
IR9101-124-1	80	6.4	3.1	4.7	3.4	1.0	2.2	3.5	0.1	0.5	0.3	1.6	2.5	2.1
IR13146-43-2-3	93	7.2	3.5	5.4	2.9	0.7	1.8	3.6	1.0	0.6	0.8	0.9	1.5	1.2
IR6115-1-1-1	79	7.3	4.2	5.8	3.3	0.8	2.0	3.9	0.3	0.6	0.5	1.5	3.3	2.4
IR45[c]	78	—	—	—	4.0	0.8	2.4	—	—	—	—	1.2	2.4	1.5
IR52[d]	84	—	—	—	3.3	1.0	2.1	—	—	—	—	1.6	2.7	2.1
ITA 173[e]	141	1.7	0.3	1.0	—	—	—	—	1.3	2.3	1.8	—	—	—
Mean	109	3.0	1.2	2.1	2.9	0.7	1.8	2.0	1.0	1.8	1.4	1.6	2.4	1.9

[a]Yields of most entries were severely affected by sheath blight during postflowering period. [b]Excluded from interpretation because of poor crop stand in the 1984 trials. [c]Entry was not utilized in 1983. [d]Entry was wiped out by blast in 1983. [e]Entry was not utilized in 1984.

for two growing seasons at IRRI. Weed competition in 1983 was severe, so the moderate treatment had two complete hand weedings at the early vegetative period, and the higher level had three. In 1984, the moderate treatment had one hand weeding and the high level had two.

Cultivars differed greatly in weed suppression ability (Table 7). In 1983, weed dry weight at harvest varied from 0.4 t/ha for Salumpikit (134 cm tall) to 7.3 t/ha for IR6115-1-1-1 (69 cm) with two hand weedings. In 1984, weed weights with 1 hand weeding varied from 0.98 t/ha for Salumpikit to 4.11 t/ha for IR9782-111-2-1-2.

In both years, taller varieties suppressed weeds better by shading them out. Cultivars less than 100 cm tall could not compete with weeds. Weed weights for these cultivars averaged 2.0 to 4.0 t/ha with moderate weed management.

Cultivars taller than 120 cm suppressed weed growth best. However, they frequently lodged severely before maturity. Several intermediate height cultivars suppressed weeds well without lodging. They included UPL Ri-5, UPL Ri-7, IR6023-10-1-1, and BR319-1.

In 1984, plots with lower weed weights had higher grain yields under moderate weed management. The four intermediate height entries cited yielded best, along with tall B3622E-Tb-5-4-4 and IR12721-24-3-1. The shorter entries yielded poorly (Table 8).

Relative yields, computed as the yield with one hand weeding as a fraction of the yield with two hand weedings, varied from .45 to 1.15 among the entries. Short entries had the lowest relative yields, and taller cultivars had the highest.

The intermediate height cultivars yielded better at moderate weed control levels than at high levels (Fig. 11). The lower yields of the shorter cultivars corresponded with strikingly higher weed weights.

Table 8. Weed weights and grain yields of plant height groups of elite upland rice cultivars when grown under moderate weed management level (one hand weeding). IRRI, 1984.

Group	Entries (no.)	Plant ht (cm)	Weed wt (t/ha)	Yield (t/ha)
Short (<100 cm)	8	82	3.4	1.5
Intermediate (100-115 cm)	7	106	1.9	2.0
Tall (116-130 cm)	7	121	2.0	1.9

These studies suggest that upland rice cultivars suitable for cultivation under less than optimum weed control may be from 100 to 115 cm tall or taller. Cultivars of that height more effectively suppress weed growth by shading.

This research developed and tested a visual scoring system for assessing weed suppression (Table 9). The system considered the density of weeds in the plot and the height of the weed canopy in relation to the rice canopy. Scores taken at flowering and recorded by two individuals strongly correlated with dry weight of weeds at harvest.

RICE RATOONING

Plant Physiology Department

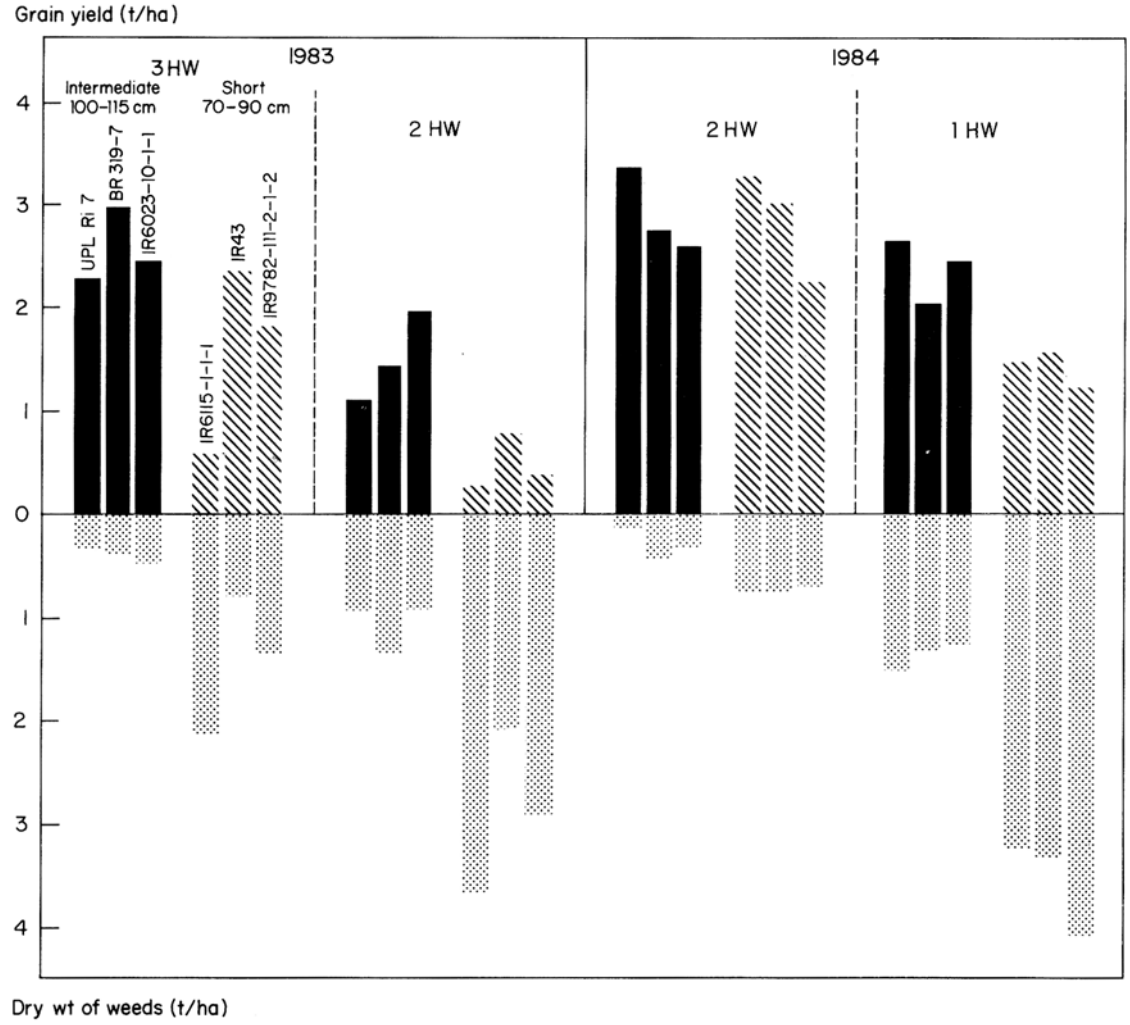
Ratooning could increase rice production per unit area and per unit time. In tropical Asia, rice ratooning has not been accepted because of generally low yields, lack of varieties which ratoon well, insect and disease problems, uneven maturity which complicates harvesting, and lack of proper ratoon cultural practices.

Ratooning would be more productive and economic with improved inherent ratooning ability of cultivars and suitable packages of main- and ratoon-crop management practices. Research examined biological mechanisms and cultural factors affecting ratooning.

Dormant buds. When IR44 was ratooned at 15-cm height, the 4th to 7th nodes from the top were available for regrowth. Regeneration was lower at shorter cutting height because about 73% of dormant buds at the basal node were dead.

Bud development. At main crop cutting, buds at the first, second, and third nodes from the cut end did not vary appreciably in average length. However, bud length varied greatly starting at 2 d after cutting. From the sixth day after cutting, the bud at first node grew faster than those at second and third nodes. Eight days after cutting, secondary tillers showed on the ratoon tillers at the first nodes.

In the ratoon crop with three nodes in the stubble, the two upper nodes are the important source of ratoon tillers. Ratoon tillers from the upper nodes often broke because they did not develop or had poorly developed root systems.



11. Comparison of grain yield and weed weights among 3 cultivars of intermediate and short stature when grown under less than optimum weed management. IRRI, 1983-84.

Thus they wholly depended on main-crop tillers for mechanical support and nutrition. Some tillers from lower nodes developed root systems and may derive nutrients directly from soil as do main-crop tillers.

Regeneration time. Ratoon tiller regeneration time varied from 1 to 10 d after cutting. Sixty percent of the plants developed first ratoon tillers in 3 to 5 d. Plants not producing ratoons in 10 d rarely produced any.

Tillers per plant varied from 5 to 19 at 3 wk after cutting, 20 to 34 at 6 wk, and 19 to 26 at 12 wk. More ratoon tillers appeared if plants regenerated tillers early.

Selection for good ratooning ability can be based on earliness of ratoon tiller production. Plants regenerating tillers late (>7 d) would not mature uniformly and may be discarded.

Culm thickness. Culm thickness in IR44 varied from 2 to 5 mm. Ratoon tillers were produced irrespective of culm thickness. Nevertheless, a few thin culms failed to support tiller growth and tillers died early. Average ratoon tillers per tiller-producing culm varied from 1.33 to 2.90. Thick culms produced more ratoon tillers than did thin ones. The origin of ratoon tillers seems independent of culm thickness.

Temperature. Rice ratooning depends on carbo-

Table 9. Visual scoring scale system for assessing weed suppression ability.

A. Weed Density		
L – Low		
M – Moderate		
H – High		
B. Weed Canopy (in relation to crop canopy)		
L – Lower		
S – Same		
H – Higher		
C. Subjective Rating Score		
1 Excellent	–	Nil to low weed density, with weed canopy height much below crop canopy height.
3 Good	–	Low to moderate weed density, with weed canopy lower than or equal to crop canopy height.
5 Fair	–	Moderate weed density, with weed canopy height lower or equal to crop canopy height.
7 Poor	–	Moderate to high weed density, with weed canopy height equal to crop canopy height.
9 Unacceptable	–	High weed density, with weed canopy height above crop canopy height.

Table 10. Effect of temperature after cutting the main crop on regeneration, plant height, productive tillers, and grain yield in the IR44 ratoon crop. IRRI, 1984.

Day/night temperature	Regeneration (%)	Plant height (cm)	Productive tillers (%)	Grain yield (g) per plant
37°/27°	83	73	82	1.1
29°/21°	100	63	68	9.2
23°/20°	58	52	35	2.1

hydrates accumulated in main crop stubble and roots. Temperature during ripening is critical to carbohydrate content.

After cutting, IR44 plants were placed in growth cabinets with day/night temperatures of 37°/27°C (high), 29°/21°C (medium), and 23°/20°C (low).

More tillers regenerated at medium temperature, followed by those at high temperature (Table 10). High temperature after cutting produced very fast ratoon growth, shown by plant height, and a high number of productive tillers.

Grain yield was optimum at medium temperature. High temperature resulted in high sterility while low temperature resulted in fewer panicles per plant, hence low yields.

Light intensity. The effects on ratooning ability of light intensity before and after main crop cutting was evaluated. Plants were grown in 0%, 40%, and 60% shading.

Shading before main crop cutting hurt ratooning more than shading after main crop cutting (Table 11). Poor regeneration in shade may be due to reduced photosynthesis and low carbohydrate in the culm.

Tiller production was inconsistent in shaded and unshaded conditions. Reduced light intensity before and after main crop cutting did not significantly influence grain yield per plant and other yield components.

Ratoon grain yields differed remarkably among treatments because of poor regeneration and missing hills.

Growth regulators. Rapid leaf senescence of the main crop partly accounts for low yield of ratoon rice. Carbohydrates are produced mainly through photosynthesis during ripening; therefore, late leaf senescence increases carbohydrate accumulation.

Table 11. Effect of light intensity before and after cutting of main crop on grain yield and its components in the IR44 ratoon crop. IRRI, 1984.

Treatment	Regeneration (%)	Panicles/plant (no.)	Spikelets/panicle (no.)	Spikelet fertility (%)	1000-grain weight (g)	Grain yield (g)	
						Per plant	Per treatment
Before cutting							
40% shading	44	11	57	47	18.71	4.4	31
60% shading	19	13	52	47	18.80	4.5	14
After cutting							
40% shading	81	16	45	44	19.68	6.1	64
60% shading	63	12	45	40	19.28	4.5	36
Control	81	10	54	50	19.44	5.4	57

Delaying leaf senescence of the main crop through growth regulators could improve the ratoon crop.

Gibberellic acid (Ga_3) at 100 ppm, applied 15 d after main crop flowering, significantly increased ratoon yield mainly because of increased panicles per plant. Ethrel and kinetin at the concentrations used had no effect on regeneration, ratoon tillering, ratoon yield, and its components.

Seedlings per hill. With IR44, more seedlings per hill resulted in improved plant stand of the ratoon crop and earlier ratoon tiller regeneration. Four seedlings per hill gave the highest main crop and ratoon yields. More seedlings per hill meant fewer missing hills in the ratoon crop.

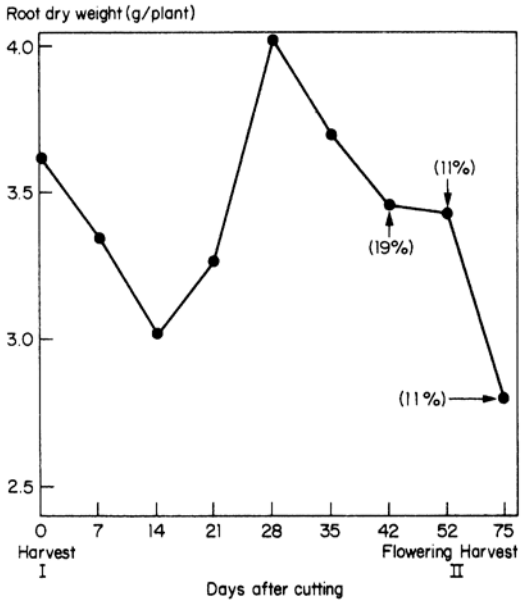
Root system of main and ratoon crops. Root distribution and changes in root dry weight of ratoon crop were investigated in 1983 WS. Mature plants were ratooned by cutting stalks 15 cm aboveground. The harvesters stood on planks to prevent disturbing main crop root system. Immediately after cutting, 40 kg N/ha was topdressed.

Most roots (70 to 80%) at main crop harvest and up to 35 d after harvest (DAH) were generally reddish brown. The proportion of black (dead) roots continuously increased. A few white (new) roots developed from nodes close to the ground. From 42 DAH, most plants had well developed white roots from ratoon tillers, but some tillers lacked roots.

Root dry weight declined from 0 to 14 DAH (Fig. 12), probably because during initial growth of the ratoon tillers, the mother culms and roots supplied the carbohydrates needed. Root dry weight increased from 14 to 28 DAH and thereafter declined gradually up to 75 DAH. The period 14-28 DAH corresponds to time of new root production. Figure 12 shows the mean root dry weight from ratoon tillers as a percentage of total root dry weight at 42, 52, and 75 DAH.

Ratoon tiller development in IR44 appears to depend primarily on the main crop root system for nutrients at least up to 21 DAH. Thereafter new roots from ratoon tillers contribute, but minimally.

Time of ratoon crop harvest. High ratoon yield depends on ratoon growth duration. Long duration reduces daily productivity per hectare. Although IR44 is a good ratooning variety, its ratoon crop matures unevenly and growth extends over 100 d. Uneven maturity poses problems in ratoon crop harvesting. The effect of time of harvest on ratoon yield was investigated to determine optimum harvest time.



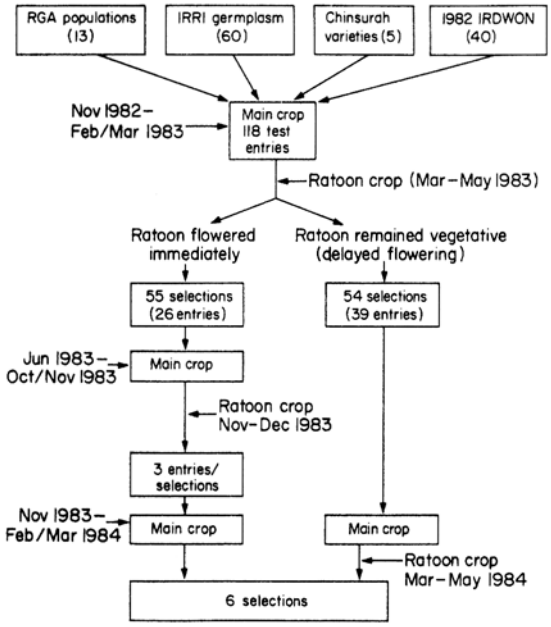
12. Root production in the ratoon crop of IR44. IRRI, 1983 WS. The values in parentheses are the root dry weight from ratoon tillers as percentage of total root dry weight.

Ratoon crop was harvested at 75, 80, 85, and 90 d after main crop harvest. Ratoon grain yields varied from 136 g/m^2 for early harvest (75 d after main crop harvest) to 196 g/m^2 for late (85 d) harvest. A lower percentage of fully filled grains accounts for the lower yields with early harvest. Optimum time of IR44 ratoon harvest seems to be 80-85 d after main crop cutting.

SELECTING DEEP WATER RICES WITH RATOONING ABILITY

Plant Physiology Department

Six outstanding selections were obtained from 118 entries evaluated for ratooning ability (Fig. 13). The selections showed consistent high percentage of regeneration, high main crop yield, and relatively good lodging resistance for at least two seasons (1982-84) at IRRI. Bases for selection were high ratoon tiller number (≥16), minimum of 3 leaves/tiller before flowering, and resistance to viral diseases in the field. Some entries exhibited segregation for flowering in the ratoon crop. Further selections were made for entries flowering imme-



13. Selection of deep water rices with ratooning ability. IRRI, 1982-84. RGA = rapid generation advance, IRDWON = International Rice Deep Water Observational Nursery.

diately after ratooning and those with delayed flowering. The other features of main and ratoon crops appear in Table 12.

PHYSIOLOGICAL BASES OF HETEROSIS

Plant Physiology Department

Dry matter production. High dry matter production leads to high yields of F_1 hybrids. Growth analysis of four F_1 hybrids and their parents in the field revealed that leaf area ratio (LAR) and relative leaf growth rate (RLGR) were high for F_1 hybrids when they had high relative growth rate (RGR). F_1 hybrids had large leaves. However, RGRs of F_1 hybrids were not always higher than those of parents, although hybrids produced more dry matter. Hence, high dry matter production of F_1 hybrids relates to high RLGR and also to initial heavy dry matter. Seeds of F_1 hybrids were heavier than those of the parents. High RLGR and large seed size are responsible for heterosis for dry matter production.

Yield at different spacings. Heterosis for yield was high at wide spacing (Table 13). Heteroses in spikelet number and 1,000-grain weight, which means increased sink size, were responsible for heterosis in yield. Very little heterosis was noted in percentage of filled spikelet and panicle number.

With close spacing, large spikelet number was caused by large panicles, and at wide spacing, by large panicles and increased panicle number. Large panicles might be intrinsic to F_1 hybrids.

Average yield of F_1 hybrids and heteroses in yield at spacings of 20×20 cm and 30×30 cm suggest optimum F_1 spacing between these spacings.

Roots of F_1 hybrids. Roots of F_1 hybrids were heavier than those of the midparents because of their high dry matter production. However, dry matter partitioning into roots was less in F_1 hybrids than in their parents.

F_1 hybrids had more roots than their midparents, and may have thicker roots than their parents because heterosis and heterobeltiosis in root length per root dry weight tended to be less than one. However, heteroses in morphological characters of roots were not higher than those of shoot growth.

Table 12. Plant characters[a] of outstanding deep water rices selected for ratooning and sown November 1983-84, IRRI.

Selection	Main crop							Ratoon crop		
	1	2	3	4	5	6	7	8	9	10[b]
Gowai 50-9 (Acc. 6493A)	104	141	15	18	3	9	1	93	17	+
Cholamon 658 (Acc. 6517A)	133	177	19	21	7	5	1	85	20	–
Karkati 87 (Acc. 6618A)	117	152	21	15	9	5	1	97	35	–
CN691-3	120	117	20	32	0	7	7	95	24	–
CN658-R-R-R (Jaladhi 2/CR1005)	125	140	22	16	3	3	7	97	27	–
CN665-R (Pankalash/OC1393)	125	156	10	15	5	5	7	83	24	–

[a] 1 = growth duration (d), 2 = plant height (cm), 3 = panicles/plant (no.), 4 = grain yield/plant (g), 5 = lodging score (1 = good), 6 = cold tolerance (1 = good), 7 = elongation (1 = good), 8 = regeneration (%), 9 = tillers/plant (28 DAH), 10 = flowering. [b] + = flowered, – = nonflowering.

Table 13. Average grain yield of F_1 hybrids and heterosis for yield components at different spacings. IRRI, 1984 DS.

Spacing (cm)	Av grain yield (t/ha) of F_1 hybrids	Heterosis					
		Grain wt	Spikelet no.	Panicle no.	Spikelet no./panicle	Filled spikelets (%)	1000-grain wt
20 X 20[a]	5.5	1.14	1.16	0.99	1.15	0.95	1.06
30 X 30[a]	5.3	1.22	1.08	0.90	1.16	1.03	1.10
40 X 40[a]	4.6	1.23	1.22	1.09	1.07	0.96	1.06
100 X 100[b]	1.3	1.47	1.47	1.17	1.28	1.00	1.01

[a]Av for 5 F_1 hybrids. [b]Av for 4 F_1 hybrids.

Table 14. Average heterosis of 18 F_1 hybrids grown in culture solution. IRRI, 1984.

	Heterosis
Plant dry weight	1.23
Root dry weight	1.20
Root-plant ratio	0.98
α-NA oxidation/plant	1.15
α-NA oxidation/g root	0.95

This was also true under low nitrogen condition, where roots grew vigorously.

F_1 hybrids showed heterosis in root activity (Table 14). The rate of α-naphthylamine oxidation per plant was larger than the means of parents. The α-naphthylamine oxidation per gram root dry weight of F_1 hybrids was slightly less than the means of parents.

Genetic evaluation and utilization (GEU) program

Grain quality and nutritional value

Cereal Chemistry, Plant Breeding, Agricultural Economics, Multiple Cropping, and Statistics Departments, and International Rice Testing Program

BREEDING PROGRAM AND EVALUATION **36**
- Intermediate-amylose and other elite lines **36**
- Screening for rice aroma **36**
- Chalkiness by rice meter **37**
- *Wx* gene product in starch granules **37**
- Protein screening of replicated yield trials **37**
- Protein screening of 1982 IRTP nursery **37**
- Protein distribution as screening technique **38**
- Flotation method for protein screening **38**

GRAIN QUALITY AND NUTRITIONAL FACTORS **39**
- Fissuring resistance of brown rice **39**
- Country samples **39**
- Kinetic studies on rice cooking **40**
- Rice water for diarrhea treatment **41**
- Starch properties and insulin response **41**
- Extruded rice noodles from dry-milled flour **42**
- Extrusion-cooked rice **42**
- Energy and amino acid contents of nonrice crops **43**

BY-PRODUCTS AND RESIDUES **43**
- Oil content of brown rice and bran **43**
- Varietal differences in straw feed value **44**

BREEDING PROGRAM AND EVALUATION

Cereal Chemistry, Plant Breeding, and Statistics Departments, and IRTP

Intermediate-amylose and other elite lines (*Cereal Chemistry and Plant Breeding*). Analysis of the quality factors of intermediate-amylose lines derived mainly from C4-63G (alkali spreading value 3) and BPI-121-407 (alkali spreading value 7) showed that alkali spreading value correlated significantly with cooked rice Instron hardness and amylograph consistency in the dry (DS) and wet season (WS) crops. Gel consistency correlated significantly with both properties only in WS. Amylose content (AC) correlated with cooked rice texture only in DS crop.

Among 10 variety candidates evaluated for quality characteristics, 4 were high (25-33%) amylose, 5 were intermediate amylose (20-25%), and 1 was waxy. Three high amylose lines had alkali spreading value 7 and one had 5. The high amylose variety IR62 was verified to have alkali spreading value 5, soft gel consistency, low amylograph consistency, and soft Instron cooked rice hardness close to those of intermediate AC rices (Table 1). IR62 had softer cooked rice than hard gel IR42 and medium gel IR36. Four of the 5 intermediate AC lines had alkali spreading value 3-5 and 3 had softer cooked rice than that of IR48 with alkali spreading value 7.

The waxy line IR21015-196-3 is contaminated with translucent nonwaxy grains and had harder cooked rice and gel consistency than the standard Malagkit Sungsong (Table 1). Another waxy line, IR18818-87-2, was closer to Malagkit Sungsong in properties. Nonwaxy contaminant grains may have contributed to cooked rice hardness of these two waxy lines, higher in IR21015-196-3 than in IR18818-87-2.

Screening for rice aroma (*Cereal Chemistry*). A sample of freeze-dried Malagkit Sungsong rice plants (7-wk-old) together with a commercial sample of pandan flavoring were analyzed at the Western Regional Research Center (WRRC), USDA. Vacuum steam distillation-continuous extraction of the straw followed by capillary gas-liquid chromatography-mass spectrometry (GLC-MS) showed another component present in greater concentration with elution temperature and MS ions similar to those of 2-acetyl-1-pyrroline, the major aroma constituent of cooked rice and pandan leaves. Popcorn and oat volatiles also showed the characteristic "popcorn" line odor at the correct GLC retention time of 2-acetyl-1-pyrroline, but also had coeluting compounds. The commercial liquid pandan flavor contained vanillin and a "cracker odor" type compound other than 2-acetyl-1-pyrroline. By GLC-MS, the WRRC laboratory confirmed for the U.S. Food and Drug Administration that samples of supposedly Basmati imported rice were nonaromatic. In a typical capillary GLC of Basmati rice volatiles using a 150-m-long × 0.64 mm i.d. pyrex capillary wall coated with

Table 1. Mean quality characteristics of selected IR varieties and intermediate-amylose and waxy lines. IRRI, 1983-84.

Variety or line	Amylose content (% dry basis)	Alkali spreading value	Gel consistency (mm)	Amylograph consistency (BU)	Cooked rice[a] Instron hardness (kg)
IR36	28	4	36	310	7.5
IR42	27	7	30	645	8.6
IR62	28	5	77	175	6.2
IR48	22	7	36	220	7.5
IR18348-36-3	22	4	71	95	6.2
IR28150-84-3	22	4	64	90	6.6
IR31851-63-1	23	4	56	140	6.4
IR31868-64-2	22	4	52	140	7.3
Malagkit Sungsong	1	7	62[b]	10	5.1
IR21015-196-3	8	7	38[b]	50	6.0
IR18818-87-2	4	7	43[b]	40	5.4

[a]Cooking water-rice ratio of 2.1 for high-amylose rices, 1.9 for intermediate-amylose rices, and 1.1 for waxy rices. [b]Neutral gel consistency.

Table 2. Range and correlation between growth duration, BRP, and rough rice yield in replicated yield trials. IRRI, 1983 WS and 1984 DS.

Property	1983 WS[a] (n = 508)			1984 DS[b] (n = 507)		
	Range	Correlation coefficient		Range	Correlation coefficient	
		Growth duration	Rough rice yield		Growth duration	Rough rice yield
BRP (%)	8.0- 13.1	−0.39**	−0.19**	6.6- 12.0	−0.36**	−0.06
Growth duration (d)	98.0-151.0		−0.39**	100 -148		0.03
Rough rice yield (t/ha)	1.3- 4.8			2.8- 8.1		

[a]Check sample data — IR36: 11.5% BRP, 2.6 t/ha; IR42: 10.5% BRP, 3.8 t/ha. [b]Check sample data — IR36: 10.0% BRP, 6.2 t/ha; IR42: 8.5% BRP, 7.0 t/ha.

Carbowax 20-M, 2-acetyl-1-pyrolline is peak 62. Peak 62 was very small or almost absent in nonaromatic rices. Temperature program was 30 min at 50° C, then increased to 170° C at 1° C/min and then 2 h at 170° C.

Chalkiness by rice meter (*Cereal Chemistry*). Plant breeders use a visual scoring system for chalkiness of nonwaxy grains: 0 = none, 1 = less than 10%, 5 = 10-20% chalky, and 9 = greater than 20%. A Japanese Rice Meter for measuring brown-rice translucency was tested on milled rice and found satisfactory. The correlation between visual scoring and the instrument was not always significant. Whereas visual scoring disregards the degree of chalkiness of the translucent fraction on nonwaxy grain and concentrates only on the completely chalky portion, the instrument estimates overall translucency in a linear scale from 0 to 100%. Chalkiness over 20% in the visual method gets the same score of "9."

***Wx* gene product in starch granules** (*Cereal Chemistry*). Japanese researchers have shown that the major protein of nonwaxy rice starch granules is the *Wx* gene product with molecular weight (MW) 60,000, which increases in amount with AC of the starch. Using rice starch granules deproteinized by dodecyl benzene sulfate extraction, researchers verified by sodium dodecyl sulfate-polyacrylamide disc gel electrophoresis that the MW 60,000 subunit protein was the major protein of purified starch granules. Its quantity increased with AC but was a broader band in IR8 than in IR5, IR32, IR36, and IR42 starch. No protein band showed in the IR29 waxy starch.

Protein screening of replicated yield trials (*Cereal Chemistry, Plant Breeding, and Statistics*). Monitoring of brown rice protein (BRP) continued in replicated yield trials in DS and WS. BRP correlated negatively with growth duration in both crops. The negative correlation between BRP and rough rice yield was significant only in 1983 WS (Table 2). BRP was higher in WS than in DS, but yields were higher in the DS crop. The variety-candidate lines had BRP of 9.0-11.4% in WS and 8.0-9.4% in DS. The check varieties again showed higher yields but lower BRP for IR42 than for IR36 (Table 2).

Lines with yields similar to IR36 but higher protein in 1984 DS were IR35337-4-3-2-3 with 11.4% BRP and 6.2 t yield/ha and IR34615-75-1-1 with 11.3% BRP and 6.5 t yield/ha. IR26760-27-1 with 13.2% BRP yielded only 5.4 t/ha. Lines that had higher BRP than IR36 in the 1983 WS were IR25861-35-3-3 (12.0% BRP, 3.25 t/ha) and IR18349-22-1-2-1-1 (12.60% BRP, 3.04 t/ha). IR32419-81-2-3-3 (11.3% BRP, 4.01 t/ha) had higher yield than IR36.

Studies in 1983 and 1984 WS on the harvest index of medium- and early-maturing IR varieties showed higher harvest index and nitrogen harvest index for shorter-duration rices. In 1984 WS trial on the partitioning of nutrients during the reproductive stage, IR36 and IR58 had higher indexes than IR42 and H4 (Table 3). Nitrogen (protein) content in panicle and leaf blades was also higher in shorter-duration rices.

Protein screening of 1982 IRTP nursery (*Cereal Chemistry, IRTP, and Statistics*). The season effect on protein content at the relatively fertile IRRI farm has been a constraint in screening for genetic differences in protein content among varieties and lines. IRTP samples allow comparing the effect of

Table 3. Harvest index, nitrogen harvest index, and nitrogen content of plant parts of one traditional and three modern varieties differing in growth duration, IRRI, 1984 WS.

Variety	Growth duration (d)	Harvest index	Nitrogen harvest index	N content in harvest		
				Panicles	Leaf blades	Leaf sheaths + culms
H4	130	0.39 ± 0.07	0.56 ± 0.15	1.18 ± 0.13	1.04 ± 0.37	0.46 ± 0.20
IR42	142	0.43 ± 0.05	0.54 ± 0.08	1.36 ± 0.11	1.23 ± 0.31	0.70 ± 0.14
IR36	113	0.60 ± 0.02	0.70 ± 0.04	1.65 ± 0.23	1.64 ± 0.34	0.85 ± 0.22
IR58	105	0.59 ± 0.07	0.68 ± 0.02	1.57 ± 0.10	1.81 ± 0.16	0.76 ± 0.10

location on BRP of common varieties. Pooled grains of 27 common entries to the 1982 very early, early, and medium maturity International Rice Yield Nursery (IRYN), obtained through IRTP, were screened for BRP and compared for rough rice yield and growth duration (seeding to flowering) at 18 IRYN-VE sites, 12 of IRYN-E, and 19 of IRYN-M, with 7 locations common to all 3 nurseries. BRP was consistently highest at Havana, Cuba, with grain yields higher than those at IRRI (Table 4).

Protein ranking of samples differed with location. The correlation coefficient between duration and BRP was significant in 11 of 17 locations for IRYN-VE, 8 of 12 for IRYN-E, and only 3 of 10 for IRYN-M. Protein content was lowest in Raipur, M.P., India. The ranges in growth duration, BRP, and yield at the various locations were very large. No location could be definitively suitable for screening rices for BRP.

Table 4. Mean and standard deviation of BRP and rough rice yield at three IRYN nurseries sites in 1982. IRRI, 1983-84.

Nursery and property	Mean and standard deviation		
	IRRI	Havana (Cuba)	Raipur (Madhya Pradesh, India)
IRYN-VE			
BRP (%)	9.2 ± 0.7	11.0 ± 0.7	6.7 ± 0.6
Yield (t/ha)	3.7 ± 2.0	4.4 ± 0.9	5.6 ± 1.0
IRYN-E			
BRP (%)	8.6 ± 0.9	11.0 ± 1.0	7.0 ± 0.8
Yield (t/ha)	4.0 ± 1.0	5.4 ± 1.0	2.3 ± 0.5
IRYN-M			
BRP (%)	8.2 ± 0.8	10.0 ± 1.0	6.3 ± 0.5
Yield (t/ha)	4.0 ± 2.0	5.3 ± 0.7	3.2 ± 0.5

Protein distribution as screening technique (*Cereal Chemistry*). Cooperative studies with scientists at the University of Durham (UK) verified that 10% rice bran-polish removal with either an abrasive or a friction mill removed mainly the aleurone layer except in the protruding ridges where a portion of the subaleurone layer was lost. The inner cell wall of the aleurone was generally left in milled rice. Thus, protein loss (18% of BRP) is mainly confined to the aleurone layer, nucellus, seed coat, pericarp, and germ. Stereological morphometry using protein dyes showed similar gradient in protein content decrease from subaleurone layer to starchy endosperm in both average-protein and high-protein IR36 brown rices. In rices with relatively shallow ridges and grooves, BRP content determines milled rice protein content since a constant fraction of BRP is lost on milling.

Samples of IR36 and IR42 brown rice with similar BRP showed slight difference in the protein distribution pattern in their endosperms. The protein gradient was slightly steeper for IR42 than for IR36, although both had similar protein content at 24-μm distance from the aleurone layer.

Flotation method for protein screening (*Cereal Chemistry and Plant Breeding*). Scientists at the University of Nebraska, USA, developed a sucrose-sodium chloride flotation method to screen for high-protein wheat grains in segregating populations. Prolonged soaking magnified the differences in density among grains because of hydration of wheat gluten. A similar flotation method was tested on IR36 and IR42 rough rices differing in BRP (9 and 13% for IR36 and 8 and 12% for IR42). In both varieties, the sodium chloride solution required to sink the lowest-protein sample (sp gr 1.12-1.16) was not dense enough to float the highest-protein sample (4% more BRP). Similarly, sodium chloride needed

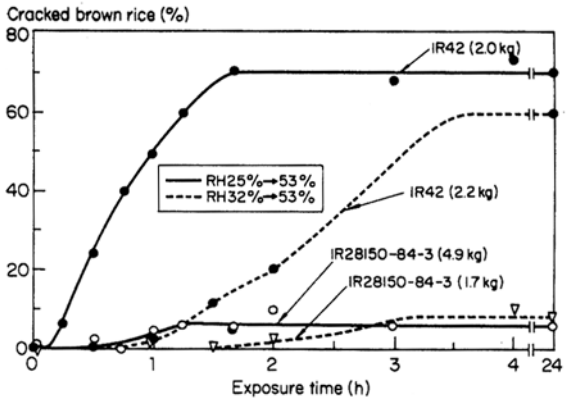
to float the highest-protein rough rice (sp gr 1.20) also floated the lowest-protein sample. Differentiation in rough rice density was somewhat better for IR36 at 0.027 than for IR42 with 0.004.

GRAIN QUALITY AND NUTRITIONAL FACTORS

Cereal Chemistry, Agricultural Economics, and Multiple Cropping Departments

Fissuring resistance of brown rice (*Cereal Chemistry*). A major source of broken grains during milling is cracked or fissured brown rice. Dried grain, including warm freshly-milled rice, may fissure when it **adsorbs** moisture. Lacking equipment to directly measure fissured rough rice, researchers tested fissuring resistance to screen for milling quality of IR brown rices. Of the 1983 WS crop samples, IR42 was more susceptible to fissure than IR36 and many of the lines tested with alkali spreading value 3-5 (Table 5). IR28150-84-3 brown rice best tolerated moisture adsorption stress and had the highest Instron bending hardness value.

The kinetics and equilibrium of cracking were studied using IR42 and IR28150-84-3 brown rice. Under controlled humidity, the rate and extent of fissuring of IR42 and IR28150-84-3 can be differentiated (Fig. 1). Equilibrium values were obtained faster with greater relative humidity gradient (25%→53%) than with lower (32%→53%). High bending hardness value was not required for cracking resistance in IR28150-84-3 brown rice since its other sample had hardness value (1.7 kg) lower than that of IR42 (2.0-2.2 kg).



1. Rate and extent of fissuring in IR42 and IR28150-84-3 brown rice after transfer to a higher relative humidity (RH) representing moisture increase of 0.5 to 0.8%. Instron bending hardness values are in parentheses.

Country samples (*Cereal Chemistry and Agricultural Economics*). Country samples consisted of rough rice of varieties and advanced lines obtained from Argentina, China, and Guyana and of market samples from Indonesia, the Philippines, and Thailand. The 26 samples from Argentina had mainly low AC, low gelatinization temperature (GT), and soft gel consistency. The China japonica and indica samples (3 each) differed widely in starch properties, whereas the 10 Guyana samples were mainly high and intermediate AC and either low or intermediate GT but mainly hard gel consistency. Protein content ranged from 6.4 to 9.4% for the Argentina rices and 7.1-11.7% for Guyana rices. Because of the combination of properties, Chinese indica and japonica rices showed overlapping cooked rice texture and Guyana samples had the hardest cooked rice.

Table 5. Differences in mean hardness and cracking percentage of brown rice of IR varieties and lines during moisture adsorption. IRRI, 1984.

Variety or line name	Starch type		Immature grains[b] (wt %)	Cracked grains (no. %)	Instron hardness (kg)		Cracked grains induced by moisture adsorption[c] (%)
	AC	GT[a]			Bending	Crushing	
IR36	H	I	12	14	2.2	11.4	37 (10.8→11.4)
IR42	H	L	9	33	2.1	9.9	80 (11.0→11.6)
IR28150-84-3	I	I	15	1	4.8	11.6	11 (10.8→11.5)
IR28178-111-1	I	I	20	14	3.3	11.2	43 (11.0→11.5)
IR29692-94-2	I	HI	8	29	2.9		50 (10.7→11.5)
IR29725-3-1	I	HI	4	25	2.6		55 (10.8→11.5)

[a]Gelatinization temperature. [b]Using sodium chloride flotation sp gr 1.09 for IR36 and IR42 rough rice, and sp gr 1.07 for IR28150 and IR28178. [c]Transferred from 40% relative humidity to 70% at 27°C for 45 min. Initial and final moisture contents, wet basis, are in parentheses.

Table 6. Distribution of quality properties of market samples of milled rices. IRRI, 1983-84.

Property	Distribution (% of total)		
	Indonesia	Philippines	Thailand
Low amylose (%)	2	3	25
Intermediate amylose (%)	84	7	36
High amylose (%)	14	90	39
Low GT (%)	49	69	37
Intermediate GT (%)	51	31	63
Soft gel (%)	5	5	42
Medium gel (%)	70	32	39
Hard gel (%)	25	63	19

Market samples from Indonesia, the Philippines, and Thailand were characterized to study consumer demand for rice grain quality in Southeast Asia (Table 6). The predominance of intermediate AC rices in Indonesia reflects the preference for bulu varieties with low GT. In Thailand, the low-amylose rices were mainly Khao Dawk Mali. The high percentage of high amylose rices in the Philippines is due to IR36 and IR42. The predominance of low GT and hard gel rices in the Philippines reflected the popularity of modern varieties possessing both disease and pest resistance. The intermediate and low amylose Philippine samples were Azucena and other upland varieties. The same market samples showed a wide range of milled rice protein content. Mean protein level was lowest for the Philippines (7.01%, range of 5.6-8.3%), intermediate for Thailand (7.46%, range of 6.3-9.1%), and highest for Indonesia (8.23%, range of 6.6-9.9%). Imported milled rice samples in Indonesia also had less protein than local varieties.

Kinetic studies on rice cooking (*Cereal Chemistry*). Japanese and Korean researchers have shown that japonica milled rice (30 min presoaked) has higher activation energy of cooking at 75-100° C (71-79 kJ/mole) than at 100-120° C (36-38 kJ/mole). Since the samples used were all low amylose rices with low GT, a similar study was undertaken on waxy, intermediate amylose, and high amylose indica rices, two with intermediate GT. Samples were cooked in sealed ampoules (after 30 min presoaking in predetermined optimum water level based on AC) at 80, 90, 100, 110, and 120° C. Hardness of three-grain lots of cooked rice was determined with an Instron food tester fitted with a Lucite plunger.

Extrapolated cooking time for minimum hardness (maximum softness) of cooked grain at 100° C was 15-17 min for all except 23 min for IR32. Differences in cooking time were largest at 80° and 90° C, with IR28150-84-3 having the longest period probably because of its larger grain and intermediate GT (Table 7). Reaction rate constants were lower for the two intermediate GT samples IR32 and IR28150-84-3, with longer cooking time only at 80, 90, and 100° C. Estimation of activation energy based on the Arrhenius equation showed the change in slope at 90° C, not at 100° C. The higher GT samples with longer cooking time had higher activation energy at 80-90° C, but differences were less at 100° C and higher. IR42 gave the lowest activation energy at 100° C probably because of its shortest cooking time. The partial loss of grain

Table 7. Cooking properties of four milled rices differing in AC and/or GT. IRRI, 1984.

Property	Variety or line name				Reported values
	IR29	IR28150-84-3	IR32	IR42	
AC (%)	1.7	22.6	27.8	28.3	Low
GT (°C)	66	74	72	62	Low
Water-rice ratio	1.1	1.9	2.1	2.1	1.4
Optimum cooking time (min) at					
80°C	52	134	116	41	37
90°C	24	34	36	19	25-40
100°C	15	16	23	13	15-20
Activation energy (kJ/mol) at					
80- 90°C	85	121	104	82	71-79
90-120°C	51	64	59	31	36-38

integrity was a problem for waxy IR29 and may have overestimated the values obtained.

Rice water for diarrhea treatment (*Cereal Chemistry*). Rice water or *am* was prepared (as in Annual report for 1981) from IR36 milled rice (50 g rice/500 ml water) giving about 4% solids and made up to 0.30% in sodium chloride to attain a sodium level of 50 mM. The rice water was fed at the Manila Central University-F. D. Tanchoco Hospital to treat patients 2 yr or younger suffering from acute gastroenteritis, with or without dehydration. Rice water or boiled water (control) was administered for 24 h at 100-150 ml/kg body wt or per demand as tolerated. Subjects were observed for tolerance (vomiting), frequency of bowel movement, and type of diarrhea. Of the 32 patients studied, 72% or 23 were less than 1 yr old. A higher proportion with noninvasive diarrhea improved significantly on rice water diet as compared to water alone, but not those with invasive diarrhea. Mean improvement time based on cessation of bowel movement was longer for rice water than for the water control. Results elsewhere also show that diarrhea patients better tolerated a starchy staple, such as rice, than glucose-electrolyte solutions because it releases glucose slower.

Because a major portion (45-68%) of the amylose leaches out together with lipids (oil) during cooking (Annual report for 1982), the relative retention of nonstarch (petroleum ether-soluble) and starch (soluble in water-saturated butanol, 92° C) lipids in the residual cooked grains was estimated in IR32, IR42, and IR48. Most starch lipids (1.22% of 1.40% or 87%) were retained in the cooked grain, whereas most of the nonstarch lipids (75% of 0.59%) leached out with the rice water. Since the rice water contains 45-68% of total amylose in these three samples, the amylose-lipid complex composing the starch lipids remained mainly with the insoluble amylose in the cooked rice grain rather than being extracted with the soluble amylose.

Starch properties and insulin response (*Cereal Chemistry*). Ingested starch elicits slower and later plasma glucose and insulin response than simple sugars (glucose) in man. Potato starch showed faster response than cereal starches in studies at the Veterans Administration Medical Center, Palo Alto, Ca, USA. Glucose and insulin responses of normal subjects to rices differing in AC were compared. Although total glucose responses to the first three rices were similar in Test I (Table 8), the 30-min glucose response to Labelle was significantly lower than that to Mochi gome. Difference in insulin response was striking: Labelle had significantly lower response at 0.5 and 1 h treatment than the 2 other rices, but not at 2 and 3 h, and its overall response was also lower (Table 8). In Test II a high AC rice, Newrex, later showed an even lower insulin response than Labelle (Table 8).

Analysis of AC and starch lipid content of nonwaxy milled rices showed that AC may be more important than starch lipids level in affecting rate of digestion of cooked-rice starch as reflected in glucose level in blood plasma and resultant insulin response. Starch lipids complex with amylose and may reduce the rate of starch hydrolysis. Starch lipid levels were similar in Labelle and Newrex, but insulin response was still lower in Newrex. Labelle

Table 8. Effect of starch properties on glucose and insulin responses of human adult subjects to ingested rice. Veterans Administration Medical Center (Palo Alto, Calif.) and IRRI, 1983-84.

Variety name	Plasma response[a]		Subjects (no.)	Milled rice		Starch lipids (% wet basis)
	Glucose (mg/dl)	Insulin (μU/ml)		AC (% dry basis)	GT type	
			Test 1			
Mochi gome	346 a	113 a	33	0	L	0.3
Pecos	355 a	110 a	33	15	L	0.7
Labelle	348 a	95 b	33	24	I	0.9
			Test 2			
Labelle	349 a	86 a	16	24	I	0.9
Newrex	342 a	64 b	16	28	I	1.0

[a] Based on total area of the response curve up to 3 h.

and Newrex had intermediate GT and the two others had low GT.

Extruded rice noodles from dry-milled flour (*Cereal Chemistry*). A locally fabricated single-screw extruder was evaluated at the Institute of Food Science and Technology (IFST), University of the Philippines at Los Baños (UPLB) for combined wet milling, partial gelatinization, and extrusion of IR42 (27.5% AC) milled rice flour into rice noodles. IR42 flour prepared through a pin mill was adjusted to moisture content (MC) of 35, 37.5, and 40% and extruded at 45, 50, and 55° C with cooling of the extruder barrel. Extruded noodles were dipped into boiling water for 15 s before cooling in cold water. Degree of gelatinization ranged from 50 to 82% after extrusion, but was 97-98% after dipping.

Decreasing rice-batter MC and increasing extrusion temperature together softened gel consistency (36-90 mm), decreased gel viscosity (312-663 centipoises [cps]), increased breaking strength of raw noodle (1.7-3.5 kg), decreased solids loss (0.2-1.7%), but increased water absorption ratio (1.8-3.0) during cooking, and increased crushing hardness of cooked noodles (4.6-8.3 kg). All these properties of the noodles were significantly correlated. Gel consistency and viscosity data suggest that the IR42 rice flour (gel consistency 29 mm, viscosity 1925 cps) underwent, not just gelatinization but starch breakdown during extrusion necessary for desirable noodles. Thus, moisture and temperature during processing significantly affected the properties of raw and cooked noodles from IR42 milled rice batter.

Extruded noodles (35% MC at 55° C) from eight varieties and lines differing in starch AC also showed differences in Instron hardness of raw and cooked noodles. IR32 had the softest raw noodle and IR42 the hardest, but IR45 had the hardest cooked noodle. All five noodle samples tested had gel consistency of 100 mm, corresponding to gel viscosity of 107-266 cps as compared to 547-1130 cps for the starting flours with gel consistency of 32-92 mm.

Lysine content of IR43 and IR45 extruded noodles was similar to that of the starting flour.

Extrusion-cooked rice (*Cereal Chemistry*). Rice batters were extrusion-cooked in a German twin-screw extruder at IFST, UPLB. Preliminary studies with IR43 (low AC) and IR45 (high AC) milled-rice batters showed greater expansion and softer extrudate (lowest Instron hardness) at 15% MC than at 20 and 25% MC at 120, 135, and 150° C. Eight additional flours extruded as 15%-moisture batters at 120, 135, and 150° C confirmed the minimum Instron hardness of extrudate at 150° C, but maximum expansion occurred at various temperatures. AC differed little and degree of gelatinization ranged from 88 to 104%. With increase in AC, water absorption index at 50° C tended to increase and expansion ratio and water solubility index at 50° C tended to decrease.

Extrusion cooking drastically reduced rice viscosity in 0.2 N KOH and water. The improved nutrient density made the extrudates attractive for weaning food formulations. Extrudates reconstituted in cold water to give 12% pastes had viscosities of 300-1,860 cps as compared to viscosities of 1,500-5,000 cps of the starting flour cooked at 6% concentration. Waxy rice IR29 had values of 45-55 cps for extrudate and 3,280 cps for raw-flour cooked paste. Commercial samples of precooked and instant rices have viscosities of 275 cps and 235 cps at 12% pastes.

Milled-rice viscosity in water and in 0.2 N KOH declined, probably because of starch degradation. Insoluble white particles isolated in 0.2 N KOH were mainly denatured protein, and not starch. Dispersion of IR32 and IR42 extrudates was more effective in 1.0 N KOH than in 0.2 N KOH, but resulted in slight coloration and lower viscosity. However, it confirmed the much lower viscosity (about 20%) of the extrudate relative to untreated flour.

Extrusion-cooked rice flours showed no drop in lysine content at extrusion temperatures of 120° and 135° C, but some loss at 150° C (Table 9). Rat feeding trials at the National Institute of Animal Science, Copenhagen, Denmark showed lower true digestibility and biological value of proteins in the extrudate than in rice flour, resulting in lower net protein utilization (NPU) in both samples tested. However, energy digestibility decreased less than did protein quality. Transmission electron micrographs showed intact spherical protein bodies in protein masses dispersed in gelatinized starch matrix. The intact protein bodies plus the low content of reducing sugars probably helped maintain the nutritional value of rice extrudates. A sample of rice-mungbean weaning food formula-

Table 9. Effect of extrusion cooking of IR43 and IR45 rice batters on lysine content and protein and energy utilization in growing rats. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1984.

Property	IR43		IR45	
	Raw	Extrudate	Raw	Extrudate
Protein (% wet basis)	7.50	7.69	8.62	8.81
Lysine (g/16 g N)	3.52	3.06	3.66	3.26
Cystine + methionine (g/16 g N)	5.88	5.81	4.82	4.56
Balance in growing rats[b]				
Energy digestibility (%)	97.9 ± 0.1	97.0 ± 0.1	97.1 ± 0.2	96.4 ± 0.4
True digestibility (%)	99.9 ± 0.1	96.9 ± 0.2	99.5 ± 0.2	96.2 ± 0.3
Biological value (% of absorbed N)	69.5 ± 0.3	65.9 ± 0.4	68.2 ± 0.3	65.6 ± 0.2
NPU (% of intake)	69.4 ± 0.2	63.8 ± 0.4	67.9 ± 0.3	63.1 ± 0.3

[a] At 15% moisture, 150°C, and 50 bars pressure. [b] Mean of five rats ± s.d.

tion extrusion-cooked in the same German twin-screw extruder at 150° C showed lysine content of 3.3% in protein as compared to 6.4% for the starting batter.

These studies on rice noodles and extrusion-cooked expanded rice flours suggest that gel consistency and viscosity may index starch degradation during processing. Even noodles prepared from wet-milled Thai rice flour extruded at 75-80° C had softer gel consistency than the starting flour. Commercial samples of rice noodles similarly had soft gel consistency although the starting milled rice had hard gel consistency (about 35 mm). Because viscosity of the rice gel decreases, either a high gel concentration may be used in the gel consistency test or actual viscosity rechecked with a Wells-Brookfield cone-plate microviscometer.

Energy and amino acid contents of nonrice crops (*Cereal Chemistry and Multiple Cropping*). The nutrient content of two cereals and five legumes obtained from an IRRI farming systems crop was determined for complementarity with rice in a rice-based diet. Crude fat was highest in peanuts, then in soybean, and low in three other legumes (Table 10). Protein content was highest in soybean, then in other legumes, and lowest in cereals. Energy values were highest for peanut and then soybean. Amino acid analysis showed maize and sorghum deficient in lysine and legumes low in sulfur-containing amino acids, cystine plus methionine. Maize and sorghum proteins are more deficient in lysine than is rice protein (3.5-4.0 g lysine/16 g N) and would also benefit from mixing with legumes.

BY-PRODUCTS AND RESIDUES

Cereal Chemistry Department

Oil content of brown rice and bran. Japanese researchers reported that oil (fat or lipid) content of

Table 10. Energy, fat, protein content, and levels of cystine + methionine, lysine, and tryptophan in protein of various crops in the rice farming systems. IRRI, 1984.

Crop	MC (%)	Crude fat[a] (%)	Crude protein[a] (%)	Energy value[b] (kJ/g)	Amino acid content[c] (g/16 g N)		
					Cystine + methionine	Lysine	Tryptophan
Maize	9.1-10.3	2.4- 4.6	9.6-11.4	16.1-16.3	4.0-4.4	2.4-2.5	0.6
Sorghum	10.8-11.5	2.3- 3.6	6.9- 9.1	16.3-16.4	3.2-4.2	2.4-3.2	1.1-1.3
Cowpea	10.7-11.1	0.4- 1.7	21.5-23.1	16.3-16.7	2.4-2.5	5.6-6.9	1.0-1.2
Mungbean	10.2-10.9	0.7- 1.4	22.4-26.0	16.4-16.7	2.1-2.3	7.0-7.4	1.0-1.1
Peanut	6.0- 6.6	44.5-49.9	23.0-31.7	27.2-27.7	2.5-2.7	3.1-3.3	0.7
Pigeonpea	8.9- 9.9	0.4- 1.7	21.6-23.4	16.4-16.6	2.1-2.2	4.4-4.8	0.7-0.8
Soybean	5.4- 6.9	17.0-19.6	36.5-41.8	20.8-21.4	3.1-3.6	5.1-6.1	1.3-1.7

[a] Five samples per crop. [b] Based on samples with extremes in crude fat content. [c] Based on samples with extremes in crude protein content. Corresponding levels in the FAO/WHO reference amino acid pattern are 3.5 g cystine + methionine, 5.5 g lysine and 1.0 g tryptophan/16 g N.

Table 11. Oil content of brown rice and bran-polish of IR varieties and their correlation in the replicated yield trials. IRRI, 1983 WS and 1984 DS.

Property	1983 WS		1984 DS	
	Brown rice	Bran-polish	Brown rice	Bran-polish
Degree of milling (%)	9.8-11.7 (10.6)		9.8-11.3 (10.3)	
Oil content, range (%)	1.0- 4.4	18.0-24.8	1.8 - 3.0	19.2-25.4
Oil content, mean (%)	2.1	21.6	2.1	22.0
Oil content CV (%)	16.5	2.6	6.1	4.4
Oil content LSD (5%)	0.75	1.19	0.26	1.98

Table 12. Comparative properties of IR36 and IR42 straw from 1982 WS and 1983 DS crops. Institute of Animal Science, UPLB, and IRRI, 1984.

Property[a] (% dry basis)	1982 WS		1983 DS	
	IR36	IR42	IR36	IR42
Organic matter	80.2 a	79.7 a	81.3 b	82.4 a
Crude protein	7.2 a	5.6 b	6.0 a	6.1 a
Neutral detergent fiber	63.1 a	67.5 b	67.1 a	67.9 a
Cellulose	27.5 a	30.5 b	31.6 a	31.5 a
Lignin	6.4 a	5.3 a	4.9 a	5.7 a
Silica	16.1 a	16.5 a	14.3 a	15.2 a
In vitro digestibility				
Dry matter	43.9 a	39.2 b	42.7 a	36.2 b
Organic matter	52.9 a	46.8 b	50.9 a	41.8 b

[a]About 40-60 cm long from tip of panicle. Mean of 4 N fertilizer levels (0, 30, 60, and 120 kg N/ha).

brown rice correlated significantly with bran-polish oil content of six Japanese rice varieties. To determine whether brown rice oil content can index bran oil content, 20 IR varieties from the 1983 WS replicated yield trial and 24 from the 1984 DS trial were analyzed for oil content of brown rice and of the resulting bran-polish after 10% by weight milling. Oil values were comparable for the two crops but varied more in 1983 WS (Table 11).

Brown rice oil content correlated with bran-polish oil content in the 1984 DS ($r = 0.77$**) but not in the 1983 WS crop ($r = -0.22$). The variable oil content in the 1983 WS crop may be due to extensive lodging and 20-35% immature grains. For example, field replications of IR38 had oil content of 4.1 and 2.3%. Varieties varied significantly in oil content of both brown rice and bran-polish, but varieties performed inconsistently in both seasons. IR29 (waxy) bran had the highest oil content in both crops; however, its brown rice had highest oil content only in 1984 DS.

Both wet-heat treatment (steaming 45 min at 120° C) and dry-heat treatment (5 h at 94-96° C under partial vacuum) kept the free fatty acid level of IR45 bran below 6% of the oil for 8 wk after exposure to 60-75% RH and 27-30° C. Free fatty acid level increased rapidly after 8 wk storage, although lipase activity remained lowest in wet-heat treated bran. Bacterial count in the control bran increased 700-fold during the first 3 wk of storage, but decreased by 16 wk. In contrast, mold count increased 100- to 300-fold in all 3 samples between 3 and 16 wk storage.

Varietal differences in straw feed value. Rice straw is the major ruminant feed in tropical Asia. Varietal difference in in vitro digestibility (using rumen fluid) of harvest rice straw (40-60 cm long) was observed in the 1982 WS and 1983 DS crops by animal nutritionists at the Institute of Animal Science, UPLB. IR36 had higher digestibility than IR42, a sister line similar in values to IR8 and H4 (Table 12). IR42 had higher neutral detergent fiber and cellulose content in the first crop, but not in the second.

Genetic evaluation and utilization (GEU) program

Disease resistance

Plant Pathology and Plant Breeding Departments, International Rice Germplasm Center, Entomology Department, IRRI-Japan Ministry of Agriculture, Forestry and Fisheries Collaboration, and IRRI-RUG, Belgium, Collaboration

BACTERIAL BLIGHT **46**
- Development of near-isogenic lines **46**
- Inheritance of resistance **46**
- Varietal resistance to races **47**
- Virulence of pathogen **47**
- Evaluation of lines for resistance **48**
- Field assessment of resistance **49**
- Measuring varietal resistance **49**
- Adult plant resistance **51**
  - Influence of temperature **51**
  - Lesion development and bacterial multiplication **51**

BACTERIAL LEAF STREAK **53**
- Varietal resistance **53**

BLAST **53**
- Numerical analysis of blast resistance **53**
- Virulence of pathogen **53**
- Variation among single spore isolates **54**
- Partial resistance **54**
  - Lowland varieties **54**
  - Effects of plant age **55**

BROWN SPOT **56**
- Varietal resistance **56**

SHEATH BLIGHT **56**
- Measuring resistance **56**
  - Upland nursery **56**
  - New evaluation scale **57**
  - Varietal reactions at seedling stage **57**
- Varietal resistance **57**

TUNGRO **58**
- IR variety reaction under varying disease pressure **58**
- IR variety reaction in test tube inoculation and in nursery **58**
- Reaction of tungro-resistant parents to tungro-associated viruses **59**
- Resistance to tungro and green leafhopper **59**
- Transmission by green leafhopper reared on TN1 and Pankhari 203 **60**
- Sequential transmission on tungro- and green leafhopper-resistant and susceptible varieties **60**

VARIETAL RESISTANCE TO VIRAL DISEASES **62**

PATHOTOXIN AND TISSUE CULTURE **63**

BACTERIAL BLIGHT

Plant Pathology and Plant Breeding Departments, and IRRI-Japan Ministry of Agriculture, Forestry and Fisheries Collaboration

Development of near-isogenic lines (*Plant Pathology, Plant Breeding, and IRRI-Japan Ministry of Agriculture, Forestry and Fisheries Collaboration*). IR24 and Milyang 23, improved *indica* rices susceptible to all known races of bacterial blight (BB), and Toyonishiki, an improved *japonica* rice moderately susceptible to known races, were selected as recurrent parents in a backcrossing program. Using Philippine (at IRRI) and Japanese (at Tropical Agriculture Research Center, Japan) races, $B4F_1$ progenies were developed having either of the *Xa-3*, *Xa-4*, *xa-5*, *Xa-6*, *xa-9*, and *Xa-10* genes for resistance and $B3F_1$ progenies having *Xa-1*, *Xa-2*, *Xa-kg* or *Xa-7* genes. Tests showed that at 18 d after inoculation, lesion lengths of $B4F_1$ progenies having the same gene, especially *Xa-3*, are affected by each recurrent parent (Table 1).

Inheritance of resistance (*Plant Pathology, Plant Breeding, and IRRI-Japan Ministry of Agriculture,*

Table 1. Lesion length at 18 d after inoculation in $B4F_1$ plants with one gene for resistance to BB. IRRI, 1984.

Resistant parent	Recurrent parent	Genotype[a]	Lesion length (cm)			
			Race 1	Race 2	Race 3	Race 3
Chugoku 45 (*Xa-3*)	Toyonishiki	R +	1.7	0.5	0.4	0.4
		+ +	10.7	7.8	11.3	8.2
	Milyang 23	R +	9.0	9.4	9.6	7.7
		+ +	28.1	22.9	24.3	20.6
	IR24	R +	10.8	11.2	10.2	5.3
		+ +	30.0	28.2	27.2	24.6
Java 14 (*Xa-3*)	Toyonishiki	R +	2.6	0.8	0.7	0.8
		+ +	12.4	8.6	10.4	10.2
	Milyang 23	R +	16.2	13.2	14.0	13.1
		+ +	29.0	25.3	27.2	26.1
	IR24	R +	12.3	10.2	11.9	7.9
		+ +	31.8	27.0	28.7	27.6
Zenith (*Xa-6*)	Toyonishiki	R +	3.4	1.1	0.9	1.7
		+ +	15.5	7.7	–	–
	Milyang 23	R +	16.1	14.9	15.4	10.4
		+ +	28.1	24.7	25.0	24.8
	IR24	R +	7.6	4.7	8.4	5.3
		+ +	27.5	27.9	25.9	27.6
Sateng (*xa-9*)	Toyonishiki	R +	2.3	1.1	0.6	1.7
		+ +	15.0	9.9	11.2	8.9
	Milyang 23	R +	16.7	15.1	15.2	11.6
		+ +	27.5	24.3	25.8	25.1
	IR24	R +	16.4	10.7	10.6	9.4
		+ +	29.5	26.9	26.3	30.8
IR20 (*Xa-4*)	Toyonishiki	R +	2.3	6.5	9.6	3.8
		+ +	18.0	12.3	12.6	21.9
	Milyang 23	R +	4.0	24.2	24.8	12.9
		+ +	31.3	23.4	25.7	26.4
	IR24	R +	4.2	26.6	25.5	15.0
		+ +	30.0	30.0	28.7	26.8
Cas 209 (*Xa-10*)	Toyonishiki	R +	19.3	0.8	14.8	9.3
		+ +	25.8	15.8	13.7	7.7
	Milyang 23	R +	28.9	0.2	26.9	26.5
		+ +	28.7	26.0	29.0	25.0
	IR24	R +	33.2	1.5	31.4	25.9
		+ +	32.1	28.9	29.9	22.3

[a] R + = resistant plants (heterozygous genotype), ++ = susceptible plants (homozygous genotype).

Forestry and Fisheries Collaboration). Genes identified at IRRI and in Japan were analyzed to identify similarities. *Xa-1*, *Xa-2*, and *Xa-kg* were susceptible to all Philippine races. In addition, the same genes and *Xa-10* were susceptible to all Japanese races. Thus, Kogyoku, Te-tep (Japanese differential) having *Xa-1*, *Xa-kg*, and/or *Xa-2* appear to have no additional genes for resistance to Philippine races. Cas 209 (IRRI differential) having *Xa-10* appears to have no additional genes for resistance to Japanese races. The genetic analysis of Chugoku 45 (*Xa-3*), Java 14 (*Xa-3*), Zenith (*Xa-6*), and Cempo Selak indicated these resistant varieties have one dominant gene with resistance at booting to flowering stages to four Philippine races (1-4). Sateng (*xa-9*) showed a dominant gene for resistance at adult growth stage (Table 2). In an earlier study, inoculation and scoring were at maximum tillering, when heterozygous plants might show susceptible reaction. A segregation of 1 resistant:3 susceptible was observed and the resistance gene was considered recessive. However, inoculation and scoring at booting to flowering stages showed the resistance gene of Sateng is dominant. This dominant gene is allelic to *Xa-3*. Thus, resistance genes of Chugoku 45, Java 14, Zenith, Sateng, and Cempo Selak appear identical (Table 3). This gene shows close linkage with *Xa-4*.

Varietal resistance to races (*Plant Pathology and IRRI-Japan Ministry of Agriculture, Forestry and Fisheries Collaboration*). A total of 820 resistant varieties were inoculated with 4 Philippine BB races and grouped, by reaction, into 4 categories. Group I varieties resist all four races; however, resistance is clearer at booting than at seedling stage. *Xa-3* varieties discussed earlier fall in that category. Group II varieties resist race 1 and moderately resist race 4 at seedling and later stages, but are susceptible to races 2 and 3. IR20, TKM6, and IR22 with *Xa-4* fall in this group. Group III varieties resist races 1, 2, and 3 at seedling and later stages, but react variably (MS to MR) to race 4. Varieties with *xa-5* such as IR1545-339 fall in this group. Group IV includes varieties such as DV85, which shows resistance to four races but slightly lower resistance to race 4 at seedling and later stages. Resistance to race 4 of Groups III and IV is continuous.

Virulence of pathogen (*Plant Pathology and IRRI-RUG, Belgium, Collaboration*). Virulence of the BB population shifted between 1972 and 1984 (Fig. 1). Isolates virulent to *Xa-10* gene for resistance and popular native varieties declined after the mid-70s. Conversely, isolates virulent to the *Xa-4* in varieties such as IR36 gradually increased, dominating the pathogen population since the mid-70s.

To correlate virulence with morphological, physiological, and biochemical features, 52 bacterial strains having different virulence characteristics were studied. Cluster analysis of 103 tests of 52 strains shows homogeneity of bacterial pathogens. Despite no clear-cut grouping among strains, a few phenotypic features partially differentiated them (Table 4).

SDS gel electrophoretic technique was applied to study the protein patterns of 43 *X. campestris* pv. *oryzae* strains of different races, isolated from different geographic origins. Differences in protein

Table 2. Reaction[a] to BB at booting to flowering stages of F_1 and F_2 progenies from the crosses of susceptible varieties with resistant varieties. IRRI, 1983-84.

Cross	F_1 reaction	F_2 plants (no.) with given reaction				χ^2 3:1 or 1:3	P
		RRRR	RSSMR	RRRMS	SSSS		
Toyonishiki/Chugoku 45 (*Xa-3*)	RRRR	193			65	0.005	0.99 < P
Toyonishiki/Java 14 (*Xa-1, Xa-3, Xa-kg*)	RRRR	187			78	0.378	0.5 < P < 0.7
IR24/IR20 (*Xa-4*)	RSSMR		242		75	0.304	0.5 < P < 0.7
/IR1545-339 (*xa-5*)	SSSS			54	227	4.922	0.02 < P < 0.05
/Zenith (*Xa-6*)	RRRR	165			47	0.909	0.3 < P < 0.5
/Sateng (*xa-9*)	RRRR	139			58	6.804	0.01 < P < 0.1
Toyonishiki/Sateng (*xa-9*)	RRRR	172			51	0.539	0.3 < P < 0.5
IR24/Cempo Selak (unknown)	RRRR	209			60	1.137	0.2 < P < 0.3

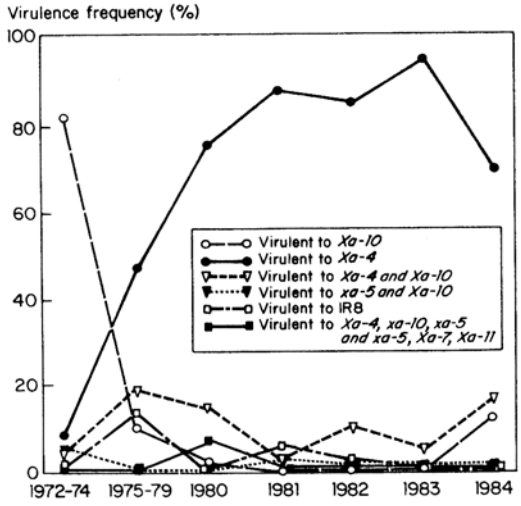
[a] R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible. In combined capital letters, the first stands for PXO 61; the second, PXO 86; the third, PXO 79; and the fourth, PXO 71.

Table 3. Reaction[a] to bacterial blight at booting to flowering stages of F_1 and F_2 progenies from crosses among resistant varieties. IRRI, 1983-84.

Cross	F_1 reaction	F_2 plants (no.) with given reaction			X^2 3:1	*P*
		RRRR	RSSMR	SSSS		
Chugoku 45 (*Xa-3*)/Java 14 (*Xa-1, Xa-3, Xa-kg*)	RRRR	547		0		
Chugoku 45 (*Xa-3*)/Zenith (*Xa-6*)	RRRR	230 (RR—)		0 (SS—)		
Chugoku 45 (*Xa-3*)/ Sateng (*xa-9*)	RRRR	253		0		
Chugoku 45 (*Xa-3*)/ Cempo Selak (unknown)	RRRR	119 (RR—)		0 (SS—)		
Java 14 (*Xa-1, Xa-3, Xa-kg*)/ Zenith (*Xa-6*)	RRRR	277		0		
Java 14 (*Xa-1, Xa-3, Xa-kg*)/ Sateng (*xa-9*)	RRRR	339		0		
Java 14 (*Xa-1, Xa-3, Xa-kg*)/ Cempo Selak (unknown)	RRRR	287		0		
Sateng (*xa-9*)/Zenith (*Xa-6*)	RRRR	355 (RR—)		0 (SS—)		
Cempo Selak (unknown)/ Sateng (*xa-9*)	RRRR	139		0		
Java 14 (*Xa-1, Xa-3, Xa-kg*)/ IR20 (*Xa-4*)	RRRR	254	90	0	0.248	$0.5 < P < 0.7$

[a] R = resistant, MR = moderately resistant, S = susceptible. In combined capital letters, the first stands for PXO 61; the second, PXO 86; the third, PXO 79; and the fourth, PXO 71.

patterns within *X. campestris* pv. *oryzae* strains were observed in zones A, B, and C. Zone B distinctly shows an additional band with strains IRN 518, IRN 452, IRN 661, IRN 629, and IRN 670. Zone C band is present in all strains but is heavy on PXO 128. Zone A lacks protein band for strains H75304, PXO 56, and IRN 629.



1. Shift in virulence of the BB pathogen from 1972 to 1984 in the Philippines, IRRI.

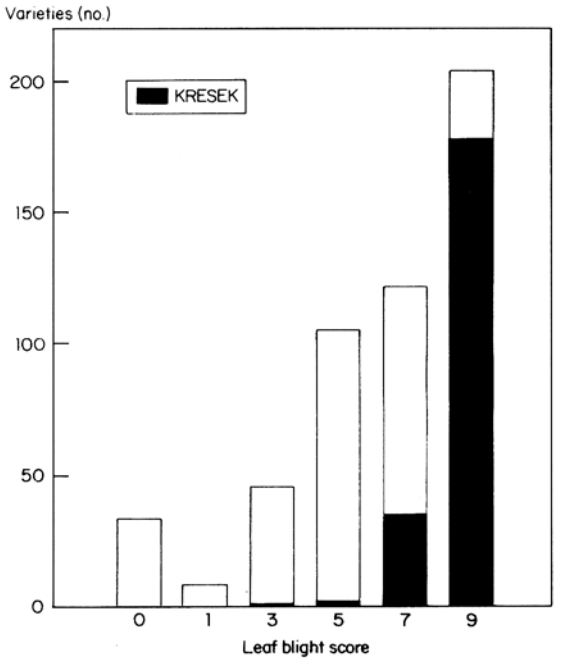
Evaluation of lines for resistance (*Plant Pathology, Plant Breeding, and International Rice Germplasm Center*). A total of 86,911 entries were evaluated for resistance to race 1 of *X.c.* pv. *oryzae* and 8,549 to race 2. Materials in the hybridization block (HB), and replicated yield trial (RYT) and some breeding materials were screened for both races. Those in the germplasm bank world collections, monthly pedigree nurseries, and observational yield trial (OYT) were screened for race 1 only. The percentage of lines resistant to the common strain (race 1) has progressively increased through continuous screening. Of the 55,571 entries showing resistance, 95% come from pedigree nurseries.

To further evaluate resistance of 522 entries from the germplasm bank world collection of our BB Screening Nursery, PXO 61 (about 10^7 cells/ml) was sprayed 3 d before transplanting (DBT). The entries were scored at 21 and 28 d after inoculation (DAI) based on percentage of leaf area infected. At 28 DAI, 72% of the entries were susceptible to race 1 (PXO 61), indicated by leaf blight and kresek infection (Fig. 2).

In the greenhouse, germplasm bank materials had been previously screened at maximum tillering and booting stages. For more efficient evaluation of

Table 4. Frequency of strains within *X. c.* pv. *oryzae* races that gave positive reaction on selected phenotypic features. IRRI, 1984.

Feature	Frequency (%)						
	Race 0	Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
Acid from							
Trehalose	100	16.6	92.3	62.5	100	85.7	100
Growth on							
Trehalose	100	16.6	100	62.5	100	100	100
Na-aconitate	25	0	84.6	25	0	100	0
Growth in the presence and reduction of 0.05% TTC	0	16.6	0	25	100	0	100



2. Susceptibility of 522 varieties to race 1 (PXO 61) of *X. c.* pv. *oryzae* 28 DAI as indicated by leaf blight and kresek. IRRI, 1984.

resistance against several races simultaneously, seedlings were screened. This allowed selection of materials with major genic or overall resistance. Ten to fifteen seedlings of each entry for each race were sown in trays, clip-inoculated 2 wk after sowing, and scored based on percentage of leaf area infection. About 1,400 entries were screened against 6 BB races in the Philippines. Varieties showing resistance or differential reactions to races were selected (Table 5). Reactions will be confirmed at maximum tillering and booting stages.

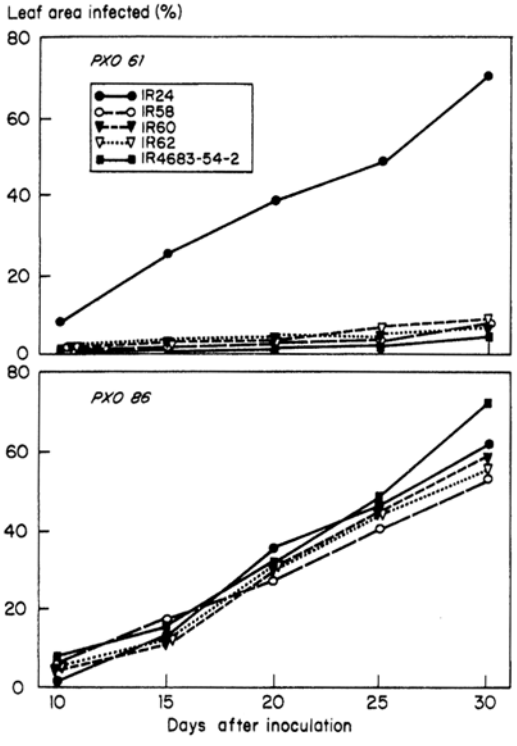
Field assessment of resistance (*Plant Pathology*). Three IRRI varieties carrying *Xa-4* gene and a line carrying *xa-5* gene for BB resistance were evaluated for stability of resistance to races 1 and 2. Except for IR24 as the susceptible check, IR58, IR60, IR62, and IR4683-54-2 resisted race 1, indicating the presence of R-gene to BB (Fig. 3). All were susceptible to race 2, indicating compatibility of *Xa-4* gene in the IRRI varieties. Therefore the *xa-5* may not have been incorporated in breeding line IR4683-54-2.

Measuring varietal resistance (*Plant Pathology*). To assess varietal resistance to BB, some scales use

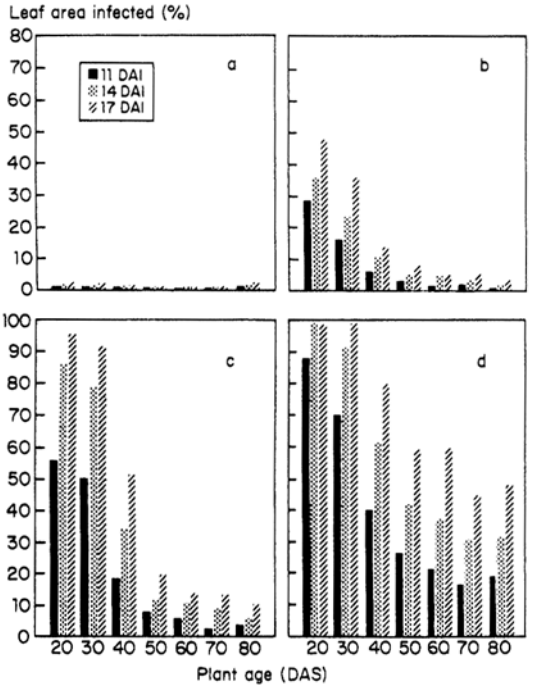
Table 5. Reactions to *X. c.* pv. *oryzae* races of selected germplasm bank materials at seedling stage. IRRI greenhouse, 1984.

Variety	Acc. no.	Visual score[a] (0-9)						
		Race 1	Race 2	Race 3	Race 4	Race 5	Race 6a	Race 6b
Kalimekri 77-5	6613	1	1	1	1	1	1	1
Aus 176	29008	1	1	1	3	1	3	7
Chota Kati	32438	1	3	3	7	1	3	3
Tower (A-4-2)	31211	3	5	5	5	5	5	9
Bali Ray	26547	5	1	5	5	1	5	7

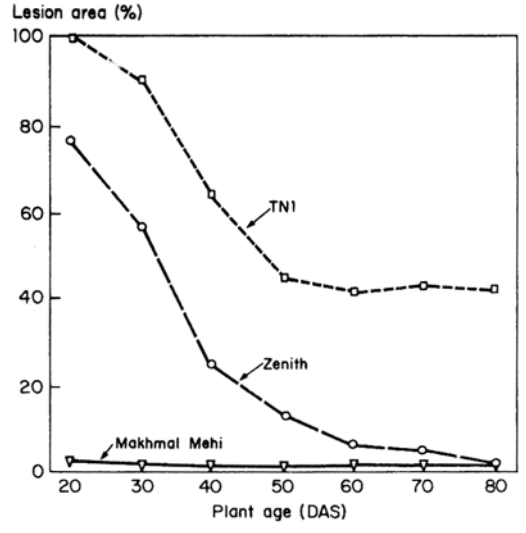
[a] 0 = no infection noted; 9 = 51% to 100% leaf area infected.



3. Lesion progression in 4 IRRI varieties and 1 line reacting to races 1 (PXO 61) and 2 (PXO 86) of the BB pathogen. IRRI, 1984.



4. Variety grouping based on BB lesion progression measured against PXO 61 of race 1. IRRI, 1984.



5. Relation between plant age and BB lesion progression in response to PXO 61 of race 1 measured at 14 DAI. IRRI, 1984.

10 divisions (0 to 9) and others use 8 (0 to 7) or 5 (1 to 5). However, these scales, including the Standard Evaluation System for Rice (SES) scoring used at IRRI, have not been tested for reliability and validity.

Therefore, we evaluated the accuracy and efficiency of the SES scoring system. Twelve scorers, varied in experience, scored four BB-infected varieties. The scorers estimated the percentage of infected leaf area of IR1545, AUS40, Yolle, and IR24. Although scorers differed, the average of their estimation was close to actual percentage of infection. Most scorers slightly underestimated the leaf area of resistant varieties.

Of 285 varieties tested, 40 were further studied as to lesion development at different plant ages. Lesion areas in response to PXO 61 of race 1 ranged from 1% to 60% measured at 11, 14, and 17 DAI; 4 distinct groups were categorized with 10% intervals among the varieties (Fig. 4). On some varieties, lesions progressed further at young plant age, but as plants grew older, lesion development on all varieties was arrested. This confirms adult plant resistance.

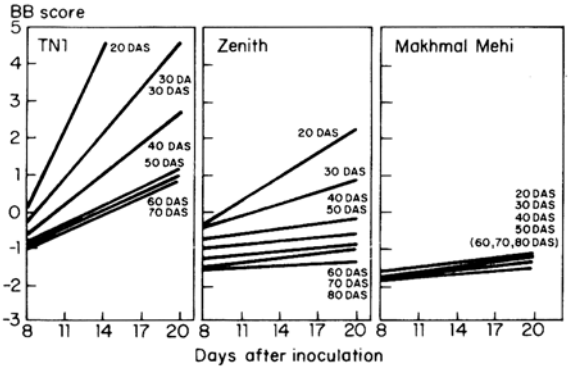
The lesions developed at 14 DAI on 3 varieties at different growth stages are shown in Figure 5.

Although it is susceptible, TN1 developed shorter lesions as it aged; however, the lesions progressed with time (Fig. 6). On Makhmal Mehi, an overall resistant rice, lesions did not progress. On Zenith, with adult plant resistance, lesions developed as on a susceptible variety at early age, but at older plant stage, lesion progression was negligible.

Varietal resistance, plant age, time of scoring after inoculation, and scoring system were tested further.

Resistance was categorized for plants of 40 varieties at 20 and 50 DAS. The disease was measured at 11 and 14 DAI. The response to PXO 61 of race 1 ranged from 0.5 to 94% lesion area infection at 11 DAI and 1.2 to 100% at 14 DAI, by an automatic leaf area meter. The infection rate and the relative area under disease progression curve (ADPC) were compared with the actual values of lesion areas and the SES scoring system. Results indicated that the relative ADPCs progressed similarly as the actual values, while infection rates did not. The actual values were further categorized by Horsfall-Barratt (H-B) scales. Most scoring systems for BB do not consider that the human eye assesses disease area logarithmically. Below 50% coverage, the eye judges the area diseased; above 50%, it judges the healthy tissue. To overcome this, H-B's scale is logarithmic, balanced around the 50% point. Therefore we modified the H-B scale (Table 6).

The modified H-B scale appears more suitable than the SES scale (Table 7). The relative ADPC values appear to fit the modified H-B scale well. Final disease rating at 50 DAS and the relative



6. BB lesion progression in susceptible TN1 and in varieties with adult-plant resistance (Zenith) and overall resistance (Makhmal Mehi) to PXO 61 of race 1. IRRI, 1984.

Table 6. Adapted Horsfall-Barratt scales for evaluation of varietal resistance to BB.[a] IRRI, 1984.

Horsfall-Barratt scale		Adapted scales	
1	0	0	0
2	0-3%	0-3%	1
3	3-6%	4-6%	2
4	6-12%	7-12%	3
5	12-25%	13-25%	4
6	25-50%	26-50%	5
7	50-75%	51-75%	6
8	75-87%	76-87%	7
9	87-94%	88-94%	8
10	94-97%	95-100%	9
11	97-100%		
12	100%		

[a] Disease is measured at 11 DAI at seedling stage, and at 21 DAI at maximum tillering.

ADPCs agreed, but the apparent infection rate of lesion development did not follow the sequence of variety ranking according to actual lesion area infection (Table 7). The modified H-B scale applied well when disease was measured at 26 DAI, but not at 14 DAI when no variety tested had more than 50% lesions. In evaluating varietal resistance to BB, it is logical to consider plant age and time of scoring after inoculation. In this regard, the modified H-B scale seems to measure resistance more adequately.

Adult plant resistance (*Plant Pathology*). *Influence of temperature*. The resistance of adult plants of Malagkit Sungsong, Zenith, IR944, and IR1695 was evaluated at 3 day/night temperature ranges (33° / 25°, 29° / 21°, and 25° / 20° C) in growth chambers. BB disease scores of M. Sungsong and Zenith were not affected by temperature change. Adult plant resistance at various leaf positions, however, was not as consistent as in the greenhouse. M. Sungsong and Zenith best expressed resistance at booting stage. They showed resistance at 25° / 20° C earlier than they did at 29° / 21° C.

Adult plant resistance of IR944 and IR1695 was only slightly affected by temperature. The lesions appeared longer than those of their parents at 33° / 25° C; however, the difference was not obvious at booting stage. Under the different temperatures, TN1 lesions developed faster at 33° / 25° C than at 25° / 20° C. Temperature did not alter scores in IR1545-339.

Lesion development and bacterial multiplication. Lesion development and bacterial multiplication in Zenith were studied to determine effect of leaf

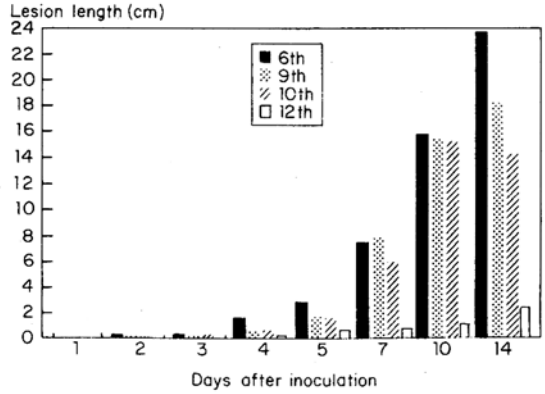
Table 7. Disease scores of varieties at 50 DAS and 14, 26, and 29 DAI, using 2 scales. IRRI, 1984.

Variety	Lesion area (%)			SES			Modified Horsfall-Barratt scale		
	14	26	29	14	26	29	14	26	29
IR9101-43-6-1	45.5	94.7	99.0	7	9	9	5	9	9
TN1	44.4	94.4	98.4	7	9	9	5	8	9
IR24	42.3	93.6	98.1	7	9	9	5	8	9
MTU 18	41.9	89.7	96.5	7	9	9	5	8	9
Khao Khao Nhay	36.5	79.9	89.6	7	9	9	5	7	8
Milyang 23	33.4	96.8	97.1	7	9	9	5	9	9
RP4-2	84.9	88.1	97.8	7	9	9	7	8	9
IR8	30.4	88.8	91.6	7	9	9	5	8	8
Binimal	30.4	89.7	96.3	7	9	9	5	8	9
CAS209	27.3	88.8	96.5	7	9	9	5	8	9
Aneira	27.1	77.6	86.7	7	9	9	5	7	7
59-439 (B11/MAS)	26.8	88.1	93.8	7	9	9	5	8	8
BG94-1	24.9	87.7	93.7	5	9	9	4	8	8
Yakai	24.7	66.2	70.8	5	9	9	4	6	6
Yolle	21.8	73.4	87.7	5	9	9	4	6	8
Kyeearni	20.8	51.0	56.2	5	9	9	4	6	6
Pyi Daw Aye	18.5	56.7	67.2	5	9	9	4	6	6
Zenith	12.7	18.9	20.0	5	5	5	4	4	4
Ase Pute Rono	14.4	28.1	29.7	5	7	7	4	5	5
Pale Angga	15.2	40.3	40.0	5	7	7	4	5	5
Banda Merah	14.2	34.3	40.4	5	7	7	4	5	5
Kauk Hnyin	14.8	53.7	63.8	5	9	9	4	6	6
Ketan Gimbruk	9.2	18.9	22.0	5	5	5	3	4	4
Gaukkyi	11.4	42.8	47.7	5	7	7	3	5	5
Pae Moku	9.1	30.1	33.0	5	7	7	3	5	5
Akundi	5.5	21.3	22.0	5	5	5	2	4	4
Tahun Gembrong	4.2	6.6	7.4	5	5	5	2	3	3
Warangal Culture 1263	4.0	12.3	14.1	3	5	5	2	3	4
Meegauk	4.0	15.9	17.8	3	5	5	2	4	4
IR20	2.6	10.0	13.8	3	5	5	1	3	4
Aus 40	2.2	7.4	9.2	3	5	5	1	3	3
Sankurcha	1.8	9.8	11.5	3	5	5	1	3	3
IR22	1.3	5.8	7.2	3	5	5	1	2	3
Aus 338	1.2	3.3	3.7	3	3	3	1	2	2
DZ78	1.0	3.2	3.6	3	3	3	1	2	2
IR1545	1.0	3.2	3.6	3	3	3	1	2	2
Makhmal Mehi	1.0	2.9	3.5	3	3	3	1	1	2
Aus 463	0.9	4.4	4.9	1	3	3	1	2	2
DV85	0.6	2.1	2.5	1	3	3	1	1	1

position on expression of adult plant resistance. Leaves were marked in ascending order from the second to flag leaf and inoculated with PXO 61.

Lesions on the 6th, 9th, and 10th leaves began to develop 48 h after inoculation and progressed very fast. On the 12th leaf, lesions showed 96 h after inoculation and developed slowly. Lesion length on those leaf positions at 14 DAI is shown in Figure 7.

Bacterial multiplication was estimated by bacteriophage method. When phage was added to maceration of 6th, 9th, and 10th leaves, the plaque count from the leaves sampled 24 h after inoculation (HAI) increased, indicating rapid bacterial multiplication. The plaque count increased



7. BB lesion development in 4 leaf positions of Zenith in the greenhouse. IRRI, 1984.

markedly 48 HAI, reached peak population at 72 h, then slightly declined. From 12th leaf tissue, plaque increased at 48 HAI, but were fewer and declined faster than those in the other leaf positions. Therefore, bacteria multiplied differently in the leaf positions of Zenith, expressing susceptibility and resistance to BB.

BACTERIAL LEAF STREAK

Plant Pathology Department

Varietal resistance. Resistant IR58 and susceptible IR14573 were chosen to study bacterial leaf streak.

Three parameters were measured: incubation period, time interval between inoculation and infection; latent period, from inoculation to first ooze production; and lesion number and size. The incubation period and latent period of IR14573 were slightly shorter than those of IR58. On IR14573, ooze production appeared continuous. Lesions were smaller and fewer on IR58 than on IR14573.

BLAST

Plant Breeding and Plant Pathology Departments

Numerical analysis of blast resistance (*Plant Breeding and Plant Pathology*). Since different races of rice blast (Bl) predominate at different sites, the data from the International Rice Blast Nursery (IRBN) could help in understanding the genetics of resistance. Variety-race interaction in rice Bl is complex, making it difficult to categorize types of resistance. A complicated race structure at particular sites, environmental variability, and the large diversity of IRBN entries make it difficult to form neat varietal groups. Numerical classification methods might overcome these difficulties.

Initially, principal component and cluster analyses were performed for entries with complete data in IRBN in 1981 and 1982. Cluster analysis formed nine major varietal groups for each year. However, many entries in one group in 1981 were in different groups in 1982. To gain accuracy, 4 overlapping 2-yr periods (1978-79, 1979-80, 1980-81, 1981-82) were analyzed.

This method appears useful for distinguishing broad varietal groups but not for studying the genetics of resistance. The discrimination level is probably too low for observing the effects of individual genes. A subset of IRBN entries was greenhouse-tested for reaction to 15 diverse Bl isolates. Five Korean isolates also were tested at the Institute of Agricultural Science of ORD, Suweon, Korea. Cluster analysis formed 7 major groups; however, the 93 varieties and breeding lines showed many reaction patterns. Therefore, even under controlled conditions using single spore isolates, racial and varietal diversity is high.

Virulence of pathogen (*Plant Pathology*). Rice Bl race studies often select varieties that react clearly to various pathogen isolates. But if such differential varieties are not grown widely, the resistance genes they carry are irrelevant to pathogen evolution in farmers' fields. Therefore this research examined virulence patterns in three Philippine *Pyricularia oryzae* populations using Philippine varieties and the Japanese differential variety set.

Isolates from Zamboanga del Sur could not usually attack IR varieties not grown in the upland areas whereas these isolates could attack locally grown Denorado and C22 (Table 8). Conversely,

Table 8. Frequency of isolates from three *P. oryzae* populations virulent to various rice varieties. Philippines, 1984.

Variety	Frequency (%) of virulent isolates[a]		
	Nueva Ecija	South Cotabato	Zamboanga del Sur
IR36	100	100	3
IR42	100	100	21
IR50	100	100	0
IR52	100	100	0
IR54	88	100	17
IR56	0	50	7
IR58	100	96	7
IR60	63	82	0
Denorado	0	0	69
Kinandang Patong	83	71	100
C22	0	0	76
B40	100	100	69
UPLRi3	0	0	21
UPLRi5	6	0	14
C1528-32-2	25	36	55
Yashiromochi	100	89	79
Fukunishiki	0	0	0
Aichi Asahi	100	100	100
Tsuyuake	0	43	3
PI No. 4	0	0	0
Kanto 51	0	50	7
Ishikari-shiroke	6	7	24
Shin 2	44	14	24
Toride 1	6	4	34

[a] N=16 for Nueva Ecija, 28 for South Cotabato, 29 for Zamboanga del Sur.

IR varieties are grown in Nueva Ecija and South Cotabato and a high proportion of isolates from these areas could attack the IR varieties, but not C22 and Denorado.

Grouping isolates based on their reaction to Philippine varieties produced logical results. Isolates from each of the three populations were adapted to cultivars grown in their area of origin and, therefore, were grouped together using cluster analysis. With cluster analysis based only on reactions to the Japanese differential set, isolates were grouped more randomly and the groupings could not be explained by knowledge of the varieties cultivated in each region. Some isolates reacted identically to Japanese differentials, but differently to Philippine varieties (Table 9). Thus, in studying *P. oryzae* populations from different regions, it is best to use varieties grown in those regions.

Variation among single spore isolates (*Plant Pathology*). IRRI-Korea collaborative research studied variation among single spore isolates from single lesions and monospore derived cultures. Ten single spore isolates were made from each of 5 single lesions on Milyang 15. International Bl differentials and Milyang 15 were inoculated with spore suspensions from these isolates in two replications. Only one reaction pattern (race) was detected among the 50 single spore isolates. Monospore subcultures were obtained from the original cultures and tested. These reacted identically as their parent isolates except for those derived from culture M15-3S. The M15-3S isolate set was tested in late September; cooler greenhouse temperatures perhaps affected results. Variant isolates are usually retested, but the M15-3S set could not be tested again in 1984 because of poor late season growth of the differentials.

Results confirm that single spore isolates derived from single lesions or monospore cultures generally are of one race.

Partial resistance (*Plant Pathology*). *Lowland varieties*. In the lowland tropics Bl seldom damages IR36 but does cause loss in IR50. Similarly, in Korea, Milyang 30 and Milyang 42 show less disease in the field than Milyang 57 and Suweon 264, which became susceptible soon after release. In the greenhouse, isolates of *P. oryzae* pathogenic to all six varieties were selected to measure components of partial resistance.

Relative disease efficiency (the number of lesions produced per unit leaf area) was less for IR36, Milyang 30, and Milyang 42 than for IR50, Milyang 57, and Suweon 264 when the fifth fully extended leaf was inoculated (Table 10). This relationship held when the sixth partially extended leaf was inoculated, but with many more lesions. The four isolates tested differed in the number of lesions caused, but no isolate × variety interaction was detected.

Lesions on IR36, Milyang 30, and Milyang 42 were smaller than those on IR50, Milyang 57, and Suweon 264. Sporulation from the lesions 12 d after inoculation also differed, with Milyang 42 and Milyang 30 producing the fewest spores per area of lesion and IR50 and Suweon 264 producing the most. As with lesion number, there was no significant isolate × variety interaction for either lesion size or lesion sporulation.

The relative partial resistance of these six varieties as measured in greenhouse inoculations

Table 9. Reaction of Philippine varieties and Japanese differential varieties to three Bl isolates.[a] IRRI, 1984.

Variety	Disease reaction[b]		
	N-2-3 (IR50)	C-1-13 (IR60)	Z-1-1 (Denorado)
	Philippine varieties		
IR36	+	+	–
IR42	+	+	–
IR50	+	+	–
IR52	+	+	–
IR54	+	+	–
IR56	–	–	–
IR58	+	+	–
IR60	±	+	–
Denorado	–	–	±
Kinandang Patong	+	+	+
C22	–	–	+
UPLRi3	–	–	–
UPLRi5	–	–	–
C1528-32-2	–	–	+
	Japanese differentials		
Yashiromochi	+	+	+
Fukunishiki	–	–	–
Aichi Asahi	+	+	+
Tsuyuake	–	–	–
PI No. 4	–	–	–
Kanto 51	–	–	–
Ishikari shiroke	–	–	–
Shin 2	–	–	–
Toride 1	–	–	–

[a]N-2-3 = Nueva Ecija, C-1-13 = South Cotabato, Z-1-1 = Zamboanga del Sur. Varieties in parentheses are the original hosts. [b]+ = susceptible, ± = moderately resistant, – = resistant.

Table 10. Relative disease efficiency of 6 rice varieties measured as lesions per 100 cm^2 on the fully extended fifth leaf and the partially extended sixth leaf after inoculation with 4 *P. oryzae* isolates.[a] IRRI, 1984.

Variety	Lesions (no./100 cm^2)								Variety means[b]	
	Y8421		Y8427		Y8422		Y8425			
	5th	6th	5th	6th	5th	6th	5th	6th	5th	6th
Milyang 42	10.8	136.4	3.0	160.8	1.3	68.3	0.0	43.2	5.0 a	102.2 a
IR36	5.6	234.4	0.6	108.9	1.6	173.6	0.0	17.4	2.6 a	133.6 a
Milyang 30	26.8	162.8	10.2	180.3	8.3	107.8	0.3	117.2	11.4 b	142.0 a
Suweon 264	74.7	366.0	13.8	261.1	21.2	233.9	5.4	41.4	28.8 c	225.6 b
Milyang 57	65.5	308.2	35.8	336.8	23.5	223.5	1.1	63.3	31.5 c	232.9 b
IR50	64.3	416.2	46.4	466.9	3.8	309.6	11.2	186.3	31.4 c	344.8 c
Isolate means[c]	41.3 d	270.7 d	18.3 c	252.5 cd	9.9 b	186.1 b	4.5 a	78.1 a		

[a] Mean of 5 replications. Analysis of variance showed no isolate X variety interaction. [b] In the column, variety means followed by a common letter are not significantly different (P = 0.05) by Duncan's multiple range test. [c] In the row, isolate means followed by a common letter are not significantly different (P = 0.05) by Duncan's multiple range test.

matches resistance performance in farmers' fields.

Effects of plant age. In upland varieties C22 and Denorado, the effects of plant age on partial resistance were studied. Denorado has been durably resistant in farmers' fields in Zamboanga del Sur, whereas C22 became susceptible soon after release there. Staggered planting produced plants of various ages which were inoculated at one time with an isolate of *P. oryzae* pathogenic to both varieties. Daily measurements of sporulation from individual lesions began 4 DAI. Lesion number per unit leaf area and lesion size were measured 10 DAI.

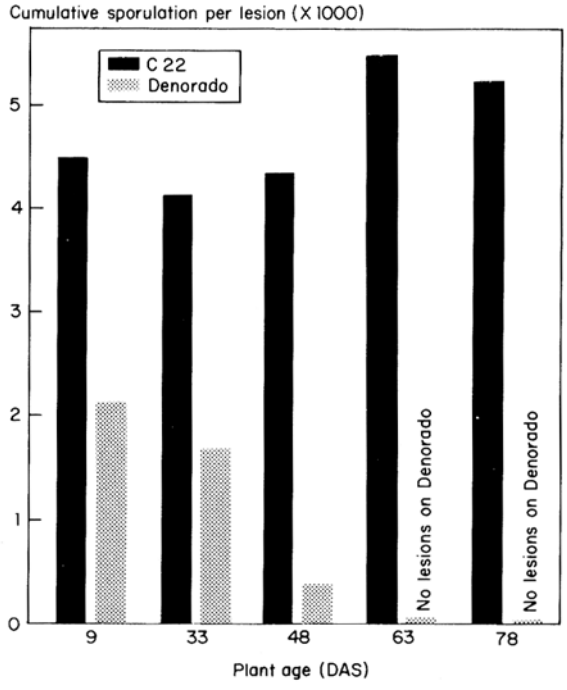
In both varieties, relative disease efficiency (lesions/ 100 cm^2 of leaf) decreased with increasing plant age (Table 11). Lesion numbers decreased faster in Denorado than in C22. Lesion size did not vary greatly with plant age. Cumulative spores per lesion decreased in older Denorado plants but remained constant in C22 (Fig. 8).

The incubation period (inoculation to lesion appearance) did not change with increasing plant age in C22. In Denorado, however, latent period

Table 11. Effect of plant age on relative disease efficiency and lesion size in C22 and Denorado.[a] IRRI, 1984.

Days after seeding	Lesions (no./ 100 cm^2)	Lesion size (mm^2)
	C22	
9	39.9 c	5.69 a
33	3.40 b	17.31 b
48	0.84 a	14.94 b
63	1.04 a	18.25 b
78	0.88 a	15.65 b
	Denorado	
9	44.9 c	5.44 b
33	1.03 b	5.69 b
48	0.05 a	4.35 b
63	0 a	0 a
78	0 a	0 a

[a] In a column within a variety, separation of means is by Duncan's multiple range test.



8. Effect of plant age on cumulative sporulation per blast lesion. IRRI, 1984.

significantly increased in 48-d-old plants. In C22 the infectious period (when lesions produce spores) increased slightly with plant age, whereas in Denorado the infectious period decreased sharply.

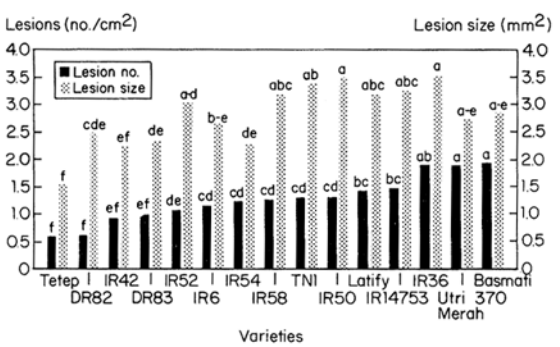
In general, plant age affected partial Bl resistance, with Denorado showing increasing resistance on older plants.

BROWN SPOT

Plant Pathology Department

Varietal resistance. To study varietal resistance to 3 isolates of the brown spot (BS) pathogen *Bipolaris oryzae*, 1-mo-old seedlings were inoculated. Varieties differed significantly in number of lesions and lesion size (Fig. 9). Of 15 varieties tested, Tetep was most resistant and Basmati 370, Utri Merah, and IR36 were among the more susceptible.

Tetep, IR58, and IR36 were chosen for inoculation at reproductive and ripening stages. Panicles were inoculated by injecting spore suspensions at booting and by spraying inoculum onto the panicles at flowering and milk stages. When disease was measured as percentage of discolored grains, the varieties did not differ although inoculation time and method had a significant effect. Plants injected at booting produced mature panicles with highest grain discoloration; those inoculated at milk stage showed least discoloration. Flowering stage inoculations showed intermediate discoloration. The same trend showed in measurements of spikelet sterility. Although Tetep, IR58, and IR36 differed in susceptibility to BS as seedlings, they appeared equally susceptible to panicle inoculations when disease was measured as percentage of grain discoloration. Also, the lack of isolate × variety interaction indicates no race specificity.



9. Mean lesion no. and mean lesion size on 15 varieties inoculated with 3 isolates of *Bipolaris oryzae* at the seedling stage. IRRI, 1984.

SHEATH BLIGHT

Plant Pathology Department

Measuring resistance. At IRRI, research to improve the evaluation system for resistance to sheath blight (ShB) identified proper plot management technique and developed an evaluation scale.

Upland nursery. In lowland conditions, maintaining high planting density and high humidity is difficult. Accordingly, disease reactions vary highly.

To minimize variation and to provide more favorable disease conditions, two upland nurseries were established, one with overhead sprinkling system (28 entries) and the other in a rainfed upland area (60 entries).

In both nurseries, the inoculum — a mixture of sterilized soil and 14-d-old culture of *Rhizoctonia solani* isolate LR in rice grain-rice hull mixture (1:3) at the ratio of 1:2 soil/inoculum (wt/wt) — was topdressed uniformly at the base of rice plants 30 DAS.

Initially the disease developed uniformly in both nurseries. Subsequently, however, disease was greater in the upland nursery with sprinklers than in the rainfed upland (Table 12), perhaps because of prolonged high humidity from overhead sprinkling.

Table 12. Sheath blight severity of selected rice varieties and lines evaluated under upland conditions. IRRI, 1984.

Variety, line	Severity[a]	
	Upland with sprinkler system	Rainfed upland
IR27325-63-2-2	9.88 ab	5.23
Ta-poo-cho-z	13.10 abc	2
IR8	13.17 abc	7.08
IR5	13.82 abc	8.48
IR20	15.89 abc	10.86
RP4-14	35.29 cdef	24.70
Taebaegbyeo	44.08 defg	22.85
IR1317-392-1-2	48.96 efg	45.54
IR36	55.39 fgh	36.34
IR58	71.90 h	54.12
IR9729-67-3-85	73.53 h	58.71
Average	35.91	25.08

[a]Varietal reaction: 0 = highly resistant, 100 = highly susceptible.

The pathogen can survive better under dry than submerged conditions. Thus, additional inoculum needed for each evaluation would be much less in the upland nursery than in lowland plots.

New evaluation scale. Under highly favorable conditions (such as humidity due to frequent rainfall), rapid progress of ShB starting from booting stage can severely infect leaves, often more than the sheath itself (Fig. 10). Severe damage on the three upper leaves, including the flag leaf, can reduce yield significantly.

Conventional evaluation scales, including SES, are based mainly on the relative positions of the uppermost lesions along the sheath area without properly considering leaf area damaged. A new scale was prepared to also reflect varietal differences in leaf infection (Table 13). In this scale, the uppermost lesion's position was determined, not by its relative vertical height as in SES, but by leaf or sheath positions counted from the flag leaf (Fig. 11). The relative disease intensity for each grade was computed arbitrarily relative to yield loss for each grade.

Varietal reactions at seedling stage. Evaluation of adult plants requires large space and time, and plant growth duration is highly variable. Therefore detecting varietal resistance at the seedling stage with artificial inoculation would be more efficient.

To explore this, 40-d-old plants of selected cultivars were inoculated by injecting mycelial suspension, prepared from 2-d-old cultures on PDA medium enriched with urea (1.3 g/litre), into the interstices between the sheath and the leaf. Leaf blades were moved before inoculation to reduce photosynthesis which favors ShB development. Severity was calculated using a scale based on lesion type (Table 14).

Varietal differences in severity coincided with those of adult plants in the field (Table 15). Nevertheless, variation among plants within a variety was high.

Varietal resistance. No cultivar highly resistant to ShB has been identified. The few moderately resistant cultivars are taller and mature later.

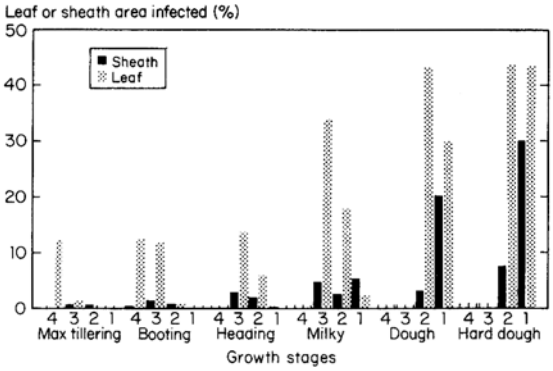
Table 13. Scale for evaluation of ShB severity[a] at adult plant stage 25 d after flowering (DAF). IRRI, 1984.

Grade	Leaf or sheath no.[b]	Area infected (%) Leaf		Sheath	Relative disease intensity
0	3	< 5	and	< 5	0
1	3	6-25	and/or	6-25	5
3	3	> 25	and/or	> 25	10
	2	6-25	and/or	6-25	
5	2	> 25	and/or	> 25	30
7	1	6-25	and/or	6-25	50
9	1	> 25	and/or	> 25	100

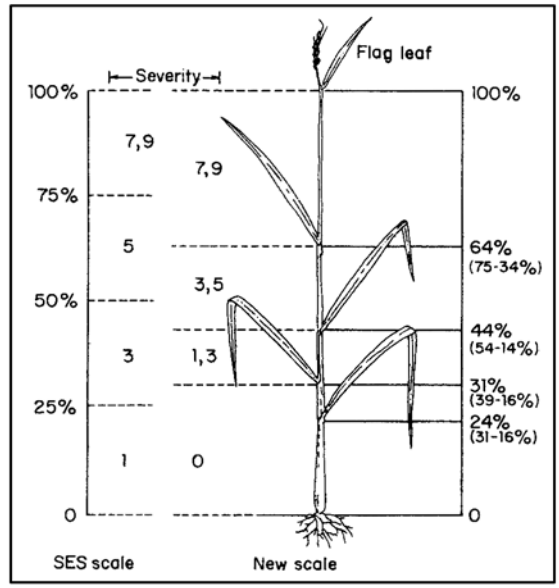
$$\text{Severity (25 DAF)} = \frac{0(n_0) + 5(n_1) + 10(n_3) + 30(n_5) + 50(n_7) + 100(n_9)}{\text{Total number of tillers observed}}$$

where: $n_0 - n_9$ = number of tillers classified as 0 – 9 grades, respectively.

[b] Flag leaf/sheath = 1.



10. ShB damage at different growth stages of IR36. Staggered plantings synchronized all growth stages under the same environment. IRRI, 1984. The numbers 1-4 indicate position of leaf or sheath counted from the flag leaf.



11. Scoring scheme of the SES scale and the new scale for ShB. IRRI, 1984.

Table 14. Scale for evaluation of ShB severity[a] at seedling stage. IRRI, 1984.

Grade	Relative disease intensity	Lesion type
0	0	No lesion. Dark brown streak or blurred spots.
1	5	Small roundish lesions less than 5 mm, surrounded by dark brown margin.
3	10	Oval or roundish lesion 0.5-1 cm in diameter, surrounded by dark brown margin with dark gray center.
5	30	Elongated or elliptical lesions 1-3 cm in diameter, surrounded by dark brown margins with whitish gray, water-soaked or darkened centers.
7	50	Well extended lesions > 3 cm in length, bounded with diffused light brown areas or orange-colored margins with gray or whitish centers.
9	100	Highly extended lesions more than 3 cm in length, without distinct margins.

[a] Formula for severity the same as for adult stage.

Table 15. Reaction of seedlings and adults of selected rice cultivars to ShB. IRRI, 1984.

Variety or line	Seedling		Adult	
	Prevailing lesion type	Severity[a]	Severity[b]	SES score[a]
Ta-poo-cho-z	0-3	8	7.6	1
IR27325-63-2-2-2	0-3	10	7.6	3.4
RP4-14	3-5	24	30	4.3
Taebaegbyeo	3-5	30	33.5	3.7
IR1317-392-1-2	5-7	50	47.3	4.6

[a] Av of 1 evaluation. [b] Av of 2 evaluations.

Table 16. Semidwarf cultivars with short to intermediate growth duration evaluated as resistant or moderately resistant to ShB. IRRI, 1984.

Variety, line	Maturity (DAS)	Height (cm)	Severity[a]
Kataktara DA2	97	109	27.81
Nampungbyeo	100	86	12.83
IR18350-175-2-3	102	88	30.78
Ratna	105	75	30.03
Ta-poo-cho-z	114	105	7.55
RP4-14	114	106	30
IR21912-131-3-3-2-2	119	96	28.54
IR9729-67-3-85 (control)	105	95	66.12
Mahsuri (control)	145	142	10.48

[a] Av of 2 evaluations with 3 and 4 replications except for Ratna, Kataktara DA2, Nampungbyeo, and Mahsuri, which are averages for 1 evaluation.

Our results confirm that ShB is generally more severe with shorter varieties that mature early. However, several cultivars such as Ta-poo-cho-z, Nampungbyeo, Kataktara DA2, RP4-14, and Ratna were infected consistently less; some of them are early or intermediate in maturity and are semidwarf (Table 16). Those cultivars will be studied for resistance characteristics under diverse environmental conditions.

TUNGRO

Plant Pathology and Entomology Departments

IR variety reaction under varying disease pressure (*Plant Pathology*). Field trials evaluated how IR varieties react to tungro (RTV) under low disease pressure at IRRI and under high disease pressure at Guimba, Nueva Ecija, in 1984 WS.

Three-week-old test seedlings were transplanted singly in hills and naturally infected. Plant symptoms were scored 1 mo after transplanting. Leaf samples randomly taken were tested by latex for RTV-associated viruses.

The varieties differed according to disease pressure. At IRRI (low pressure), the susceptible check IR22 had 47% infection. IR36 and IR42, which are moderately resistant to green leafhopper (GLH), had 6 and 15% infection. Varieties with high vector resistance had very low RTV infection. IR22 was most infected with rice tungro bacilliform virus (RTBV) plus rice tungro spherical virus (RTSV), followed by IR42 and IR36. If infected at all, other varieties had RTSV alone at low level (Table 17).

At Guimba, IR22, IR36, IR42, and IR62 had high RTV infection. Other varieties had very low infection. Infection with either RTBV plus RTSV, or RTSV alone was greater in most varieties at 60 d after transplanting (Table 18).

Varieties with high insect resistance can escape infection or have low infection. RTSV infected independently in both sites.

IR variety reaction in test tube inoculation and in nursery (*Plant Pathology*). Each seedling of 26 IR varieties was confined in a test tube with 1 GLH which had fed on plants with RTBV plus RTSV or RTSV alone. Seedlings were tested by latex for RTBV and RTSV 30 DAI. Leaf samples collected from IR varieties planted in the RTV nursery at IRRI (1983 WS, and 1984 DS) were tested similarly.

Table 17. Reaction of IR varieties to RTV at IRRI, a low disease pressure area, 1984 WS.

Variety	RTV infection[a] (%)	Plants infected[b] (%)			
		RTBV + RTSV	RTBV	RTSV	Healthy
IR22 (susceptible check)	47.2 d	52.5	22.5	16.9	8.1
IR36	5.7 b	6.3	8.8	26.4	58.5
IR42	15.4 c	31.6	12.7	33.5	22.2
IR50	0.1 a	0.0	0.6	0.0	99.4
IR52	1.0 a	0.0	0.0	0.0	100.0
IR58	1.7 a	5.0	0.6	11.3	83.1
IR60	0.1 a	0.0	0.0	0.0	100.0
IR62	0.7 a	0.0	0.0	11.3	88.7

[a]Scored 1 mo after transplanting based on symptoms. Separation of means by Duncan's multiple range test at the 1% level. [b]Leaf samples of 120-160 plants were tested 30 d after transplanting.

Table 18. Reaction of IR varieties to RTV at Guimba, Nueva Ecija, a high disease pressure area, 1984 WS.

Variety	Tungro infection[a] (%)	Plants infected[b] (%)							
		30 DT				60 DT			
		RTBV + RTSV	RTBV	RTSV	Healthy	RTBV + RTSV	RTBV	RTSV	Healthy
IR22 (susceptible check)	88.2 c	60.0	8.4	20.8	10.8	90.8	0.8	8.4	0.0
IR36	87.2 c	19.2	10.8	35.8	34.2	69.2	2.5	24.1	4.2
IR42	87.8 c	34.2	5.0	36.7	24.1	89.0	0.0	9.3	1.7
IR50	0.8 a	0.0	0.0	1.6	98.4	0.0	1.6	6.7	91.7
IR52	1.0 a	0.0	0.8	2.5	96.7	6.7	5.0	15.8	72.5
IR56	1.9 a	3.3	0.8	24.2	71.7	25.0	1.6	46.7	26.7
IR58	0.4 a	0.0	0.0	3.3	96.7	3.3	4.2	10.8	81.7
IR60	0.1 a	0.0	0.8	0.8	98.4	1.7	1.7	10.8	85.8
IR62	63.1 b	10.0	4.2	37.5	48.3	46.7	5.8	41.7	5.8

[a]Scored 1 mo after transplanting, based on symptoms. Separation of means by Duncan's multiple range test at the 1% level. [b]Tested leaf samples of 120-160 plants. DT = days after transplanting.

When doubly infected plants were used as a virus source, percentage infection range was 0-53 for RTBV plus RTSV, 21-86 for RTBV alone, and 0-12 for RTSV alone (Table 19).

In the RTV nursery, 50,000 tungro-infected TN1 plants per hectare were transplanted to obtain high disease pressure. RTBV plus RTSV, and RTSV alone infected more plants than in the greenhouse test for almost all IR varieties tested (Table 20). Under such high RTV and GLH pressures, susceptible varieties were mostly infected with RTBV + RTSV. Even RTV-resistant IR28, IR29, IR50, IR52, IR56, IR58, and IR60 obtained higher infections. High percentage infection with RTSV alone in the field indicates it is an independent disease at IRRI. IR20, IR26, IR30, and IR40 were infected mostly with RTBV alone, indicating their resistance to RTSV but susceptibility to RTBV. The four varieties have TKM6 as a common parent.

Reaction of tungro-resistant parents to tungro-associated viruses (*Plant Pathology*). TKM6, Gam Pai 30-12-15, Peta, and Ptb 18 seedlings were inoculated with RTBV + RTSV or RTSV alone by one viruliferous GLH per seedling. Plants were tested for viruses 1 mo after inoculation. TKM6, Gam Pai 30-12-15, and Peta were mostly infected with RTBV by GLH that fed on RTBV + RTSV sources (Table 21). RTBV and RTBV + RTSV were relatively low on Ptb 18. TKM6 was not infected with RTSV.

Resistance to tungro and green leafhopper (*Plant Pathology*). Reactions to RTV of nine varieties with varying levels of GLH resistance were tested. Insects confined on Utri Merah, Utri Rajapan, and TN1 gave higher nymphal survival and longer lifespan. GLH fed on xylem and phloem of these varieties but only on xylem of other test varieties.

Inoculation of each seedling of Utri Merah, Utri

Table 19. Reactions of IR varieties to RTV-associated viruses in test tube inoculation. IRRI, 1983-84.

Variety	RTBV + RTSV source				RTSV source	
	Plants tested	Plants infected (%)			Plants tested	Plants infected (%)
		RTBV + RTSV	RTBV	RTSV		
IR5	49	29	43	0	56	45
IR8	47	11	72	0	47	32
IR20	28	0	86	0	55	0
IR22	56	46	45	0	56	82
IR24	55	13	49	0	59	20
IR26	55	2	80	0	58	0
IR28	51	6	47	0	55	29
IR29	49	6	49	0	58	21
IR30	45	0	67	0	56	4
IR32	38	32	26	8	57	53
IR34	45	7	36	2	54	31
IR36	33	12	45	3	57	47
IR38	41	32	39	12	54	52
IR40	50	0	66	2	46	0
IR42	51	29	45	0	58	53
IR43	47	11	49	0	58	29
IR44	52	31	31	2	43	56
IR45	53	11	45	2	53	28
IR46	32	53	25	6	32	78
IR48	48	44	21	4	42	57
IR50	56	9	29	5	56	43
IR52	46	4	28	4	51	24
IR54	48	6	29	2	54	33
IR56	58	16	24	3	50	52
IR58	51	4	31	4	49	27
IR60	57	4	37	2	49	29

Rajapan, and Gam Pai 30-12-15 with one, three, or five RTV-viruliferous GLH resulted in low percentage infection regardless of GLH number (Fig. 12). Most infected seedlings contained RTBV alone, except TN1. Seedlings were also exposed to GLH that fed on plants infected with RTSV alone. Utri Merah had remarkably low RTSV infection even at five GLH/seedling (Fig. 13).

RTBV-infected ASD7 and ASD8 showed severe symptoms comparable to TN1 infected with RTBV + RTSV. In contrast, Utri Merah and Utri Rajapan showed mild symptoms with either both viruses or RTBV alone. Plants infected with RTSV alone showed no symptoms.

Most RTV-resistant varieties resist GLH. Utri Merah and Utri Rajapan are susceptible to GLH, but resist RTV infection and seem tolerant of RTV-associated viruses.

Transmission by green leafhopper reared on TN1 and Pankhari 203 (*Plant Pathology and Entomology*). TN1-reared GLH from the Plant Pathology Department and Pankhari 203-reared GLH from the Entomology Department were tested for transmission of RTV-associated viruses using one and five insects per seedling. The insects fed for 4 d on RTBV- and RTSV-infected TN1 plants and were allowed to inoculate TN1 and Pankhari 203 seedlings for 24 h. After 1 mo, all inoculated plants were tested by latex.

TN1-reared GLH transmitted both RTBV and RTSV to TN1 but more RTBV to Pankhari 203. Infection increased slightly when insect numbers increased (Fig. 14). Transmission by Pankhari 203-reared GLH highly infected TN1 seedlings with RTBV + RSTV and highly infected Pankhari 203 with RTBV regardless of insect number per seedling. This indicates Pankhari 203 resists RTSV infection as well as GLH. Symptoms of RTBV infection on Pankhari 203 were very mild.

Sequential transmission on tungro- and green leafhopper-resistant and susceptible varieties (*Plant Pathology*). To further understand resistance to

Table 20. Reactions of IR varieties to RTV-associated viruses in the RTV nursery at IRRI, 1983 WS.

Variety	1983 wet season				1983 dry season			
	Plants tested	Plants infected (%)			Plants tested	Plants infected (%)		
		RTBV + RTSV	RTBV	RTSV		RTBV + RTSV	RTBV	RTSV
IR5	42	50	5	43	52	98	2	0
IR8	25	96	0	4	42	95	2	2
IR20	45	20	60	7	47	4	96	0
IR22	33	76	0	21	49	96	2	2
IR24	43	0	58	2	44	64	36	0
IR26	36	6	19	0	50	0	100	0
IR28	49	43	14	20	48	44	17	10
IR29	48	21	13	10	46	33	33	4
IR30	49	18	29	8	42	7	93	0
IR32	48	56	10	25	50	100	0	0
IR34	53	74	0	19	50	62	28	2
IR36	40	45	0	40	42	98	2	0
IR38	50	40	28	14	52	98	2	0
IR40	49	12	53	4	49	0	100	0
IR42	45	91	0	9	48	100	0	0
IR43	42	71	10	2	42	86	14	0
IR44	41	69	0	17	43	100	0	0
IR45	36	86	0	14	36	94	3	3
IR46	50	96	2	2	55	98	0	2
IR48	43	88	0	12	45	100	0	0
IR50	49	18	14	22	41	47	25	10
IR52	31	19	10	42	38	61	21	13
IR54	50	18	10	36	43	42	28	12
IR56	44	14	11	11	49	71	2	2
IR58	30	20	0	43	29	38	3	31
IR60	52	13	13	27	41	24	17	10
TN1	63	95	0	3				

Table 21. Reactions of donors for RTV resistance to RTV-associated viruses. IRRI, 1984.

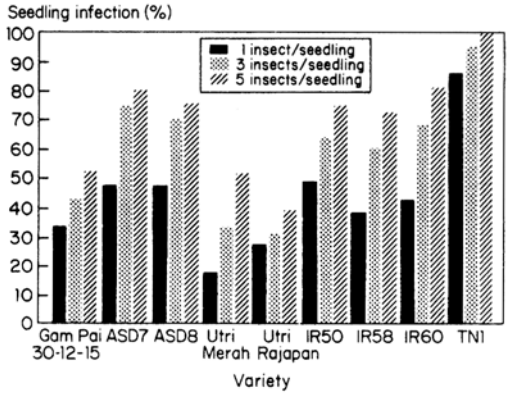
Accession no.	Variety	Reaction to		Plants infected[c] (no.)					
		GLH[a]	RTV[b]	RTBV + RTSV source				RTSV source	
				RTBV + RTSV	RTBV	RTSV	None	RTSV	None
35	Peta	3	I	6	20	0	10	4	29
237	TKM6	3	S	0	28	0	4	0	32
6105	Ptb 18	1	I	3	2	0	13	7	20
831	Gam Pai 30-12-15	3	R	0	20	0	19	3	32

[a]Data from IRRI Entomology Department, based on 1-9 scale: 1-3 = resistant, 5-7 = moderately resistant, 9 = susceptible. [b]Greenhouse mass screening results at IRRI, 1963-80. [c]Viruses were detected by the latex test.

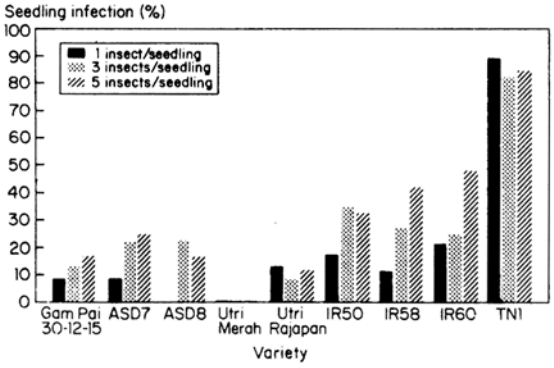
RTV-associated viruses, this study determined virus occurrence among resistant and susceptible varieties inoculated sequentially.

RTV-viruliferous GLH were allowed 4-h inoculation access time in sequence alternatively on a) GLH-susceptible but RTV-resistant Habiganj DW8, and GLH- and RTV-susceptible TN1, or b) GLH-resistant but RTV-susceptible IR5492 and TN1. Each test also used a reciprocal sequential transmission. All plants were tested by latex 1 mo after inoculation.

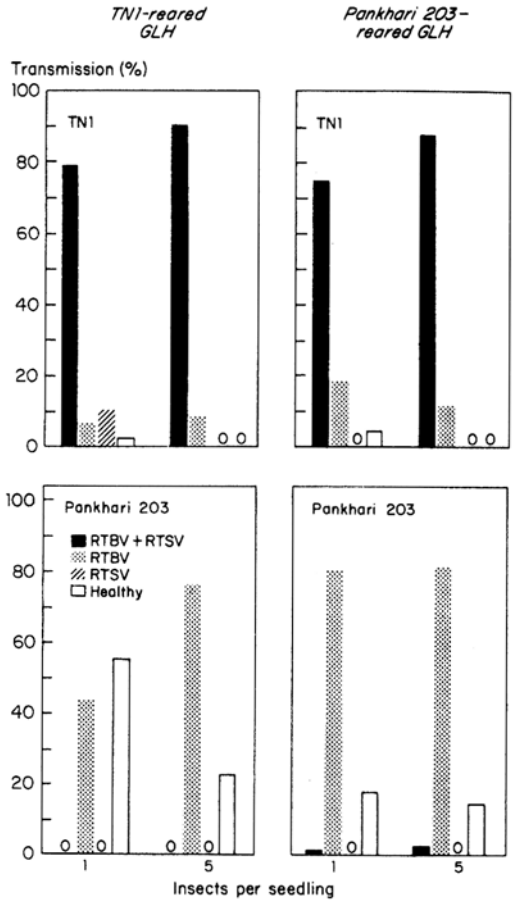
When insects initially fed on Habiganj DW8 then on TN1, TN1 generally had higher RTBV infection (Fig. 15a). However, when the series started on TN1 (Fig. 15b), RTBV + RTSV was higher but decreased in subsequent series. Generally, no viruses



12. Percentage RTV seedling infection in 9 varieties inoculated in the test tube with 1, 3, or 5 GLH. IRRI, 1984.



13. Reaction of 9 rice varieties to RTSV as detected by latex test or ELISA when inoculated in the test tube by 1, 3, and 5 viruliferous GLH. IRRI, 1984.



14. Transmission of RTV-associated viruses by GLH reared on TN1 (greenhouse colony) and on Pankhari 203 (40th generation). IRRI, 1984.

were detected in Habiganj DW8. Similarly, when IR5492 was the initial variety (Fig. 15c) followed by TN1, RTBV alone was generally detected in infected plants. In the reciprocal test (Fig. 15d), more plants were infected with RTBV + RTSV in the initial variety TN1, but decreased markedly in the subsequent series.

The results further indicate the link between infection with RTBV alone and plant resistance to either vector or virus.

VARIETAL RESISTANCE TO VIRAL DISEASES

Plant Pathology Department

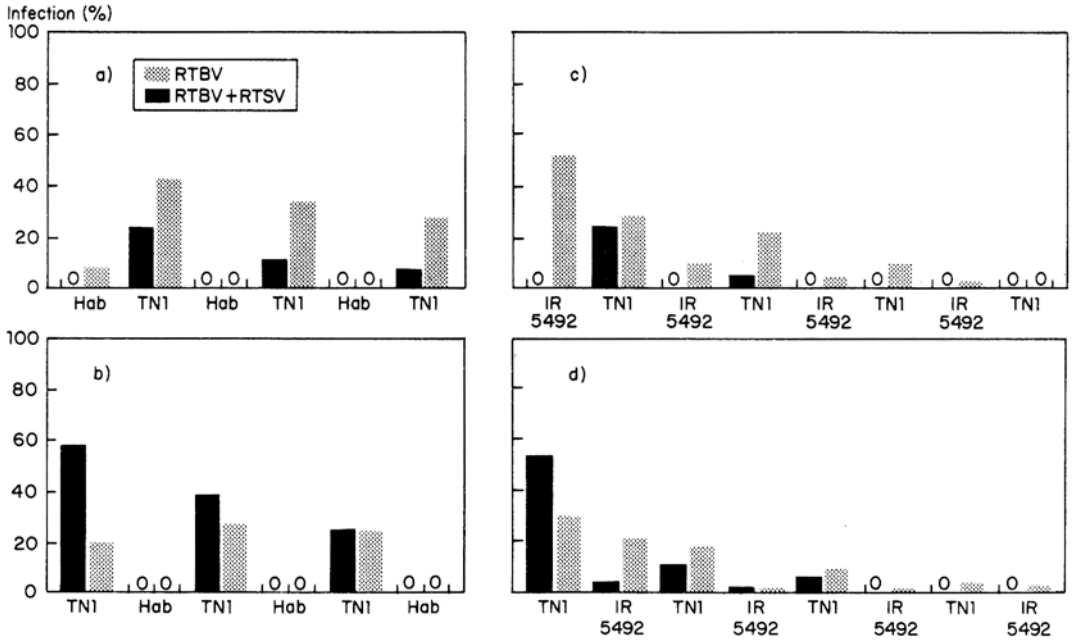
Total entries tested for RTV, grassy stunt virus strains GSV 1 and GSV 2, and ragged stunt virus (RSV) in 1984 were 11,324, 3,433, 1,656, and 7,802, respectively. Entries showing resistance to viral diseases are

RTV

7366	PI 184675-2
11062	G 378
26322	Chingir
35219	Bogor Mas
35366	Padi Ampek Bulan
35392	Padi 4 Bulan
35394	Papah Aren
35588	Cempo Abang
37488	Kashia Binni
37748	Laki 1120

RSV

39247	CR 157-392-4
18034	Kuatih Merah
18500	Pekal Gambrong



15. Reaction to RTV-associated viruses of Habiganj DW8 and IR5492 as detected by latex test following 4-h sequential transmission with TN1. Infection with RTSV was very low. Order of GLH feeding: a) Habiganj DW8 first, b) TN1 first, c) IR5492 first, d) TN1 first. IRRI, 1984.

PATHOTOXIN AND TISSUE CULTURE

Plant Pathology Department

Tissue culture is mainly used to select desirable mutants from cell cultures to regenerate plants possessing desired traits. Evolving disease-resistant varieties using tissue culture depends on three conditions: 1) callus should react to pathogens exactly as intact plants do, 2) a chemical (toxin) determining the disease must be identified, and 3) callus should react to the chemical as intact plants do.

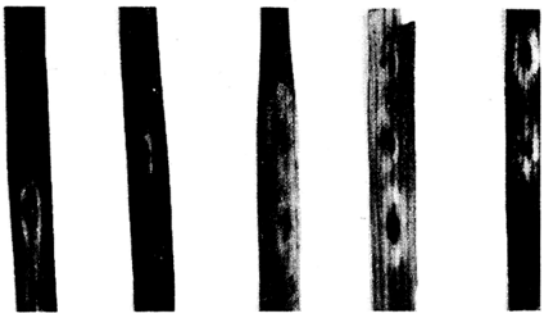
Rice calli and intact rice plants reacted the same way to *Helminthosporium oryzae* (Table 22). Five rice varieties had different reactions to six isolates of *H. oryzae*: IR8 was resistant to isolate 34, IR36 to isolates 34 and 47, TN1 to isolate 47, Co 20 to isolate 36, and CH45 to isolate 202. All varieties were susceptible to isolate 46 and resistant to isolate 41. Results were similar when single spores of the six isolates were inoculated on calli of the five varieties.

The fungus produced a toxin which elicited the characteristic brown spot symptoms on rice leaves (Fig. 16). Rice culture IR17488-2-3-2-2-3 showed

Table 22. Reaction of whole plants and calli to *Helminthosporium oryzae* isolates. IRRI, 1984.

Isolate	Disease intensity[a]					Mycelial growth intensity on callus[b]				
	IR8	IR36	TN1	Co 20	CH45	IR8	IR36	TN1	Co 20	CH45
34	1.7	2.6	5.2	7.9	5.2	1.8	1.6	3.0	3.0	3.5
36	6.8	7.5	7.0	0.8	7.2	3.5	3.0	2.8	0	3.8
41	0.6	1.0	1.7	1.7	0.2	0	0	0	0	0
46	6.8	6.3	6.4	8.0	5.0	4.0	4.0	3.7	4.0	4.0
47	7.4	2.7	2.3	7.1	7.8	4.0	1.7	0.1	3.0	3.0
202	6.9	7.7	8.3	8.8	1.7	4.0	3.2	3.0	2.3	0

[a]Based on a scale 0 to 9: 0 = no infection, 9 = very severe infection. [b]Based on a scale 0 to 4: 0 = no growth, 4 = callus completely covered with mycelium.



16. Symptoms produced by toxin of *Helminthosporium oryzae*. IRRI, 1984.

Table 23. Relation between disease intensity induced by 2 isolates of *H. oryzae*[a] and dilution end point of activity of toxins they produced. IRRI, 1984.

Variety	Disease intensity		Dilution end point of toxin activity	
	I 46	I 41	I 46	I 41
IR8	6.3	0.6	> 500	10
IR36	6.3	1.0	> 500	1
CH45	5.0	0.2	> 500	1
Co 20	8.0	1.7	> 500	10
IR17488-2 -3-2-2-3	1.0	0	5	1

[a]Highly virulent isolate (I) 46 and less virulent I 41.

resistance to the most virulent isolate 46. Toxins produced both by the virulent isolate 46 and the least virulent isolate 41 induced brown spot symptoms on all test varieties. But with serial dilutions of toxins, the differences between susceptible and resistant varieties and between highly and less virulent isolates were discernible. The toxin from isolate 46 induced symptoms on all the susceptible varieties even when it was diluted 500 times. The resistant variety IR17488-2-3-2-2-3 showed no symptoms when the toxin was diluted more than 5 times. Toxin from isolate 41 produced no symptoms on any variety when diluted more than 10 times (Table 23).

The toxin of isolate 46 induced more electrolyte leakage in the five varieties: more in the four susceptible varieties than in resistant IR17488-2-3-2-2-3. The toxin produced by less virulent isolate 41 induced less electrolyte leakage in all varieties.

Artificially inoculated *H. oryzae* could infect several hosts such as banana, sugarcane, sorghum, maize, and tomato. The host range of the toxin and symptoms produced were similar to those of the fungus.

The purified toxin showed Rf value of 0.89 in chloroform: methanol solvent-system, and reacted to vanillin, phosphomolybdic acid, 2,4-dinitrophenyldrazine and antimony pentachloride. Toxin absorbance maxima were 241.6 nm in chloroform, 204.8 nm in methanol, and 207.0 in ethanol.

When virulent isolate 46 was subcultured several times, it lost its virulence. The avirulent isolate lost its ability to produce toxin, shown by dilution end point and electrolyte leakage assays. But when fed with toxin, it became virulent, invaded the host tissues, and produced typical brown spots.

When ferric chloride was sprayed at 10^{-2} M 48 h before inoculation, the plants became resistant to the fungus. Plants with induced resistance showed insensitivity to the toxin. The toxin was isolated from infected leaves also. All these observations suggest that the toxin may determine the disease.

Rice calli also reacted to the toxin as to the fungus. When the avirulent isolate was inoculated in IR8 callus, spores germinated within 8 h, but the germ tube grew superficially without inter- and intracellular growth. When the callus was treated with toxin, the fungus penetrated into the cells and grew profusely.

Thus, all three requirements for the success of evolving disease-resistant plants using tissue culture were satisfied in *H. oryzae*-rice interactions.

Calli of IR8, IR36, and IR54 were soaked in 25% toxin-containing liquid medium for 24-48 h and the surviving calli were grown in Murashige-Skoog tissue culture medium. Two IR8 calli survived and on regeneration showed resistance to the toxin as well as to the pathogen. The seeds from the two plants were harvested and sown in the greenhouse. The R2 generation plants also showed resistance to the pathogen.

Genetic evaluation and utilization (GEU) program

Insect resistance

Entomology and Cereal Chemistry Departments

SOURCES OF RESISTANCE **66**
- Screening program status **66**

NATURE OF RESISTANCE **67**
- IR variety insect resistance **67**
- Resistance to black bug **67**
- Caseworm development on traditional and modern varieties **67**
- Leaffolder resistance **67**
- Cross resistance to two leaffolder species **68**
- Green leafhopper feeding and growth on varieties **68**
- Efficiency of two green leafhopper species as tungro virus vectors **69**
- Tungro virus and green leafhopper feeding **72**
- Seedbox screening technique for brown planthopper on moderately resistant varieties **73**
- Feeding of brown planthopper biotype 3 on Utri Rajapan **73**
- Nitrogen fertilizer levels and brown planthopper populations **74**
- Whitebacked planthopper responses to varieties **74**
- Resistance to whitebacked planthopper in varieties with monogenic and digenic resistance **75**
- Technique for locating planthopper and leafhopper eggs in plants **76**
- Yield losses in striped stem borer-resistant varieties **76**
- Plant age effect on yellow stem borer survival **76**
- Yellow stem borer rearing technique **77**

CHEMICAL BASES OF RESISTANCE **78**
- Leaffolder feeding on extract of resistant varieties **78**
- Green leafhopper feeding on extract of a resistant variety **78**
- Extraction of allelochemics from rice plants **78**

BIOTYPES AND GENETIC CHARACTERISTICS **79**
- Mindanao brown planthopper: damage and growth **79**
- Brown planthopper color morphs **80**
- Cytology of a grass-infesting planthopper **80**
- Virulence of green leafhopper colonies **80**
- Morphometric variations between green leafhopper biotypes **81**
- Meiotic cells and chromosomes of green leafhopper **81**
- Chromosomes of rice leaffolder **82**

BIOLOGICAL CONTROL AND RESISTANCE **82**
- Biological control and varietal resistance to whitebacked planthopper **82**

SOURCES OF RESISTANCE

Entomology Department

Screening program status. Screening of *O. sativa* germplasm for resistance to insects has identified accessions with resistance to 12 of 14 insect species (Table 1). Almost 1,300 accessions resist the green leafhopper (GLH) *N. virescens*, and many resist the three brown planthopper (BPH) biotypes. However, we lack resistant donors for breeding for resistance to the caseworm and the rice bug.

To find new sources of resistance and to identify breeding sources outside the *O. sativa* collection, we are evaluating wild rices. About 50% of wild rices tested resisted various hopper species (Table 2). Several accessions have much higher levels of resistance to the whorl maggot than any *O. sativa* species. So far no accessions resistant to the

Table 1. Status of screening for varietal resistance to insects at IRRI, Sep 1984.

Insect	Year screening started	Accessions		
		Tested (no.)	Resistant (no.)	Resistant (%)
Striped stem borer *Chilo suppressalis*	1962	15,000	23	0.15
Yellow stem borer *Scirpophaga incertulas*	1962	22,920	26	0.11
Whorl maggot *Hydrellia philippina*	1965	16,918	1	0.01
Green leafhopper *Nephotettix virescens*	1967	48,961	1,272	2.60
Green leafhopper *N. nigropictus*	1972	527	66	12.53
Green leafhopper *N. malayanus*	1984	158	129	81.65
Brown planthopper *Nilaparvata lugens*				
Biotype 1	1967	45,172	418	0.93
2	1975	15,068	284	1.88
3	1975	16,402	289	1.76
Whitebacked planthopper *Sogatella furcifera*	1970	47,089	391	0.83
Zigzag leafhopper *Recilia dorsalis*	1973	2,383	36	1.51
Leaffolder *Cnaphalocrocis medinalis*	1979	20,816	117	0.56
Caseworm *Nymphula depunctalis*	1982	5,183	0	0.00
Thrips *Stenchaetothrips biformis*	1983	237	78	32.91
Rice bug *Leptocorisa oratorius*	1983	406	0	0.00
Black bug *Scotinophara coarctata*	1983	300	2	0.01

Table 2. Screening the IRRI wild rice germplasm collection for insect resistance. 31 Oct 1984.

Insect	Accessions		
	Screened (no.)	Selected for resistance[a] (no.)	Selected (%)
Brown planthopper *Nilaparvata lugens*			
Biotype 1	446	204	45.7
2	445	168	37.8
3	448	178	39.7
Whitebacked planthopper *Sogatella furcifera*	449	208	46.3
Green leafhopper *Nephotettix virescens*	447	239	53.4
Green leafhopper *N. nigropictus*	91	54	59.3
Green leafhopper *N. malayanus*	30	26	86.7
Zigzag leafhopper *Recilia dorsalis*	422	218	51.7
Striped stem borer *Chilo suppressalis*	243	13	5.3
Yellow stem borer *Scirpophaga incertulas*	322	70	21.7
Leaffolder *Cnaphalocrocis medinalis*	338	8	2.4
Whorl maggot *Hydrellia philippina*	339	7	2.1
Caseworm *Nymphula depunctalis*	304	0	0.0
Thrips *Stenchaetothrips biformis*	85	12	14.0

[a] Damage ratings of 0 to 3.

caseworm have been identified in either the *O. sativa* or wild rice collection. Some accessions are resistant to four hopper species (Table 3). Thirteen accessions consisting of six species are highly resistant to the striped stem borer (SSB) (Table 4).

NATURE OF RESISTANCE

Entomology Department

IR variety insect resistance. We evaluated varieties IR5 to IR62 against 15 rice insect pests. Many of the varieties are resistant or moderately resistant to BPH *Nilaparvata lugens* and GLH species *Nephotettix virescens*, *N. nigropictus*, and *N. malayanus* (Table 5). Several varieties are moderately resistant to the yellow stem borer *Scirpophaga incertulas* and the striped stem borer *Chilo suppressalis*. None resists the leaffolders *Cnaphalocrocis medinalis* and *Marasmia patnalis*, caseworm *Nymphula depunctalis*, or the rice bug *Leptocorisa oratorius*.

Resistance to black bug. In 1983 we screened 300 breeding lines for resistance to black bug *Scotinophara coarctata* in fields in Palawan, Philippines. Twenty lines were selected and retested in 1984 dry season (DS). In both tests, IR13149-71-3-2 and IR10781-75-3-2-2 had the lowest damage rating. In 1984, these lines rated 5 (wilting of more than 2 leaves and pronounced yellowing of the first, second, and third oldest leaves) while the susceptible local check Tjeremas rated 9 (all plants dead) (Table 6).

In 1984 wet season (WS), the 6 best lines from DS were tested to determine the effect of bug population levels of 0, 4, 10, 20, and 40 per hill. Insect feeding reduced yields least in IR13149-71-3-2.

Caseworm development on traditional and modern varieties. In a test of selected modern and traditional varieties as hosts for rice insects, the traditional variety Intan was the poorest host for caseworm. Caseworm fecundity, weight and population growth (Table 7) were lowest on traditional variety Intan, and male-to-female ratio was highest increasing from 1.0 in the 1st to 2.1 in the 5th generation.

Leaffolder resistance. Of more than 20,000 germplasm collection varieties screened since 1979, 117 show resistance to the leaffolder. In 1984, studies on mechanisms of resistance in selected varieties, resistance based on plant damage ratings,

Table 3. Accessions of wild rices resistant or moderately resistant to all hopper species[a] tested. IRRI, 1984.

Accession no.	Species name	Origin
100165	*O. latifolia*	Guatemala
100957	*O. malampuzhaensis*	India
101389	*O. malabarensis*	India
101405	*O. grandiglumis*	Taiwan
101425	*O. eichingeri*	Uganda
101426	*O. eichingeri*	Uganda
101754	*Oryza* sp.	Senegal
102383	*O. officinalis*	Indonesia
102460	*Oryza* sp.	Bangladesh
103285	*O. officinalis*	Indonesia
103286	*O. officinalis*	Indonesia
103303	*O. australiensis*	Australia
103318	*O. australiensis*	Australia
103410	*O. collina*	Sri Lanka
103414	*O. collina*	Sri Lanka
103417	*O. collina*	Sri Lanka
103421	*O. collina*	Sri Lanka
103424	*O. officinalis*	Indonesia
103425	*O. officinalis*	Indonesia
103865	*O. minuta*	Philippines
103874	*O. minuta*	Philippines
103875	*O. minuta*	Philippines
103880	*O. minuta*	Philippines
103881	*O. minuta*	Philippines
103882	*O. minuta*	Philippines
103876	*O. minuta*	Philippines
103877	*O. minuta*	Philippines
103878	*O. minuta*	Philippines
103879	*O. minuta*	Philippines
103887	*O. punctata*	Tanzania
103888	*O. punctata*	Tanzania
103889	*O. punctata*	Tanzania
103896	*O. punctata*	Tanzania
103897	*O. punctata*	Tanzania
103903	*O. punctata*	Tanzania
104059	*O. punctata*	Africa
104090	*O. australiensis*	Australia
104305	*O. longistaminata*	Guinea-Bissau

[a]Brown planthopper, green leafhopper, whitebacked planthopper, and zigzag leafhopper.

Table 4. Wild rice accessions resistant to SSB *Chilo suppressalis* Wlk. IRRI, 1984.

Accession no.	Species name	Origin
101079	*Oryza minuta*	Philippines
101137	*O. officinalis*	Philippines
101074	*O. officinalis*	Philippines
101133	*O. minuta*	Philippines
101417	*O. punctata*	Kenya
101154	*O. officinalis*	Malaysia
101141	*O. minuta*	Philippines
100122	*O. barthii*	Gambia
100894	*O. rufipogon*	India[a]
102172	*O. sativa* f. *spontanea*	India
103307	*O. rufipogon*	Taiwan
103796	*O. rufipogon/O. nivara*	Burma
103827	*O. rufipogon*	Bangladesh

[a]Seed source — origin not known.

Table 5. Resistance of IR varieties to insect pests.[a] IRRI, 1984.

Variety[b]	Maturity (DAS)	BPH biotypes			GLH		WBPH	ZL	YSB	SSB	RWM	Thrips	Black bug
		1	2	3	*N. virescens*	*N. nigropictus*							
IR5	130	S	S	S	MR	MR	S	S	S	S	S	S	S
IR8	125	S	S	S	MR	MR	S	S	S	S	S	S	S
IR20	121	S	S	S	MR[c]	MR	S	S	MR	R	S	S	S
IR22	119	S	S	S	S	MR	S	S	S	S	S	S	S
IR24	118	S	S	S	MR	MR	S	S	S	S	S	S	S
IR26	121	R	S	R	MR	R	S	S	S	MS	S	S	MR
IR28	104	R	S	R	R	R	S	S	S	S	S	S	S
IR29	112	R	S	R	R	R	S	S	S	S	S	S	MR
IR30	105	R	S	R	R	R	S	S	S	MR	S	S	S
IR32	130	R	R	MR[d]	MR	MR	S	S	S	MR	S	S	S
IR34	122	R	S	R	R	MR	S	S	S	MR	S	S	S
IR36	110	R	R	MR[d]	MR	R	S	S	MR	R	MR	S	S
IR38	123	R	R	MR[d]	MR	MR	S	S	S	MR	S	S	S
IR40	130	R	MR	S	MR	MR	S	S	MR	R	MR	S	S
IR42	132	R	R	S	MR	MR	S	S	S	MR	S	S	S
IR43	120	S	S	S	MR	R	S	S	S	MR	S	S	S
IR44	123	R	R	MR[d]	MR	R	S	S	S	R	S	S	S
IR45	120	R	S	R	MR	MR	S	S	S	S	S	S	S
IR46	112	R	S[e]	R	MR[c]	MR	S	S	S	S	S	S	S
IR48	127	R	R	S	MR	MR	MR	S	S	S	S	S	S
IR50	107	R	MR	R[d]	R	MR	S	S	MR	R	S	S	S
IR52	117	R	R	MR[d]	R	MR	MR	S	S	MR	S	S	S
IR54	120	R	R	S	R	MR	S	S	MR	MR	S	S	S
IR56	106	R	R	R	R	R	S	MR	S	MR	S	S	S
IR58	108	R	R	R	R	R	S	MR	S	MR	S	MR	MR
IR60	110	R	R	R	R	R	MR	S	S	MR	S	MR	S
IR62	110	R	R	R	R	—[f]	MR	MR	S	MR	S	R	MR

[a] Based on replicated experiments. Hopper resistance based on greenhouse evaluation of seedlings; yellow (YSB) and striped stem borer (SSB) resistance based on a screenhouse evaluation of 40- to 70-d-old plants; leaffolder (LF) and caseworm (CW) resistance based on the reaction of 30- and 11-d-old plants in the greenhouse; whorl maggot (RWM) resistance based on field observations at 30 d after transplanting. Varieties with ratings based on the Standard Evaluation System for Rice scale of 1-3 are considered resistant (R); 5-7, moderately resistant (MR); and 9, susceptible (S). WBPH = whitebacked planthopper, ZL = zigzag leafhopper. [b] All entries except IR5, IR43, and IR62 were R to *Nephotettix malayanus,* and tests for the three are still to be conducted. All entries are S to leaffolders *C. medinalis* and *M. patnalis,* except that IR62 is still to be tested for *M. patnalis.* All entries are S to caseworm *N. depunctalis* and rice bug *L. oratorius.* [c] Occasional S reactions. Least resistant of the IR varieties except for IR22 which is highly S. [d] Reaction to biotype varies, occasionally S and often R. [e] Has field resistance to biotype 2. [f] Tests still to be conducted.

was related to lower rates of oviposition and survival compared to those of the susceptible check TN1 (Table 8).

Cross resistance to two leaffolder species. Recently, leaffolder species *Marasmia patnalis*, which causes damage identical to that of the common leaffolder *Cnaphalocrocis medinalis,* was found abundant in fields in Laguna Province. Varieties previously known to be moderately resistant or susceptible to *C. medinalis* were screened to determine resistance to the two leaffolder species. The two species damaged plants similarly, indicating that varieties tested which were moderately resistant to *C. medinalis* were also moderately resistant to *M. patnalis* (Table 9). Breeding for resistance to *C. medinalis* using those varieties as donors should provide resistance to *M. patnalis*.

Green leafhopper feeding and growth on varieties. Feeding of GLH females on nine genetically diverse rice varieties was monitored with an electronic recording device. Tested were GLH-resistant Pankhari 203 (*Glh 1*), ASD7 (*Glh 2*), IR8 (*Glh 3*), Ptb8 (*glh 4*), ASD8 (*Glh 5*), IR36 (*Glh 6*), Moddai Karuppan (*Glh 7*), the highly resistant IR29 (resistance gene not identified), and the susceptible TN1 (no resistance gene). Distinct differences in waveforms for probing, salivation, phloem feeding, and xylem drinking were recorded on resistant and

Table 6. Reaction of selected breeding lines to black bug.[a] Palawan, Philippines, 1984 DS.

Line or variety[b]	Black bugs (no./hill) 20 DI	Plant reactions[c] at indicated days after infestation (DI)	
		40	60
IR13149-71-3-2	149.0 abc	4.0 a	5.0 a
IR10781-75-3-2-2	132.8 ab	4.0 a	5.5 a
IR18350-175-2-3	155.0 abc	5.5 ab	7.5 ab
BG379-1	200.0 c	5.5 ab	8.0 b
IR19661-23-3-2-2	125.8 ab	5.5 ab	8.0 b
IR12721-24-3-1	172.8 bc	6.5 abc	8.0 b
BW295-4	128.8 ab	7.5 cdef	8.0 b
BR316-15-4-4-1	130.8 ab	6.0 abc	8.5 b
BR445-60-1b	161.8 bc	7.0 bcdef	8.5 b
IR13240-108-2-2-3	134.5 ab	7.0 bcdef	8.5 b
IR25774-3-1-1	169.0 bc	7.0 bcdef	8.5 b
IR36 (check)	167.0 bc	7.0 bcdef	8.5 b
BG400-1	133.8 ab	8.5 g	9.0 c
B2791b-Mr-257-3-2	144.8 abc	6.5 abc	9.0 c
B3981c-Pn-200-2-2	97.0 a	8.5 g	9.0 c
Cul. 6914	169.8 bc	8.5 g	9.0 c
IR2979-24-1	133.3 ab	7.0 bcdef	9.0 c
IR13415-9-3	161.0 bc	7.0 bcdef	9.0 c
C1754-5	121.1 ab	7.5 cdef	9.0 c
IR31917-31-3-2	148.5 abc	8.0 def	9.0 c
Tjeremas (green base local check)	203.0 c	7.5 cdef	9.0 c

[a] Av of 4 replications. [b] Breeding lines selected from the 300 test entries screened in Jul-Dec 1983. [c] Scale of 0-9: 0-3 = resistant, 4-6 = moderately resistant, 7-9 = susceptible.

Table 7. Population growth of caseworm starting with 5 pair of moths each generation.[a] IRRI, 1984.

Variety	Adults emerging (no./generation)				
	I	II	III	IV	V
IR20	150 a	281 c	156 bc	182 b	220 c
IR36	152 a	285 c	180 bc	328 c	234 c
IR50	156 a	290 c	238 c	160 b	195 c
Intan	139 a	93 a	95 a	36 a	51 a
Peta	142 a	168 b	104 b	41 a	79 b
Utri Rajapan	141 a	165 b	138 bc	45 a	101 bc

[a] Mean of 4 replications. I-V = 1st to 5th generation.

susceptible plants (Table 10). GLH primarily were phloem feeders on susceptible TN1 plants but xylem drinkers on resistant ones (Fig. 1). GLH females made significantly more brief probes on resistant varieties than on TN1. However, duration of salivation did not correlate with resistance. Parallel bulk seedling screening and the insect's growth (Table 11) indicated the phloem ingestion period is the best criterion for evaluating resistance to GLH and its transmitted tungro (RTV) virus. Thus, electronic monitoring can help germplasm evaluation against sucking insects and diseases they transmit.

Efficiency of two green leafhopper species as tungro virus vectors. *N. virescens* was a more efficient vector of RTV than *N. malayanus* (Fig. 2). Forty-eight percent GLH-susceptible TN1 plants were infected by viruliferous *N. virescens* and only 30% by *N. malayanus*. On IR42, infection was 33% with *N. virescens* and 0% with *N. malayanus*.

Table 8. Varietal resistance of selected accessions to the rice leaffolder.[a] IRRI, 1984.

Variety	Accession no.	Damage rating indices	Eggs (no.)		Larval survival (%)
			Free choice	No choice	
CO 7	6041	2.6 ab	45 c	166 a	28 bcd
ASD7	6303	4.6 bc	50 de	142 a	22 bcd
ARC5752	12119	7.4 de	31 cd	198 a	26 bcd
Yakadayan	36408	5.8 cd	36 cd	152 a	22 bcd
IR5685-26-1-9	39433	4.6 bc	29 cd	168 a	20 ab
BK116-3B-18	39558	1.4 a	28 ab	236 a	34 bcd
Hata Pandaca	40804	2.6 ab	28 ab	188 a	32 bcd
Shete	46671	9.0 e	37 cd	149 a	38 cd
TKM6 (resistant check)	–	1.4 a	20 a	193 a	16 a
TN1 (susceptible check)	–	9.0 e	57 e	374 b	50 d

[a] Av of 5 replications.

Table 9. Greenhouse screening of rice varieties for rice leaffolder resistance. IRRI, 1984.

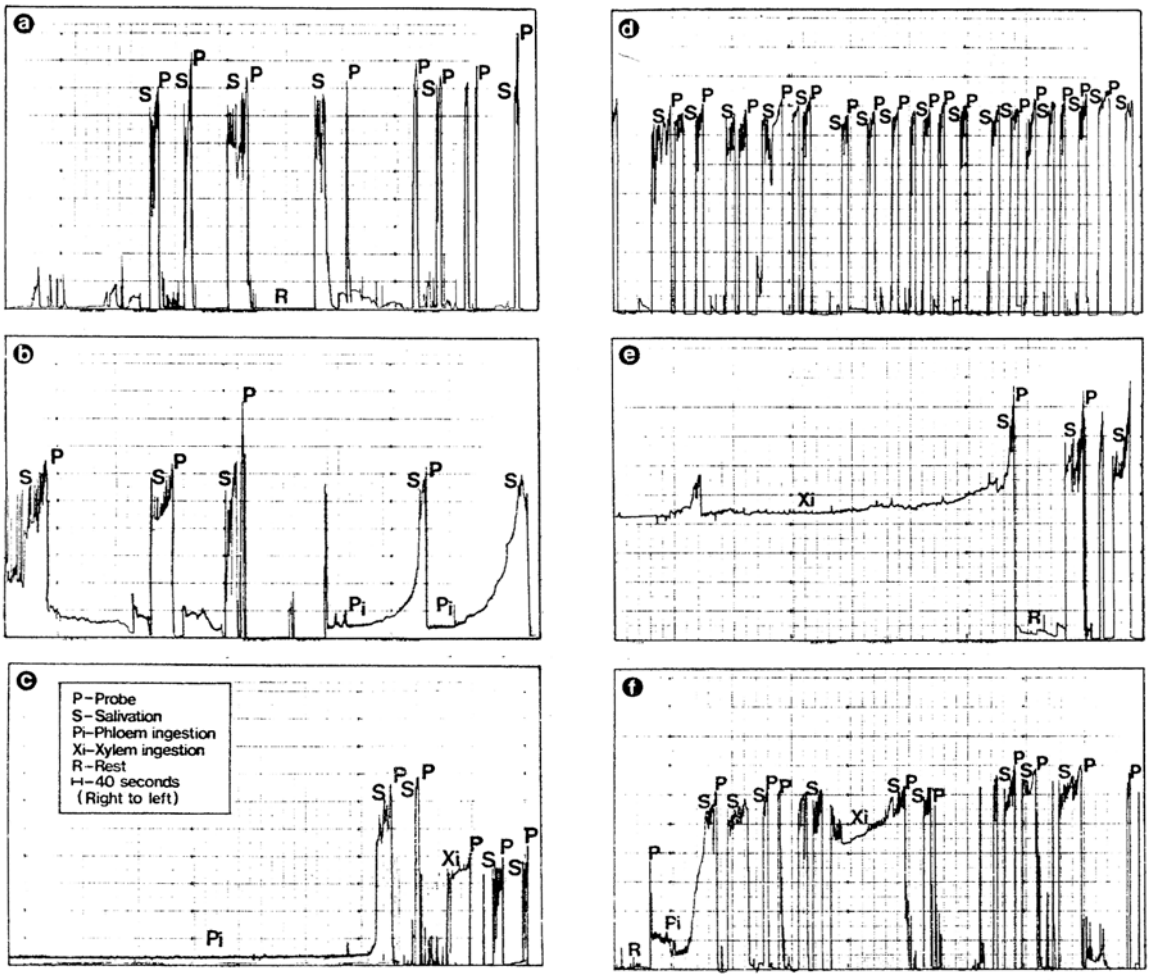
Variety	Accession no.	Origin	Leaf damage[a] (%)			
			C. medinalis		*M. patnalis*	
			Damage rating	Scale[b]	Damage rating	Scale[b]
TN1	105	Taiwan	27.3 d	–	25.5 f	–
ARC6650	12308	India	22.0 cd	9	22.4 ef	9
IR36	1187	Philippines	21.0 cd	9	22.3 ef	9
Shete	46671	India	21.1 cd	9	20.1 def	9
ARC5752	12119	India	20.6 cd	9	19.1 cdef	9
ARC10560	20992	India	19.8 cd	7	19.8 def	9
ARC10550	12507	India	19.7 cd	7	19.0 cdef	7
BKN-BR 1008-21	–	Thailand	22.0 cd	9	15.1 abcdef	7
Khao-rad	48069	Thailand	17.4 abc	7	19.2 cdef	7
Balam	49020	Bangladesh	16.0 abc	7	19.6 def	9
Calixto	47166	Philippines	21.8 cd	9	13.6 abcdef	7
Khao-Ma Khaek	47852	Thailand	18.1 abc	7	17.0 bcdef	7
IR5685-26-1	39433	Philippines	19.0 bcd	7	15.5 abcd	7
Gorsa	49088	Bangladesh	16.3 abc	7	17.8 cde	7
Karpur Kanti	46048	India	15.6 abc	7	17.9 cde	7
Bora	49157	Bangladesh	16.3 abc	7	15.2 abcdef	7
Biron	49154	Bangladesh	17.7 abc	7	13.5 abcdef	7
Yakadayan	36408	Sri Lanka	17.1 abc	7	13.3 abcdef	7
Muthumanikam	15327	Sri Lanka	18.1 abc	7	12.3 abcd	5
Vashaipoo Samba	–	India	14.8 abc	7	13.8 abcdef	7
CO 7	6041	India	12.9 abc	5	15.2 abcdef	7
ASD7	6303	India	16.5 abc	7	11.6 abcd	5
Kataribhog	46076	India	14.3 abc	7	12.9 abcd	7
W1263	11657	India	15.9 abc	7	10.7 abc	5
Ptb 33	19325	India	12.9 abc	5	13.3 abcdef	7
ASD5	5812	India	13.4 abc	5	11.6 abc	5
TKM6	237	India	13.3 abc	5	10.1 abc	5
IR4707-106-3-2	47459	Philippines	9.6 a	5	13.4 abcdef	7
Darukasail	45493	India	14.9 abc	7	7.9 a	5
GEB24	5909	India	9.7 ab	5	8.7 ab	5
Mean			17.2		15.6	

[a] Av of 6 replications. [b] Scale 0-9: 0-3 = resistant, 4-6 = moderately resistant, 7-9 = susceptible.

Table 10. Means of electronically recorded events during 180-min feeding by *N. virescens* on selected resistant and susceptible varieties. IRRI, 1984.

Variety	Electronically recorded events[a]				Tungro disease rating[b]
	Probes (no.)	Salivation (min)	Xylem drinking (min)	Phloem feeding (min)	
IR29	71 b	16.6 b	25.0 bcd	0.0 a	I
ASD7	108 c	23.5 cd	21.6 ab	0.4 a	I
Pankhari 203	78 b	20.6 bc	33.7 e	0.7 b	I
IR36	122 c	30.3 d	30.4 d	1.3 bc	S
IR8	111 c	21.5 cd	19.5 ab	1.6 bc	S
Ptb8	109 c	13.5 a	27.2 cd	3.3 bcd	S[c]
Moddai Karuppan	109 c	19.8 b	21.8 abcd	4.0 cde	S
ASD8	81 b	20.1 bc	19.9 abc	6.0 de	I
TN1 (susceptible check)	25 a	13.2 a	11.0 a	31.8 e	S

[a]Av of 10 replications, each replication using a new insect and a new plant. [b]Tungro disease rating from IRRI greenhouse was provided by H. Hibino, virologist. I = intermediate, S = susceptible. [c]Data from Heinrichs and Rapusas (1983).

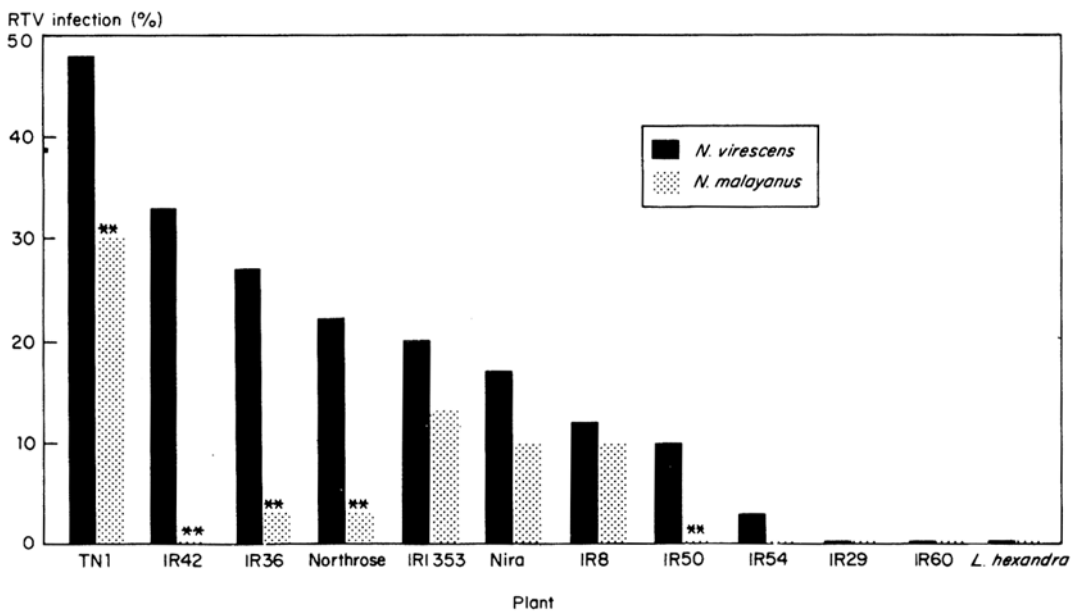


1. Waveforms recorded during GLH feeding on susceptible TN1 (a, b, c) and resistant Pankhari 203 (d, e, f) using an electronic monitor. IRRI, 1984.

Table 11. Growth of GLH nymphs on susceptible and resistant rice plants.[a] IRRI, 1984.

Variety	Nymphs becoming adults (%)	Developmental period (d)	Growth index[b]	Phloem feeding (min)	Insect damage rating[c]
IR29	8 a	21.5 b	0.4 a	0.0 a	3.8 b
ASD7	10 a	22.0 b	0.5 a	0.4 a	4.7 b
Pankhari 203	48 abc	23.6 b	2.0 b	0.7 b	4.0 b
IR36	75 cd	22.7 b	3.3 cd	1.3 bc	6.1 bc
IR8	70 bc	23.9 b	2.9 bc	1.6 bc	4.8 b
Ptb8	88 de	15.4 a	5.6 d	3.3 bcd	3.7 a
Moddai Karuppan	98 e	16.1 a	6.1 d	4.0 cde	3.3 a
ASD8	28 ab	23.5 b	1.2 a	6.0 de	5.1 b
TN1 (susceptible check)	93 de	13.8 a	6.7 d	31.8 e	9.0 c

[a] Av of 4 replications, each replication with 10 first-instar nymphs. [b] Percent nymphs becoming adult divided by mean developmental period (d). [c] Av of 5 replications. Scored on a 0-9 scale: 0 = highly resistant, 9 = highly susceptible.



2. Percentage of tungro (RTV)-infected plants after feeding of vector GLH species *N. virescens* and *N. malayanus*. IRRI, 1984.

Neither species could inoculate highly resistant IR29 and IR60, or the weed *L. hexandra*, a host of *N. malayanus* but not of *N. virescens*.

Tungro virus and green leafhopper feeding. GLH damage, rated by the seedbox screening of seedlings, is positively related to RTV infection in varieties tested. When exposed to viruliferous GLH, varieties most susceptible to GLH were also most susceptible to RTV.

In a study of the relationship between GLH feeding rate, number of feeding punctures, and RTV infection on resistant, moderately resistant, and susceptible varieties, feeding punctures were least on the susceptible variety under sustained feeding (Table 12). Although total honeydew excreted was equal on all varieties, amount of basic honeydew, indicating phloem feeding, was 100% on the susceptible variety and only 10% on resistant. Feeding punctures and total feeding were not correlated with RTV infection, but percent basic

Table 12. Feeding punctures, honeydew excretion, and RTV infection by *N. virescens*. IRRI, 1984.

Variety[a]	Feeding punctures (no.)	Total area of honeydew spots (mm^2)	Area of basic honeydew spots (%)	RTV infection (%)
IR8 (MR)	82 ab	188 a	49 b	76 c
IR24 (MR)	125 d	179 a	52 b	71 c
IR40 (MR)	110 c	172 a	43 b	43 b
IR29 (R)	88 bc	197 ab	10 a	14 a
IR22 (S)	45 a	228 b	100 c	99 d

[a]MR = moderately resistant, R = resistant, S = susceptible.

honeydew was. Apparently xylem feeding (acidic honeydew) does not result in RTV infection, but phloem feeding can.

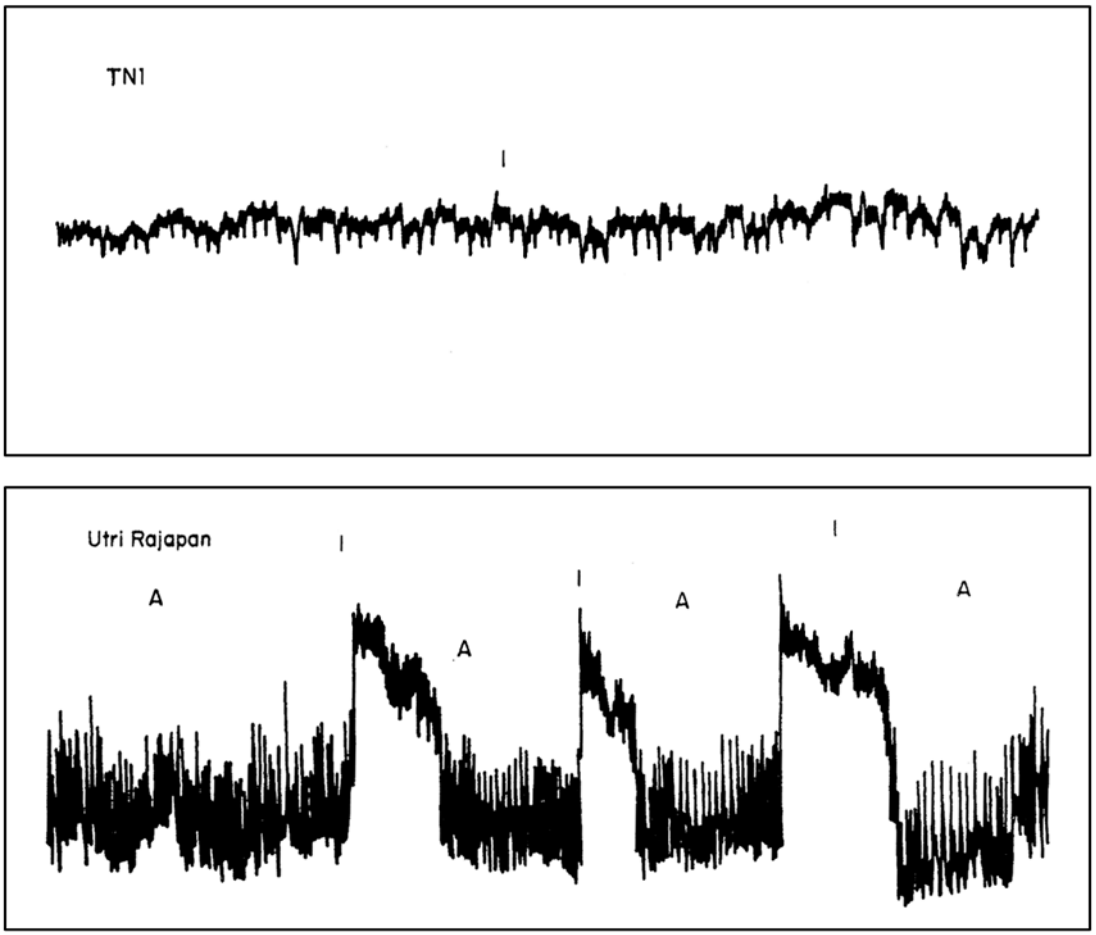
Seedbox screening technique for brown planthopper on moderately resistant varieties. We currently use the standard seedbox screening technique (SSST) to identify varieties that highly resist BPH. We are also interested in identifying varieties with moderate resistance as they may have minor genes providing moderate resistance to all biotypes (horizontal resistance). Therefore we modified the SSST (MSST) by using fewer BPH to infest each seedling and infesting 20-d-old rather than 7-d-old plants. In the SSST, the test insects kill the plants; in the MSST, progeny of the test insects kill the plants. SSST damage ratings are taken when the susceptible check dies, usually at 7 d after infestation (DI); MSST ratings are taken at about 25 DI. When we used MSST, varieties such as ASD11, Utri Rajapan, and IR36 as older plants had high resistance to BPH biotype 3; with SSST, seedlings were rated moderately resistant at 7 DI and susceptible at 12 DI (Table 13).

Feeding of brown planthopper biotype 3 on Utri Rajapan. In 1982, Utri Rajapan had a high level of tolerance for BPH biotypes 1, 2, and 3 and had moderate levels of antibiosis to biotypes 1 and 3. In 1984 we electronically measured the feeding of biotype 3. Waveforms of hoppers feeding on Utri Rajapan were compared with those of hoppers

Table 13. Resistance of rice varieties to BPH biotype 3 in the standard seedbox screening technique (SSST) and the modified seedbox screening technique (MSST). IRRI greenhouse, 1984.

Variety	Resistance rating[a]			
	SSST		MSST	
	7 DI	12 DI	25 DI	30 DI
ASD11	5.4 c	9.0 c	1.0 a	1.0 a
GEB24	9.0 d	9.0 c	9.0 b	9.0 b
V. P. Samba	9.0 d	9.0 c	9.0 b	9.0 b
CO 29	9.0 d	9.0 c	9.0 b	9.0 b
CO 32	9.0 d	9.0 c	9.0 b	9.0 b
Peta	9.0 d	9.0 c	9.0 b	9.0 b
Intan	9.0 d	9.0 c	9.0 b	9.0 b
Utri Rajapan	5.4 c	9.0 c	1.0 a	1.0 a
Binato	9.0 d	9.0 c	9.0 b	9.0 b
Raminad	9.0 d	9.0 c	9.0 b	9.0 b
IR36	5.0 c	9.0 c	1.0 a	1.0 a
IR42	5.0 c	9.0 c	1.0 a	1.0 a
IR46	1.8 b	3.0 b	1.0 a	1.0 a
IR56 (resistant check)	1.0 a	1.4 a	1.0 a	1.0 a
IR60	1.0 a	1.4 a	1.0 a	1.0 a
ASD7 (susceptible check)	9.0 d	9.0 c	9.0 b	9.0 b

[a]1-3 = resistant, 5 = moderately resistant, 7-9 = susceptible, DI = d after infestation.



3. Feeding patterns of BPH biotype 3 on susceptible TN1 and on moderately resistant Utri Rajapan. Continuous ingestion (I waveform) is interrupted (A waveform) on Utri Rajapan. IRRI, 1984.

feeding on susceptible TN1. Ingestion was continuous in TN1. In Utri Rajapan, ingestion was repeatedly interrupted (Fig. 3). The A waveform indicates interruption.

Nitrogen fertilizer levels and brown planthopper populations. The effect of N levels on relative rice resistance to BPH biotype 2 was tested. Populations when N fertilizer was not added to the paddy soil were equal for the susceptible IR26 and Utri Rajapan and moderately resistant Triveni. When N levels were increased to 100 or 200 kg N/ha, populations increased significantly on IR26 and Utri Rajapan, but only modestly on Triveni. N level did not significantly affect BPH population levels on IR60, which retained its high level of BPH resistance even at high N levels.

Whitebacked planthopper responses to varieties. Various behavioral and physiological responses involved in whitebacked planthopper (WBPH) establishment on rice varieties with diverse resistance genes were investigated. The varieties tested were resistant Mushkan 41 (*Wbph 1*), N22 (*Wbph 1*), N32 (*Wbph 1*), ARC10239 (*wbph 2*), ADR52 (*Wbph 3*), Podiwi A8 (*wbph 4*), WC1240 (*Wbph 1* + 1 recessive ?), Colombo (*wbph 2* + 1 recessive ?), IR2035-117-3 (*Wbph 1* + *wbph 2*), and susceptible TN1 (no resistance gene). In a free-choice test, WBPH females were attracted equally to resistant and susceptible varieties, but after 8 h, significantly more WBPH settled on susceptible TN1 plants than on resistant varieties. WBPH females ate and assimilated significantly less on resistant varieties

than on susceptible TN1. They also grew better on TN1 plants than on resistant varieties. Significantly lower adult survival and fecundity, egg hatchability, and population increase were observed on resistant plants than on susceptible TN1; however, oviposition was similar. IR2035-117-3 was least suitable for WBPH establishment, and Podiwi A8 had the poorest resistance (Table 14).

Resistance to whitebacked planthopper in varieties with monogenic and digenic resistance. Varieties having one or two major genes for WBPH resistance were evaluated to determine the effect of gene number on WBPH growth and development. Varieties tested differed distinctly in resistance, as indicated by adult recovery, nymphal period, growth index, and population growth. However, resistance was not related to gene number (Table 15). IR2035-117-3 with two genes had the highest resistance while NP130 with the same genes had low resistance.

Table 14. Relative intensity of responses of WBPH to resistant and susceptible rice varieties.[a] IRRI, 1984.

Variety	Intensity of response at each establishment stage									
	Orientation (1 h after release)	Settling (48 h after release)	Food intake	Food utilization	Growth (growth index)	Survival		Fecundity	Oviposition	Egg hatchability
						Male	Female			
ADR52	1.2	0.2	0.4	0.3	0.5	0.5	0.2	0.2	0.8	0.4
ARC10239	0.9	0.2	0.2	0.2	0.4	0.5	0.2	0.3	1.0	0.4
Colombo	0.9	0.2	0.2	0.3	0.3	0.5	0.2	0.3	0.8	0.3
IR2035-117-3	0.9	0.1	0.1	0.1	0.2	0.4	0.2	0.1	0.9	0.4
Muskhan 41	1.0	0.2	0.3	0.2	0.4	0.6	0.3	0.4	1.0	0.4
N22	1.1	0.2	0.6	0.5	0.4	0.6	0.3	0.3	0.9	0.5
N32	1.0	0.2	0.3	0.2	0.2	0.4	0.2	0.3	0.9	0.4
Podiwi A8	1.1	0.3	0.7	0.7	0.6	0.7	0.4	0.5	1.0	0.7
WC1240	1.0	0.2	0.2	0.3	0.5	0.5	0.2	0.3	0.9	0.4
TN1 (susceptible check)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[a]Calculated as the ratio between each WBPH response to a test plant and to the susceptible check TN1. The lower the number, the greater the test variety resistance to WBPH compared to that of TN1.

Table 15. Adult recovery, nymphal period, growth index, and population growth of WBPH on different rice varieties.[a] IRRI, 1984.

Variety	Genes	Adult recovery (%)	Nymphal period (d)	Growth index[b]	Population growth (progeny/female)
N22	*Wbph 1*	76.7 bcd	11.6 bcd	6.57 bcd	19 ab
ARC10239	*Wbph 2*	63.3 abc	11.8 bcde	5.40 abc	54 cde
ADR52	*Wbph 3*	66.7 abcd	11.5 bcd	5.85 bc	25 bc
Podiwi A8	*wbph 4*	71.7 abcd	11.2 b	6.41 bcd	89 e
N'Diang Marie	*Wbph 5*	76.7 bcd	11.1 b	6.87 bcd	35 bcd
IR2035-117-3	*Wbph 1 + Wbph 2*	50.0 a	13.4 e	3.81 a	7 a
NP130	*Wbph 1 + Wbph 2*	80.0 bcd	11.4 bc	7.03 cd	28 bc
CI 5662-2	*Wbph 1 + Wbph 2*	76.7 bcd	11.3 bc	6.76 bcd	33 bcd
ARC5752	*Wbph 1 + Wbph 2*	68.3 abcd	12.0 cde	5.74 bc	42 bcde
Chaia Anaser	*Wbph 1 + Wbph 3*	76.7 bcd	11.8 bcde	6.51 bcd	63 de
Katuyjar Dhan	*Wbph 1 + Wbph 3*	59.3 ab	11.6 bcd	5.15 ab	64 de
Colombo	*Wbph 2* + 1 recessive	81.7 cd	12.2 de	6.70 bcd	13 ab
368	*Wbph 1* + 1 recessive	68.3 abcd	11.8 bcde	5.83 bc	35 bcd
WC1240	*Wbph 1* + 1 recessive	65.0 abcd	11.7 bcd	5.51 bc	27 bc
65	*Wbph 1* + 1 recessive	75.0 bcd	11.1 b	6.76 bcd	55 de
274A	*Wbph 1* + 1 recessive	65.0 abcd	11.4 bc	5.72 bc	39 bcd
TN1	—	85.0 d	11.0 a	7.71 d	88 e

[a]Av of 10 replications. [b]Survival/mean growth period in days.

Table 16. Ovipositional response of BPH, WBPH, and GLH, and hatchability of their eggs on plants of susceptible and resistant rice varieties.[a] IRRI, 1984.

Variety	Resistance genes	Eggs laid (no./5 females in 24 h)	Eggs hatched (%)
	BPH		
ASD7	*bph 2*	138 a	69 a
IR8	none	134 a	88 b
IR20	none	130 a	86 b
IR26	*Bph 1*	135 a	72 a
Mudgo	*Bph 1*	142 a	69 a
Rathu Heenati	*Bph 3*	132 a	74 a
TN1	none	140 a	96 c
	WBPH		
ADR52	*Wbph 3*	111 a	39 c
ARC10239	*Wbph 2*	109 a	35 b
IR2035-117-3	*Wbph 1 + Wbph 2*	115 a	31 a
N22	*Wbph 1*	117 a	52 d
Podiwi A8	*wbph 4*	125 a	74 de
TN1	none	120 a	94 e
	GLH		
ASD7	*Glh 2*	97 a	65 b
ASD8	*Glh 5*	84 a	74 cde
IR8	*Glh 3*	85 a	70 bc
IR36	*Glh 6*	80 a	71 cd
Moddai Karuppan	*Glh 7*	99 a	78 de
Pankhari 203	*Glh 1*	87 a	64 a
Ptb 8	*glh 4*	82 a	80 de
TN1	none	92 a	95 e

[a] Av of 5 replications. In each replication, 5 gravid females were caged on a 30-d-old plant. For each insect, means in a column followed by the same letter are not significantly different ($P<0.05$) by Duncan's multiple range test.

Technique for locating planthopper and leafhopper eggs in plants. Eggs of BPH, WBPH, and GLH were revealed *in situ* in susceptible and resistant plants using a simple staining technique. Plants containing insect eggs were bleached in boiling water 5 to 7 min, kept in 95% ethyl alcohol 3 d, and then immersed in 1% aqueous acid fuchsin solution 2 d. Washing under running water differentiated stained eggs from destained plant tissue. Egg counts with a 20X binocular microscope showed BPH, WBPH, and GLH females laid eggs in all varieties; however, significantly fewer eggs hatched on resistant rice varieties than on susceptible ones (Table 16).

Yield losses in striped stem borer-resistant varieties. In a screenhouse test, varieties resistant, moderately resistant, and susceptible to SSB, based on deadheart counts, were evaluated for ability to yield despite infestation. First-instar larvae were infested at panicle emergence at rates of 0, 5, 10, and 20 larvae per hill. Yield loss in resistant IR36 ranged from 11% at 5 larvae to 24% at 20 larvae per hill, and susceptible IR36 losses ranged from 52 to 74% at 5 and 20 larvae per hill (Table 17). Results show that IR36, IR40, IR52, and IR54 maintain yields under severe borer infestation.

Plant age effect on yellow stem borer survival. Studies in 1983 WS indicated IR46 was susceptible to YSB at maximum tillering, resistant at panicle initiation and booting, and susceptible at flowering,

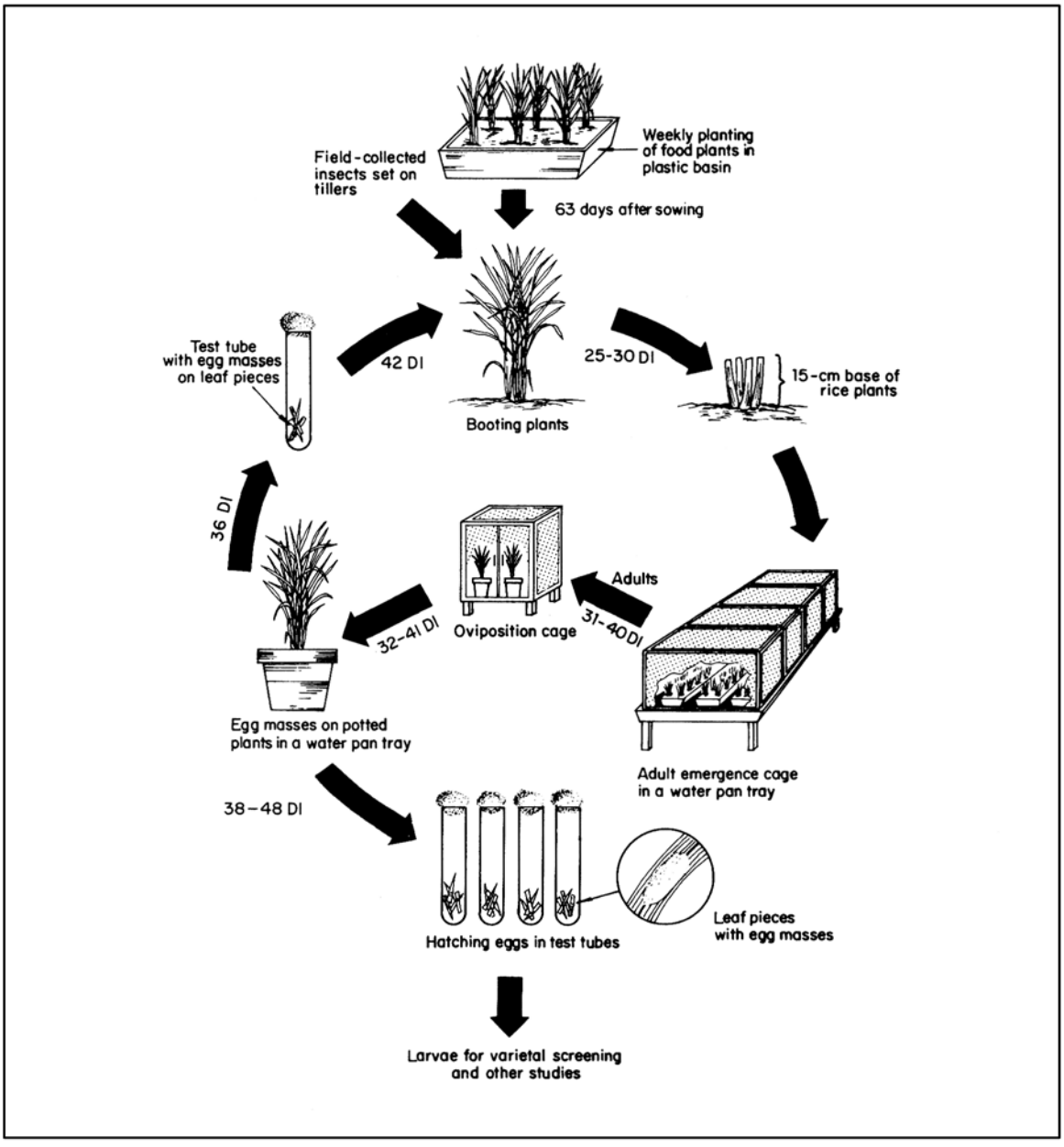
Table 17. Percent yield loss in varieties of varying levels of resistance under 3 levels of SSB infestation. IRRI, 1984.

Variety	Level of resistance[a]	Yield loss (%) at indicated number of larvae/hill		
		5	10	20
IR36	R	11.0	17.8	24.2
IR40	R	18.9	17.0	21.5
IR52	MR	11.2	20.9	26.3
IR54	MR	15.9	29.8	33.5
IR29	S	40.2	40.5	48.9
IR46	S	51.8	64.6	73.5

[a] Based on deadheart counts in previous studies. R = resistant, MR = moderately resistant, S = susceptible.

based on deadheart and whitehead counts. Results in 1984 show YSB survival to the adult stage on IR46 was lowest at panicle initiation and increased at booting and flowering.

Yellow stem borer rearing technique. It requires many larvae to hand-infest varieties and breeding lines. In screening for resistance to YSB, we developed a technique for rearing YSB in IR60 plants (Fig. 4). IR60 seedlings are planted weekly in a basin. At 63 d after sowing, 2 larvae are placed in a slit cut in each tiller. Infested plants are placed in a water pan tray. Larvae pupate 25-30 d after infestation (DI). Plants are then cut to 15 cm and enclosed in a cage where adults emerge at 31 to 40 DI. Adults



4. YSB rearing technique. IRRI, 1984.

are transferred to the oviposition cage. Egg masses are placed in test tubes at 36 DI and hatching larvae are used to maintain the culture. At 38-48 DI, eggs are placed in test tubes and hatching larvae are allowed to infest plants in screening tests. By weekly infesting 6 plants in each of 10 plastic basins, we can obtain enough larvae to weekly infest the plants in a 2.5- × 26-m bed.

CHEMICAL BASES OF RESISTANCE

Entomology and Cereal Chemistry Departments

Leaffolder feeding on extract of resistant varieties (*Entomology*). Larvae fed on TN1 leaves dipped in steam distillate extracts of rice varieties having varying levels of resistance to leaffolder. Extracts from all varieties killed more larvae than did the IR36 check. TKM6, Darukasail, IR5865, and Kataribhog performed best (Table 18). Extracts from Darukasail and ASD7 best reduced the hatchability of leaffolder eggs.

Table 18. Percent leaffolder *C. medinalis* larval mortality and unhatched eggs when treated with extracts of steam-distilled oils obtained from rice varieties. IRRI, 1984.

Variety	Accession no.	Larval mortality[a] (%)	Unhatched eggs[b] (%)
TKM6	237	46 a	18 abc
Darukasail	45493	42 a	30 a
IR5865	39433	39 ab	11 abc
Kataribhog	46076	39 ab	14 abc
IR60	63493	37 abc	14 abc
BKNBR1008-21	—	31 abc	13 abc
IR50	53433	23 abc	20 abc
W1263	11657	18 bc	9 bc
ASD7	6303	13 bc	26 ab
IR36 (susceptible check)	30416	9 c	5 c

[a]Larvae were fed TN1 leaves dipped in oil of a 2,000 ppm steam distillate extract from rice varieties. [b]Eggs laid on TN1 leaves were dipped in a 2,000 ppm extract of the steam distillate oil.

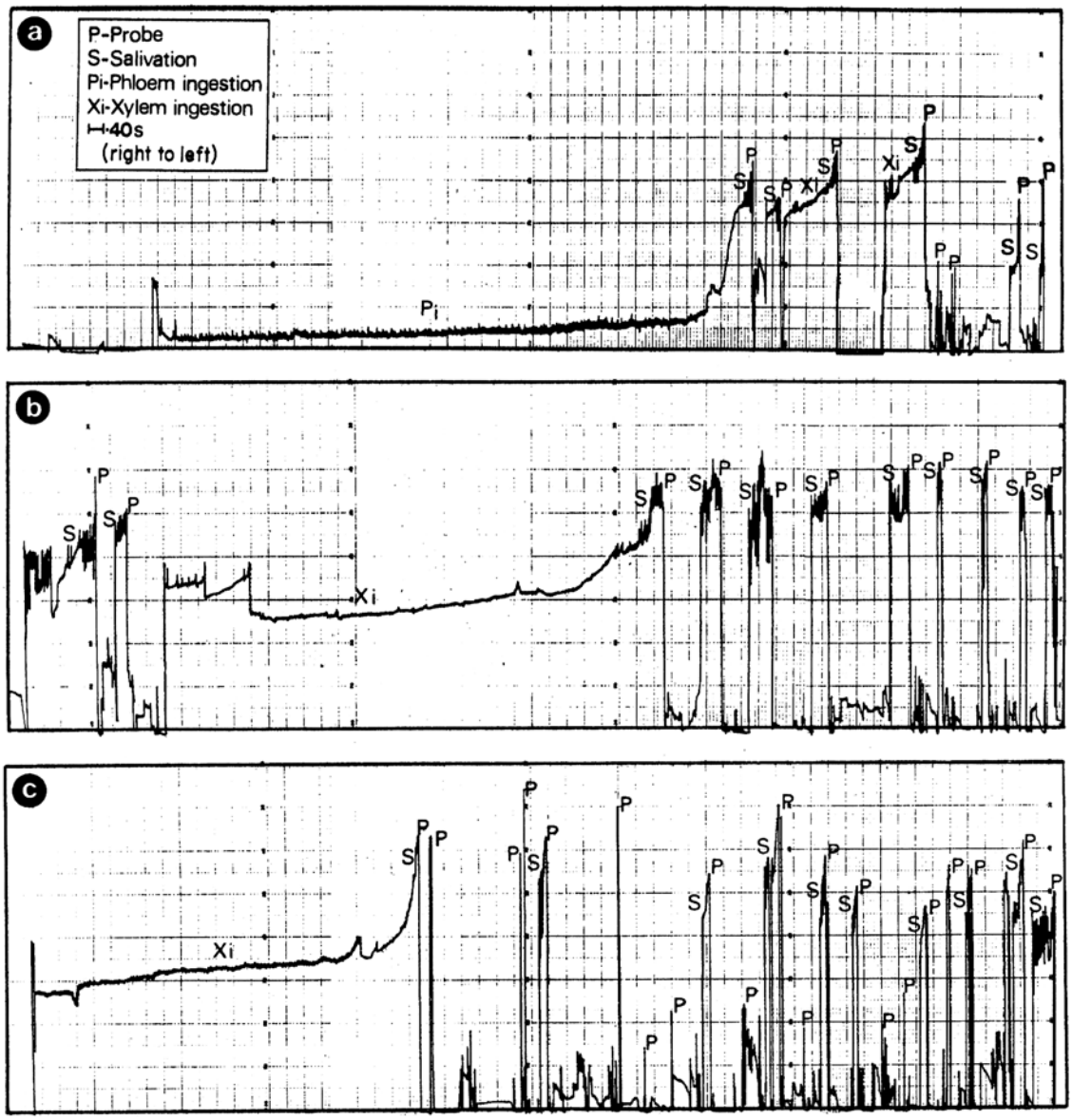
Green leafhopper feeding on extract of a resistant variety (*Entomology*). GLH primarily feeds on phloem on susceptible TN1, but drinks from xylem on resistant ASD7 plants. TN1 plants were sprayed with steam distillate extract of ASD7 plants, and feeding was monitored with an electronic device and a lignin-specific dye (Table 19, Fig. 5). Phloem feeding was significantly less on plants sprayed with ASD7 extract at 500, 1000, 2000, and 4000 ppm than on control TN1 plants sprayed with acetone-water mixture. The reduced phloem feeding on the extract-treated plants was associated with significantly more probing and longer salivation and xylem drinking.

Extraction of allelochemics from rice plants (*Entomology and Cereal Chemistry*). A procedure was developed to extract and concentrate large amounts of rice plant allelochemics. Because repellent and feeding deterrent factors were not detected in methanolic and aqueous extracts of rice plants, the procedure involved steam distillation and extraction with diethyl ether. Chopping of rice plants improved crude oil recovery from 0.06 to 0.16 mg/g fresh or frozen rice plants. The recovered oil was yellow and smelled sweet. For both BPH-susceptible (IR8) and resistant (IR26) rice plant extracts, silicic acid chromatography concentrated the active fractions better than did florisil and alumina. Activity of isolated fractions was monitored by a seedling dip bioassay against BPH

Table 19. Means of electronically recorded events during 180-min feeding period by GLH females on TN1 rice plants sprayed with different concentrations of steam distillate extract of ASD7.[a] IRRI, 1984.

Extract concn[b] (ppm)		Means of electronically recorded events			
		Probes (no.)	Salivation (min)	Phloem feeding (min)	Xylem drinking (min)
500		79 b	12.8 d	13.3 cd	12.5 a
1000		99 a	16.8 c	5.5 c	20.9 b
2000		104 a	17.7 c	2.6 b	28.7 c
4000		116 a	21.4 b	1.8 b	36.9 d
0 (susceptible check TN1 seedlings)[c]	Control	30 c	11.6 d	34.4 d	10.4 a
0 (resistant check ASD7 seedlings)[c]	Control	111 a	24.3 a	0.5 a	22.7 bc

[a]Av of 10 replications, each replication using a new insect and a new plant. [b]All concentrations were prepared in a mixture of acetone and water (4:1 parts). [c]Sprayed with acetone-water mixture (4:1 parts).



5. Electronically recorded waveforms during GLH feeding on a) susceptible TN1 and b) resistant ASD7 rice seedlings, both sprayed with acetone-water mixture (4:1 parts), and c) TN1 seedlings sprayed with 4,000 ppm steam distillate extract of ASD7 plants. IRRI, 1984.

biotype 1 nymphs and gas liquid (GLC) and thin-layer chromatograph (TLC). The most active fraction from silicic acid TLC of IR26 crude oil eluted between 100% hexane and hexane-diethyl ether (H/E) 80:20 by vol, indicating nonpolar compounds. Corresponding GLC patterns of silicic acid fractions showed effective separation and the sharpest peaks (4 in all) for the H/E 85:15 fraction. The 12.8 min peak was the major peak in the H/E 85:15 fractions of both IR8 and IR26. However, the split first peak was mainly the 9.8 min peak in IR26 and 10.1 in IR8.

BIOTYPES AND GENETIC CHARACTERISTICS

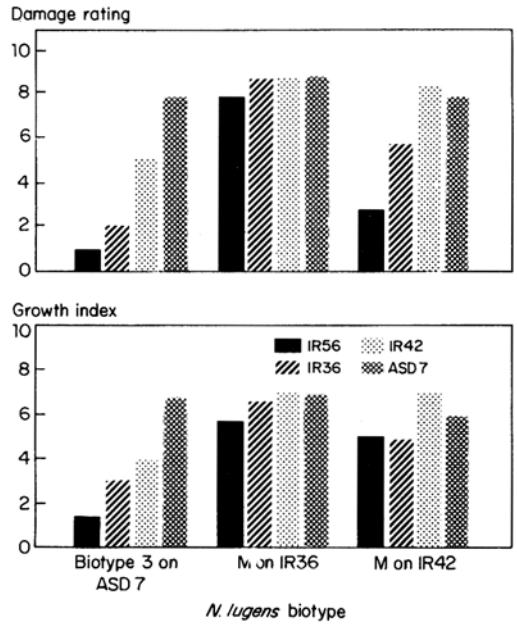
Entomology Department

Mindanao brown planthopper: damage and growth. BPH collected from IR56 in Mindanao,

southern Philippines, were reared in the greenhouse for 20 generations on IR36 and IR42. Damage ratings in the modified seedbox screening test and growth index of the Mindanao BPH were compared with those of biotype 3 reared for several years on ASD7 in the greenhouse. Damage on four varieties by the IR42 colony was similar to that by biotype 3. Damage ratings with IR36 colony were 8-9, indicating the four varieties were susceptible (Fig. 6). Growth index test results were similar except that IR42 BPH colony grew better on IR56, IR36, and IR42 than did that of biotype 3. Apparently, BPH which develop on IR36 are virulent to all varieties tested, whereas IR56 and IR36 are resistant to biotype 3 on ASD7.

Brown planthopper color morphs. Genetic plasticity of BPH enables it to survive in changing environments. By selective breeding in insectary-reared BPH populations, eight color morphs were produced at IRRI: orange, brownish-orange, brown, orange brown, dark brown, blackish brown, brownish black, and black. Dark brown, the body color of most wild BPH, is considered normal; the others are considered mutants.

Cytology of a grass-infesting planthopper. Two species of the genus *Nilaparvata* inhabit the Philippines. One, the BPH *N. lugens*, is a rice pest; the other, *N. bakeri*, feeds mainly on grass. We studied cytology of *N. bakeri* males collected from *Leersia hexandra* grass and compared it with *N. lugens*. Spermatocytes of newly emerged males were examined using the standard squash and staining techniques. The male genomic complement of *N. bakeri* was 2n=29 (14 IIA + XO), comprising 14 homomorphic bivalent autosomes and a univalent X-chromosome. Females had a diploid complement of 2n=30 (14 IIA + XX), comprising 14 homologous autosomes and a bivalent (XX) sex chromosome. At pachytene (Fig. 7c), the relative mean lengths of chromosomes ranged from 35.5 mm to 143.5 mm. At diakinesis (Fig. 7e), chromosomes reached maximum contraction. At later diakinesis (Fig. 7f), homomorphic chromosomes moved toward the center, forming an elongated cluster. Lengths (in μ) of the 14 synapsed homologs were 2.1, 2.4, 2.8, 3.0, 3.0, 3.1, 3.4, 3.7, 4.0, 4.0, 4.1, 4.4, 4.8, 4.8. The univalent sex chromosome was isolated from the autosomes.



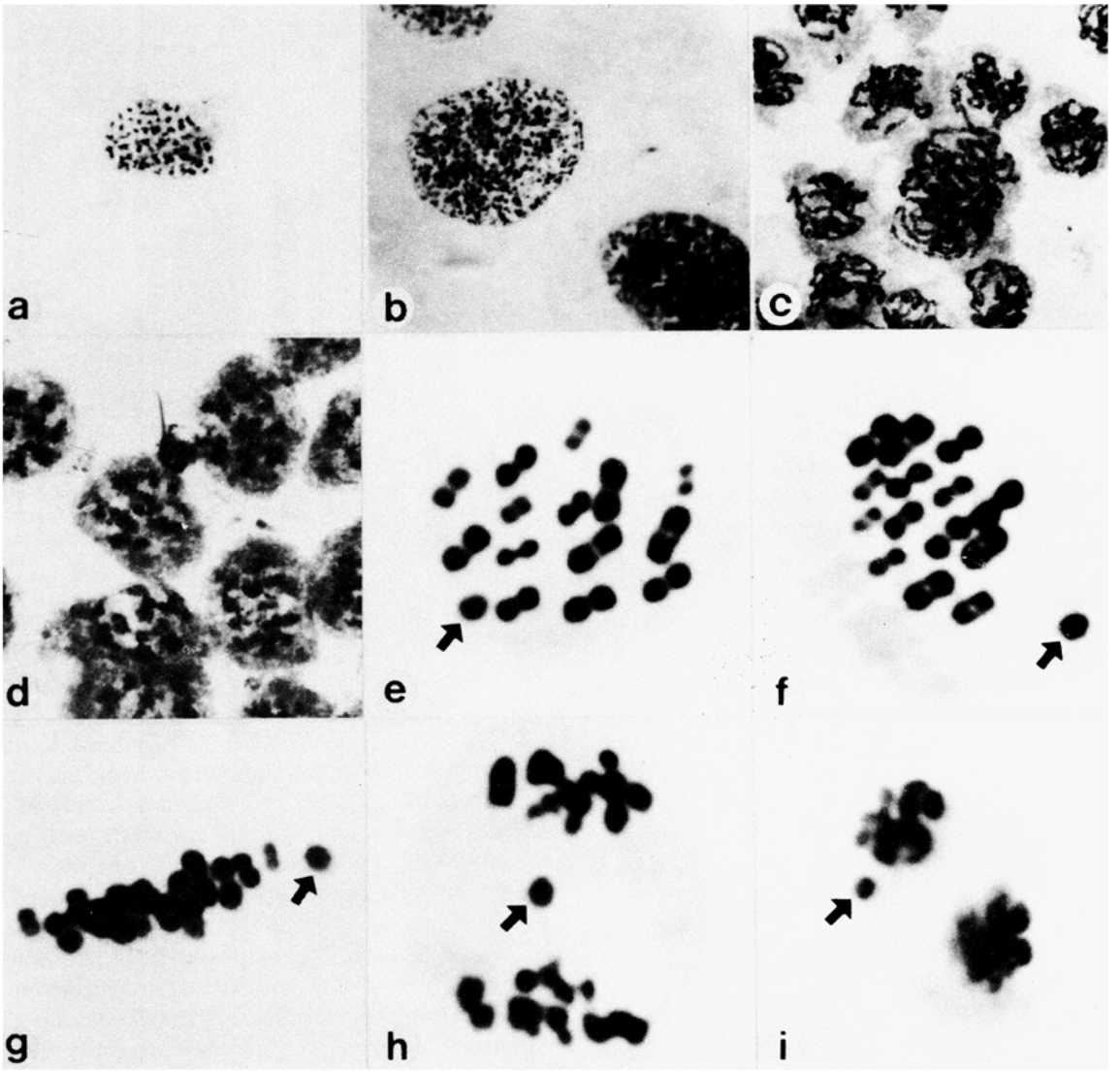
6. Damage ratings and growth indices of BPH biotype 3 reared on ASD7 for 50 generations and colonies collected from IR56 in Mindanao and reared on IR36 and IR42 for 20 generations, when feeding on IR56, IR36, IR42 and ASD7.

The grass-infesting *N. bakeri* has the XX-XO system, while *N. lugens* has XX-XY chromosomes.

Virulence of green leafhopper colonies. *N. virescens* colonies reared on Pankhari 203, IR8, Ptb 8, TAPL 796, and Moddai Karuppan for 38 generations were compared with a colony maintained on susceptible TN1 for 100 generations. The colonies were tested for ability to damage Pankhari 203, ASD7, IR8, Ptb 8, ASD8, TAPL 796, and Moddai Karuppan. TN1 was the susceptible check.

Colonies are most virulent to their own rearing varieties (Fig. 8). Some colonies have cross virulence, such as Pankhari 203 colony on IR8 and Ptb 8 colony on TAPL 796.

In another study, colonies reared on resistant varieties Ptb 8 and IR42 for 6 generations and a colony reared on susceptible TN1 for 50 generations were compared for virulence against the 3 varieties. Results show Ptb 8 and IR42 colonies had not completely adapted to their rearing varieties; their population growth was highest on susceptible TN1. However, population growth of the Ptb 8 colony



7. First meiotic stages in spermatocytes of *N. bakeri:* a) interphase, b) leptotene, c) pachytene, d) diplotene, e) diakinesis, f) premetaphase, g) metaphase I, h) anaphase I, i) telophase I. The sex chromosome is indicated by an arrow. IRRI, 1984.

was higher on Ptb 8 than on IR42 and IR42 colony growth was higher on IR42 than on Ptb 8.

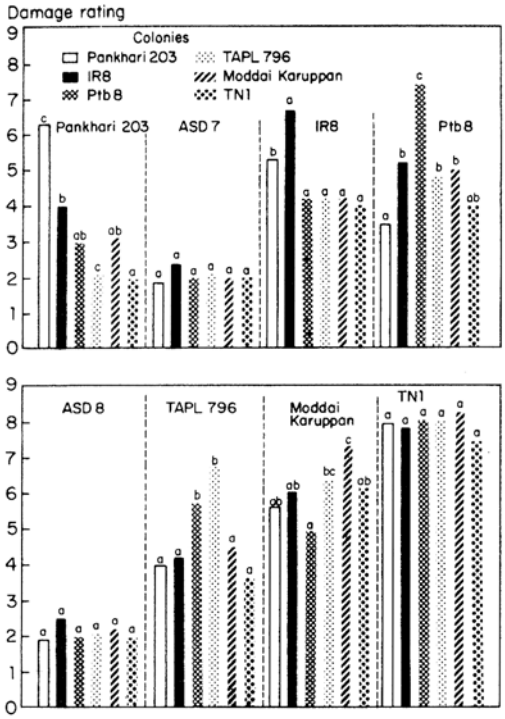
Morphometric variations between green leafhopper biotypes. Resistant rice varieties react differently in Bangladesh and the Philippines to GLH *N. virescens*, considered allopatric biotypes. We compared morphometric variations of GLH populations from the two countries and found significant differences in male and female genital, abdominal, tarsal, and antennal characters of two color morphs, one with black spotted corium on the tegmen and the other with uniformly green tegmen.

Meiotic cells and chromosomes of green leafhopper. Spermatocytes of insectary-reared, newly emerged *N. virescens* adults were examined using the standard squash technique and lacto-aceto-orcein staining method. Spermatogonia divided mitotically, followed by reductional-equational

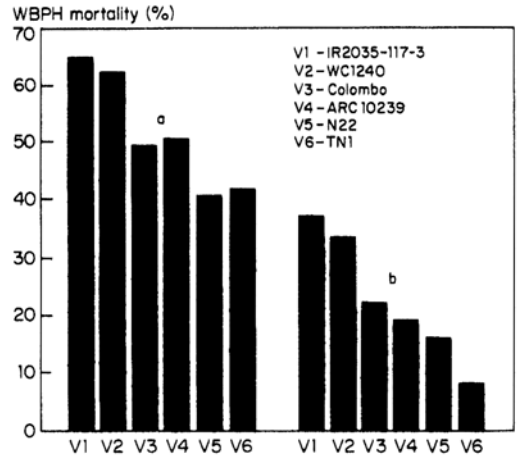
meiosis of spermatocytes. The primary spermatocytes at diakinesis had seven bivalent autosomes and a univalent X-chromosome. The genomic component of *N. virescens* males, therefore, is 2n=15 (7 IIA + XO). At pachytene the relative mean lengths of chromosomes ranged from 0.074 mm to 0.189 mm. The sex chromosome measured 0.083 mm, and the autosome with the nucleolar organizing region (NOR) had a relative mean length of 0.153 mm. These chromosomes condensed maximally during premetaphase into dumbbells of bivalents measured in microns as follows: 4, 3, 3, 2.5, 2.5, 2.5, 1.9, and 1. The sex chromosome measured 1 μ while the chromosome with NOR measured 3 μ.

The insemination potential of *N. virescens* males, as determined by meiotic index, approximated 0.84. Spontaneous chromosomal aberrations in individual *N. virescens* included 0.77% hypoploidy and 0.47% agmatoploidy.

Chromosomes of rice leaffolder. Leaffolder meiocytes were examined by using squash technique with lacto-aceto-orcein on the developing testes of 5th-instar male larvae. At diakinesis, the chromosomes were small globular dumbbells 1-3 μ long. In a cell with n=30, the chromosome lengths in μ were 1, 1, 1.5, 1.5, 1.5, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2.5, 2.5, 2.5, and 3. At metaphase I, these chromosomes clumped, 7 μ in length, at the cell equator. Erratic haploid chromosomes occurred up and down the mode (ranging from 40 to 5), but 30 predominated, as often as 52% in all meiotic cells of the 25 individuals examined. As the number of chromosomes increased, their lengths decreased. The aberrations in chromosome number were due to fusion and fragmentation because leaffolder chromosomes have nonlocalized centromeres. In every haploid karyotype, regardless of chromosome number, a small heterochromatic homolog measuring 1 μ was evident. This body represented the ZZ sex chromosomes. Thus, despite the chromosomal diversity of the leaffolder, the modal type had a genomic complement comprising 29 bivalent autosomes and ZZ (male) sex chromosomes. The basic karyotypic formula for male leaffolder is 2n=60 (29 AA + ZZ).



8. Damage inflicted by GLH *N. virescens* on selected varieties, including varieties they were reared on. IRRI, 1984.



9. Effect of varietal resistance on WBPH with and without the predator *Paederus fuscipes*. IRRI, 1984. a = WBPH mortality from varietal resistance plus *P. fuscipes*, b = mortality from resistance alone.

BIOLOGICAL CONTROL AND RESISTANCE

Entomology Department

Biological control and varietal resistance to white-backed planthopper. In a greenhouse test, six varieties with different resistance levels were com-

pared for effect on WBPH, with and without the predator *Paederus fuscipes*. Without the predator, (Fig. 9b), highly resistant IR2035-117-3 and WC1240 caused about 40% mortality; moderately resistant Colombo, ARC10239, and N22 caused about 20% mortality. Combined mortality (Fig. 9a) (varietal effect and predation) ranged from 65% on IR2035-117-3 to 40% on N22.

Genetic evaluation and utilization (GEU) program

Drought tolerance

Agronomy and Plant Breeding Departments, International Rice Germplasm Center, and Upland Rice Breeding

VARIETAL SCREENING **86**
- Field screening, 1984 dry season **86**
- Field screening for drought-tolerant parents **86**
- Screening at the reproductive stage **87**

FIELD EVALUATION OF RAINFED RICES **88**
- Upland rice yield trials, 1984 wet season **88**
- Upland-condition performance trials for very early lowland rices **89**
- Yield potential of rainfed lowland rices with nitrogen management practices **89**

ROOT STUDIES **91**
- Genetic studies of root systems **91**
- Root development of upland and lowland varieties in aeroponic culture **93**
- A new soil-root sampling technique for rice in flooded puddled soil **95**

SOIL-PLANT-WATER RELATIONSHIPS **95**
- Drought tolerance under limited rooting depth **95**
- Physiological and yield responses to irrigation gradient in simulated rainfed lowland **97**
  - Line source treatment and leaf water potential **97**
  - Photosynthesis **97**
  - Soil mechanical impedance and root system **97**
  - Nutrient uptake **99**

VARIETAL SCREENING

Agronomy and Plant Breeding Departments, International Rice Germplasm Center, and Upland Rice Breeding

Field screening, 1984 dry season (*Agronomy*). Drought reactions of 6,165 entries were scored 5 times in 1984 dry season (DS) compared to 3 times previously. Two scorings were at 4-d intervals at both 1-2 and 4-5 bars soil moisture tension (SMT) and 1 at 10 bars SMT at 20-cm soil depth.

Thirty-three entries consisting of 12 IRRI lines, 5 varieties from Ivory Coast, 3 each from Bangladesh, Nigeria, and the Philippines, 2 from Thailand, and 1 each from China, India, Indonesia, Italy, and Korea performed better than drought-tolerant checks Salumpikit and IR442-2-58. The 33 entries and 2 checks showed none or slight leaf tip drying at 1-2 bars SMT. However, the checks suffered more from 4-5 and 10 bars SMT than did the 33 entries. The checks had up to 50% fully dried leaves, but 3 test rices had only slight leaf-tip drying and the others dried up to 25% of the length of leaves. Twelve rices recovered fully when soil moisture stress was relieved (Table 1). Salumpikit and IR442-2-58 and the other 21 test entries had 80% recovery.

The best entries were Habiganj Aman II from Bangladesh, ITA119 from IITA (Nigeria), and IRRI line IR18349-22-1-2-1-1, with negligible effect of soil moisture stress up to 5 bars SMT.

Field screening for drought-tolerant parents (*Upland Rice Breeding*). In other trials, 4,474 germplasm accessions, breeding lines from the upland and lowland nurseries, and other materials nominated by GEU scientists were screened. About 23% showed high drought tolerance (drought score of 1-4 where 1 = tolerant, 9 = susceptible) at the vegetative stage. Of those, 15% came mostly from germplasm bank accessions. Of 618 accessions which had reproductive stage scores at the cutoff date (120 d after sowing), 56 entries (9%), mostly early maturing (100-110 d) Assam varieties of India, scored 3. A few Laotian cultivars had intermediate reaction (5).

Of upland breeding lines, 11 showed drought tolerance at reproductive stage. They included IR5178-1-1-4 and IR10004-3-1, good performers in IRTP nurseries in drought-prone areas.

From lowland breeding nurseries, 6% from deep water nurseries and 6% from medium-deep and shallow-rainfed nurseries scored tolerant to moderately tolerant at the vegetative phase. Most GEU

Table 1. Rices outstanding for drought tolerance and recovery in field screening at IRRI, 1984 DS.

Designation	Origin	Drought scores[a]					Recovery scores[b]
		1-2 bars SMT		4-5 bars SMT		10 bars SMT	
		1st	2d	1st	2d		
Cisadane	Indonesia	0	1	3	3	4	1
C22	Philippines	0	1	1	3	3	1
Dinalaga	Philippines	0	1	3	3	3	1
Habiganj Aman II	Bangladesh	0	0	1	1	3	1
ITA119	Nigeria	0	0	1	1	3	1
Ma Za Gu	China	1	1	3	3	3	1
IR841-85-1-1-2		0	1	1	3	3	1
IR18349-22-1-2-1-1		0	1	1	1	3	1
IR21015-196-3-1-3		0	1	3	3	3	1
IR21178-43-1-2-2-2		1	1	3	3	3	1
IR28878-R-R-25-9		0	0	1	3	3	1
IR31917-31-3-2-3		0	1	1	3	4	1
Checks							
Salumpikit (tolerant)		0	1	3	4	5	3
IR442-2-58 (tolerant)		0	1	4	5	6	3
IR20 (susceptible)		2	4	6	7	8	7
IRAT 9 (susceptible)		2	5	7	8	9	9

[a]1980 Standard Evaluation System for Rice (SES) 0-9 scale: 0 = no effects of soil moisture stress, 9 = all plants apparently dead. [b]1980 SES 1-9 scale: 1 = 90 to 100% plants recovered, 9 = 0-19% plants recovered.

elite lines from irrigated nurseries were intermediate. All flowered too late for computation of reproductive stage scores.

Korean breeding lines, mostly early maturing, showed tolerant to moderately susceptible reactions. Of those flowering within the stress period, 23% were moderately tolerant at the reproductive stage. The plants were rather short, but the grains were well-filled, with few sterile panicles.

Another 1,167 breeding lines were screened for field tolerance to drought under simulated rainfed-lowland culture. From the deep water nurseries, 2% were moderately tolerant, 11% intermediate, 82% moderately susceptible, and 5% susceptible at vegetative stage. At reproductive stage, 2% were moderately tolerant, 25% intermediate, 58% moderately susceptible, and 15% susceptible.

The shallow and medium-deep rainfed-lowland nurseries showed 10% moderately tolerant, 19% intermediate, 67% moderately susceptible, and 3% susceptible at vegetative phase. At reproductive stage, 2% were moderately tolerant, 5% intermediate, 56% moderately susceptible, and 37% susceptible. Likewise, 28% of upland breeding lines ranged from tolerant to moderately tolerant at vegetative stage. At reproductive stage, the distribution became 2% tolerant, 11% moderately tolerant, 25% intermediate, 52% moderately susceptible, and 10% susceptible.

The International Rainfed Rice Shallow Water Observational Nursery of IRTP provided 20% entries moderately tolerant at vegetative phase and 8% tolerant to moderately tolerant at reproductive phase. Entries that showed tolerance at reproductive phase were ITA186, RAU4057-35-20, RAU5003-10, and RTN24. They might have the escape mechanism of drought tolerance because they flowered during a mild stress period. Those lines were previously selected from drought-prone areas of Africa and India.

Screening at the reproductive stage (*Agronomy*). The 1984 DS trial included 390 genotypes, mostly entries from 1983, for further testing.

Entries of maturity classes were seeded on different dates for synchronous flowering. The randomized complete block design used three replications of the control and the stress treatments.

Water was applied by whole plot sprinkler system and gradually increased from seeding to full canopy. Thereafter, irrigation supplied water to a depth equivalent to 1.2 × pan evaporation (E_{pan}) except during the stress period which started on 10 Apr (day 0) with the last full irrigation.

To estimate spikelet fertility, 20 panicles were randomly sampled from each plot. Estimated spikelet fertility was used because in 1983 it correlated highly with actual spikelet fertility (0.93**) and with grain yield ($r = 0.85$**).

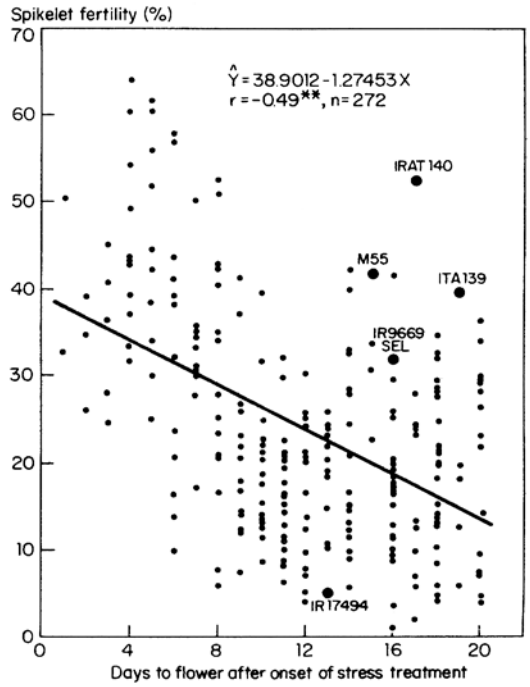
Despite staggered seeding, flowering dates ranged from stress day 1 to 20. This prohibited direct comparison. Therefore, regression analysis was used to determine the relationship between days to flower after stress treatment and spikelet fertility percentage (Fig. 1).

As in 1982, drought indices were computed to show each genotype's performance:

$$\text{Drought index} = \frac{Y\text{-}\hat{Y}}{SE_{\hat{Y}}}$$

where Y = percent spikelet fertility, $\hat{Y}$ = predicted percent spikelet fertility based on the regression results, and $SE_{\hat{Y}}$ = standard error of Y.

Table 2 shows the top 30 entries based on drought indices. Other entries with high drought



1. Relationship between days to flower of rices after imposition of stress treatment, and percent spikelet fertility. IRRI, 1984 DS.

Table 2. Top 30 entries which flowered at least 10 d after water was withheld at the stress treatment, based on computed drought indices. IRRI, 1984 DS.

Entry no.	Genotype	Flowering date	Actual fertility (%)	Predicted fertility (%)	Drought index
250	IRAT140	17	52	17	+0.26889
201	ITA139	19	40	15	+0.19258
289	TOX502-13-NK14-NIB	16	42	19	+0.17630
109	C894-7	20	36	13	+0.17552
239	M55	15	42	20	+0.16883
207	UPL Ri-7 (C1064-5)	14	42	21	+0.16212
298	ITA130	20	34	13	+0.16018
366	Benaful (Acc. no. 25839)	20	34	13	+0.15788
36	IRAT104	14	40	21	+0.14525
30	IR15413-3	18	35	16	+0.14370
68	IR19661-131-1-3-1-3	20	30	13	+0.12721
267	IR25560-132-3-2	18	33	16	+0.12683
244	Kinandang Patong	18	32	16	+0.12530
107	IR7950-2-4-1	20	29	13	+0.12184
89	IR12629-39-4-1	18	32	16	+0.12146
245	IAC1246	20	29	13	+0.11954
124	IR7950-16-1-1	20	28	13	+0.11341
316	ITA184 (TOX 516-28-103-3-1)	15	34	20	+0.10671
254	ITA235	18	30	16	+0.10536
153	IRAT106	10	40	26	+0.10232
20	IR9669 Sel.	16	32	19	+0.10192
97	IR5440-1-1-3	20	26	13	+0.09884
6	IR8997-4-4-2	18	29	16	+0.09616
193	IR33356-14-3-1-3	18	28	16	+0.09386
311	Mikotchu (Acc. no. 25893)	14	33	21	+0.09004
172	IR3646-13-3-2	18	28	16	+0.08849
21	IR11397-47	14	33	21	+0.08774
284	TOX378	16	30	19	+0.08428
91	IR13754-5	15	31	20	+0.08371
214	IR10110-24-1-1 (purple base)	17	28	17	+0.08255

indices but which flowered very early (stress day 0-9) were not listed because their values are due to escape and not to drought tolerance per se. Varieties or lines like IRAT140, ITA139, M55, and IR9669 Sel. were also top performers in 1983.

FIELD EVALUATION OF RAINFED RICES

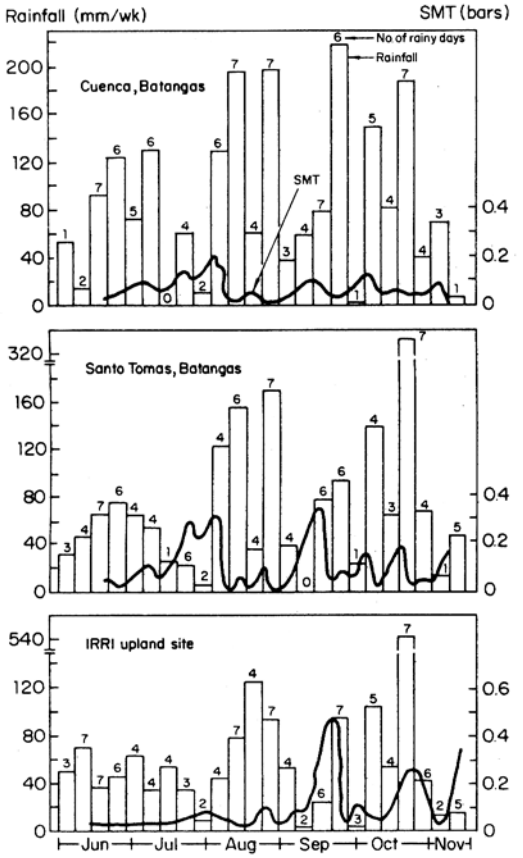
Agronomy and Plant Breeding Departments

Upland rice yield trials, 1984 wet season (WS) (*Agronomy*). Three groups of upland rice varieties and lines with 36, 25, and 27 entries were tested at IRRI, in 2 farmers' fields in Cuenca and Santo Tomas, Batangas, and at Philippine Bureau of Plant Industry stations in Ilagan, Isabela, and La Granja, Negros Occidental. One group had drought selections and Philippine Seed Board recommended varieties; the two others were IRTP materials (International Upland Rice Yield Nurseries [IURYN]-Early and IURYN-Medium maturing groups).

Cuenca had generally favorable weather (Fig. 2). Low rainfall at Santo Tomas and IRRI in early September slightly increased SMT, producing mostly empty spikelets in early maturing rices. La Granja had adequate soil moisture, but a September typhoon shattered some grains of the already ripening medium-maturing entries (Fig. 3). Ilagan had a 30-d dry spell in September; drought reactions were measured but no yields obtained.

The Cuenca site produced better IURYN-M yields and La Granja yielded better in IURYN-E (Table 3, 4). IR9560-2-6-3-1 and UPL Ri-7 produced the highest yields of 4.3 and 4.2 t/ha in Cuenca. IRAT112 yielded 4.0 t/ha in La Granja.

UPL Ri-7, a Philippine Seed Board variety, performed best (Table 3, 4). In two groups and four sites, UPL Ri-7 was either highest or among the



2. Weekly rainfall distribution and daily soil moisture tension (SMT) in IRRI and 2 farmers' fields in Batangas, Philippines, 1984 WS.

highest yielders. It headed 2 wk earlier (82-85 d after emergence [DE]) than IR43 and UPL Ri-5 (Table 5, 6). It is intermediate statured (103-109 cm), a desirable trait for both mechanical and manual harvesting. Its panicle-producing capacity was between those of IR43 and UPL Ri-5. In Ilagan, it showed drought reaction comparable to that of drought-tolerant Salumpikit and IR442-2-58 (Table 5).

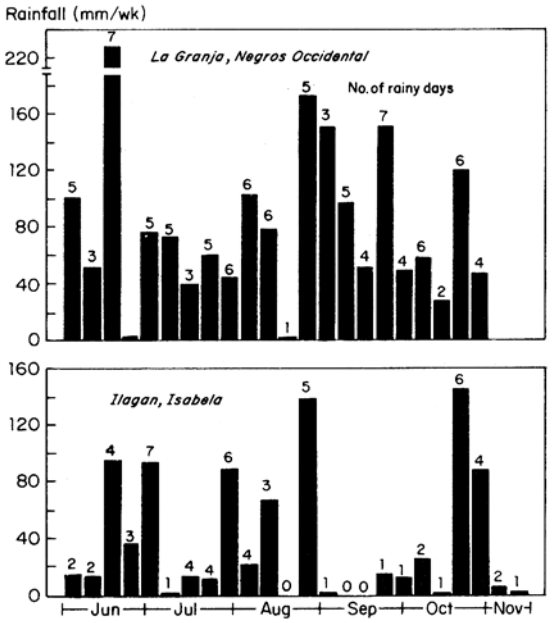
The moderate dry spells that hit IURYN-E entries in IRRI and Santo Tomas greatly reduced yields. IR9781-19-1 had the highest mean grain yield, but along with other lines, it was severely infected by various diseases (Table 6).

Upland-condition performance trial for very early lowland rices (*Agronomy*). Twenty-nine very early maturing lowland rice lines (IRYN-VE), together with Kinandang Patong as local check, were planted on 1 Jun in a Santo Tomas upland ricefield. Eighty kg N/ha was split-applied at 10 and 40 d after emergence.

Blast severely infected most entries as seedlings. Though plants recovered, neck blast followed, reducing yields to as low as 0.6 t/ha.

Four rices yielded better than Kinandang Patong (Table 7), and resisted leaf and neck blast and other diseases. BG367-4, the best yielder, had growth duration similar to that of Kinandang Patong and was one of the taller entries. The test indicates that some lowland rices could perform well under upland conditions.

Yield potential of rainfed lowland rices with nitrogen management practices (*Agronomy and Plant Breeding*). In 1984 wet season (WS), screening for yield response to N sources in rainfed fields was conducted in Santa Rosa, Laguna; Dingras, Ilocos Norte; and Guimba, Nueva Ecija. N rate was reduced from 60 kg N/ha to 30 kg N/ha using 3 N sources: prilled urea (PU, 2/3 basal incorporated + 1/3 topdressed 5-7 d before panicle initiation), forestry grade sulfur-coated urea (FG-SCU, basal



3. Weekly rainfall distribution in Bureau of Plant Industry experiment stations in Ilagan, Isabela, and La Granja, Negros Occidental, Philippines, 1984 WS.

Table 3. Grain yield of selected entries in upland rice performance trials with 4 seeding dates at 3 sites, 1984 WS.

	Grain yield (t/ha)				
	IRRI	Cuenca	Santo Tomas		
Designation	5 Jun	24 May	26 May	5 Jul	Mean
UPL Ri-7	1.6 a	4.2 a	3.4 ab	2.5 a	2.9
IR9560-2-6-3-1	1.1 b	4.3 a	3.4 ab	1.8 b	2.6
IR43	0.6 c	3.9 ab	3.6 a	1.7 b	2.4
UPL Ri-5	1.2 b	3.3 bc	2.8 bc	2.3 a	2.4
IR9995-96-2	1.4 ab	3.2 bc	2.4 c	2.4 a	2.4
Kinandang Patong (local check)	0.5 c	3.1 c	2.4 c	0.3 c	1.6
Site mean	0.7	2.9	2.1	1.4	

Table 4. Grain yield of selected entries from IURYN-E and IURYN-M at 4 sites, 1984 WS.

	Grain yield (t/ha)				
Designation	IRRI	Cuenca	Santo Tomas	La Granja	Mean
Early-maturing group (IURYN-E)					
IR9761-19-1	1.0 a	3.2 a	2.2 ab	3.2 a	2.4
IR164-5	0.8 ab	3.3 a	1.1 c	3.8 a	2.2
RP1158-90-1	0.7 bc	3.4 a	1.5 c	3.4 a	2.2
RP1899-1689-88	0.4 d	3.0 a	2.2 ab	3.0 a	2.2
IR9729-67-3	0.8 ab	3.7 a	0.4 d	3.7 a	2.2
Kinandang Patong (local check)	0.6 bcd	3.1 a	2.4 a	1.3 b	1.8
Site mean	0.7	2.7	1.3	3.0	
Medium-maturing group (IURYN-M)					
UPL Ri-7	1.6 ab	3.7 ab	3.0 ab	3.0 a	2.8
BR319-1	1.1 c	4.0 a	2.8 abc	3.1 a	2.8
IR12721-24-3-1	1.8 a	3.6 ab	2.6 bcd	2.7 a	2.7
UPL Ri-5	1.1 c	3.2 b	2.8 abc	3.3 a	2.6
IR43	1.2 bc	3.3 ab	3.5 a	2.3 a	2.6
IR9782-111-2-1-2	1.1 c	3.3 ab	2.1 cde	3.2 a	2.4
C894-21	1.5 abc	3.7 ab	1.7 e	2.7 a	2.4
Kinandang Patong (local check)	0.6 d	2.4 c	2.3 b-e	1.4 b	1.7
Site mean	0.9	2.9	2.2	2.1	

Table 5. Summary of grain yield and agronomic characteristics of selected entries in upland rice variety trials at 3 sites and drought reaction at another site, 1984 WS.

Designation	Mean grain yield[a] (t/ha)	Days to flowering (DE)	Plant height[a] (cm)	Panicles[a] (no./m^2)	Drought score[b]	Important diseases[c]
UPL Ri-7	2.9	83	103	207	4	ShB
IR9560-2-6-3-1	2.6	99	72	244	5	LSc, ShB
IR43	2.4	97	74	224	5	LSc, ShB
UPL Ri-5	2.4	97	98	172	4	ShB
IR9995-96-2	2.4	103	84	205	5	LSc
Kinandang Patong (local check)	1.6	91	127	103	4	LSc, ShB
IR442-2-58 (drought-tolerant check)	1.7	98	82	211	4	NBLS, LSc, ShB, ShR
Salumpikit (drought-tolerant check)	1.9	90	125	165	4	LSc, ShB
IR20 (drought-susceptible check)	1.5	96	76	211	5	ShB
IRAT9 (drought-susceptible check)	1.3	87	71	213	6	ShB, ShR

[a]Mean for IRRI, Cuenca, and Santo Tomas, DE = d after emergence. [b]Ilagan data where dry spell lasted 1 mo (SES scale 0-9: 0 = no symptoms, 9 = all plants apparently dead). [c]LSc = leaf scald, NBLS = narrow brown leaf spot, ShB = sheath blight, ShR = sheath rot.

Table 6. Summary of grain yield and agronomic characteristics of selected entries from IURYN-E and IURYN-M at 4 sites and drought reaction at another site, 1984 WS.

Designation	Mean grain yields[a] (t/ha)	Days to flowering[a] (DE)	Plant height[a] (cm)	Panicle[a] (no./m²)	Drought score[b]	Important diseases[c]
Early-maturing group (IURYN-E)						
IR9761-19-1	2.4	75	70	248	5	NBI, NBLS, ShB, ShR
OR164-5	2.2	73	71	250	6	LSc, NBI, NBLS, ShB, ShR
RP1158-90-1	2.2	75	76	218	6	NBI, LSc, ShB, ShR
RP1899-1689-88	2.2	75	75	265	6	LSc, ShB, ShR
IR9729-67-3	2.2	62	71	210	7	NBI, NBLS, LSc, ShB, ShR
Kinandang Patong (local check)	1.8	88	130	159	3	ShB
Medium-maturing group (IURYN-M)						
UPL Ri-7	2.8	82	109	223	5	ShR
BR319-1	2.8	84	93	210	5	LSc, ShR
IR12721-24-3-1	2.7	97	110	221	5	ShB
UPL Ri-5	2.6	95	97	211	5	ShB, ShR
IR43	2.6	97	74	250	5	LSc, ShB
IR9782-111-2-1-2	2.4	82	65	286	5	ShB, ShR
C894-21	2.4	93	96	201	5	ShB
Kinandang Patong (local check)	1.7	88	128	133	4	LSc, ShR

[a]Mean for IRRI, Cuenca, Santo Tomas, and La Granja. [b]Ilagan data where dry spell lasted 1 mo (SES 0-9 scale: 0 = no symptoms, 9 = all plants apparently dead). [c]LSc = leaf scald, NBI = neck blast, NBLS = narrow brown leaf spot, ShB = sheath blight, ShR = sheath rot.

Table 7. Performance of very early-maturing lowland rices (IRYN-VE) under upland conditions in Santo Tomas, Batangas, 1984 WS.

Designation	Grain yield (t/ha)	Days to heading[a] (DE)	Plant height (cm)	Panicles (no./m²)	Important disease[b]
BG367-4	3.6 a	82	85	245	–
IR25588-7-1	3.2 ab	76	76	213	–
IR29725-3-1-3-2	3.1 abc	79	69	261	–
UPR103-80-1-2	2.9 bc	74	69	240	ShB
Kinandang Patong (local check)	2.0 d	83	121	134	ShB
Grand mean	2.0	–	–	–	
Range	–	67-90	57-93[c]	206-330[c]	

[a]DE = d after emergence. [b]ShB = sheath blight. [c]Excludes that of Kinandang Patong.

broadcast and incorporated), and urea supergranule (USG, point placement).

The three varieties or breeding lines performing well with any N source in Santa Rosa were IR19274-26-2-3-1, IR46, and IR13146-45-2-3 (Table 8). Without fertilizer N, IR19274-26-2-3-1 produced 2.7 t/ha; IR13146-45-2-3, 2.6 t/ha; and IR46, 2.7 t/ha.

In Dingras, low rainfall during cropping reduced yields. Thus all fertilizer responses were poor. IR46 produced 1.9 t/ha without N.

In Guimba, insects and diseases reduced yields. Tungro virus severely infected IR36 and IR46 and IR46 did not produce panicles. Early maturing entries escaping stem borer infestation were IR21015-80-3-3-1-2 (3.0 t/ha), IR9729-67-3-87 (2.8 t/ha), and IR58 (2.3 t/ha).

ROOT STUDIES

International Rice Germplasm Center, Upland Rice Breeding, and Agronomy Department

Genetic studies of root systems (*International Rice Germplasm Center*). The gene action and inheritance pattern of root characters and related shoot characters in crosses between five deep-rooted

Table 8. Effect of N sources[a] and management practices on grain yield of rainfed lowland rices at 3 Philippine sites, 1984 WS.

Entries	Grain yield (t/ha)				
	0 kg N/ha	PU	FG-SCU	USG	$\bar{x}^b$
			Santa Rosa, Laguna		
IR36	2.0	2.7	2.9	2.8	2.6 de
IR46	2.7	3.6	3.5	3.3	3.3 ab
IR54	2.1	3.0	3.2	2.9	2.8 cd
IR58	1.8	2.9	2.2	2.7	2.4 e
IR13146-45-2-3	2.6	3.0	3.4	3.1	3.0 bc
IR19274-26-2-3-1	2.7	3.8	3.5	3.6	3.4 a
IR21313-39-3-2	2.3	3.1	3.5	2.9	3.0 c
IR26933-16-2-3	2.3	3.2	3.2	3.2	3.0 bc
IR21015-80-3-3-1-2	2.0	2.6	2.5	2.7	2.5 e
IR9729-67-3-87	1.8	2.6	2.8	2.6	2.5 e
$\bar{x}^b$	2.2 b	3.1 a	3.1 a	3.0 a	
			Dingras, Ilocos Norte		
IR36	1.4	1.7	2.3	2.4	2.0 ab
IR46	1.9	2.6	2.4	2.5	2.4 a
IR54	0.9	2.1	2.5	1.6	1.8 b
IR58	1.1	1.8	1.7	1.8	1.6 b
IR13146-45-2-3	1.6	1.3	2.1	1.6	1.7 b
IR19274-26-2-3-1	0.7	1.8	1.7	2.1	1.6 b
IR21313-39-3-2	0.9	1.8	2.6	2.2	1.9 b
IR26933-16-2-3	1.0	2.0	1.7	2.3	1.8 b
IR21015-80-3-3-1-2	1.1	1.5	1.8	1.9	1.6 b
IR9729-67-3-87	1.0	1.9	1.9	2.0	1.7 b
$\bar{x}^b$	1.2 b	1.9 a	2.1 a	2.0 a	
			Guimba, Nueva Ecija		
IR36	0.4	0.7	0.4	0.5	0.5 f
IR46	0	0	0	0	0 g
IR54	1.6	1.8	1.8	1.4	1.7 de
IR58	1.8	2.4	2.6	2.5	2.3 b
IR13146-45-2-3	1.6	2.1	2.1	1.8	1.9 cd
IR19274-26-2-3-1	1.6	2.3	2.1	2.1	2.0 c
IR21313-39-3-2	1.6	1.9	1.8	1.3	1.7 de
IR26933-16-2-3	1.4	1.6	1.8	1.2	1.5 e
IR21015-80-3-3-1-2	2.7	3.0	3.0	3.1	3.0 a
IR9729-67-3-87	2.3	2.8	3.2	3.0	2.8 a
$\bar{x}^b$	1.5 b	1.9 a	1.9 a	1.7 b	

[a]PU = prilled urea, FG-SCU forestry grade sulfur-coated urea, USG = urea supergranules. [b]For each site and for each N source, separation of means is by Duncan's multiple range test at the 1% level.

varieties and one shallow-rooted variety were investigated in aeroponic culture.

As do most traditional upland cultivars, Moroberekan, 20A, OS4, and Kinandang Patong have deep and thick roots, large root weight, low tiller number, tall plant stature, and large root-to-shoot ratio. The semidwarf lowland variety IR20 has those features contrasting. The drought-tolerant, dual-purpose variety MGL-2 had a combination of deep and thick roots, high tiller number, but intermediate plant stature.

In F_1 hybrids, deep and thick roots were partially dominant to overdominant to shallow roots. However, heavy root weight was not dominant in the IR20/MGL-2 cross. The high root number of IR20 and MGL-2 showed overdominance in the upland varieties. For root thickness, potence ratios of 0.03 to 0.60 indicated lack of dominance.

Analysis of the F_2 data in relation to parental and F_1 data yielded these results:

1. Multiple genes with additive and dominance effects were indicated for root length in the crosses of IR20/20A, IR20/MGL-2, IR20/Moroberekan, and IR20/Kinandang Patong.

2. Multiple genes with both enhancing and depressing effects controlled root length in IR20/OS4.
3. Multiple genes with additive and nearly equal effects mainly controlled root thickness.
4. Multiple genes with dominance and additive effects controlled root number in most crosses except IR20/MGL-2.
5. Multiple genes with dominance effects controlled root weight.
6. MGL-2 differed from the four upland varieties in gene action and inheritance pattern for root number and root weight. Multiple genes with ovipositional effects in MGL-2 controlled root number. In IR20/MGL-2, however, alleles for high root number in IR20 appeared stronger than the corresponding alleles in MGL-2. On the other hand, multiple genes with additive and slight negative dominance effects mainly controlled root weight in IR20/MGL-2.

Maternal effects in reciprocal crosses involving Moroberekan, 20A, and OS4 were noted in F_1 data. Heritability estimates (in the broad sense) showed root length and root thickness highly heritable (65 to 75%), followed by root number and root weight (50 to 65%).

For the aboveground parts, plant height was highly heritable (75 to 90%) while tiller number, root-to-shoot ratio, and dried shoot weight had rather low heritabilities. The high heritabilities of root length and root thickness showed in F_3 data. A higher proportion of deep- and thick-rooted F_3 plants were recovered from one deep- and thick-rooted F_2-derived family than in the medium-deep and medium-thick or shallow- and thin-rooted F_3 families.

Phenotypic and genotypic correlations among root characters in 30 F_1, 6 F_2, and 3 F_3 families were all positive and significant at the 1% level. The aboveground parts such as plant height and dried shoot weight were positively and significantly correlated with underground parts: root length, root thickness, root number, and dried root weight. Tiller number correlated markedly with root number and shoot weight. Results match previous findings.

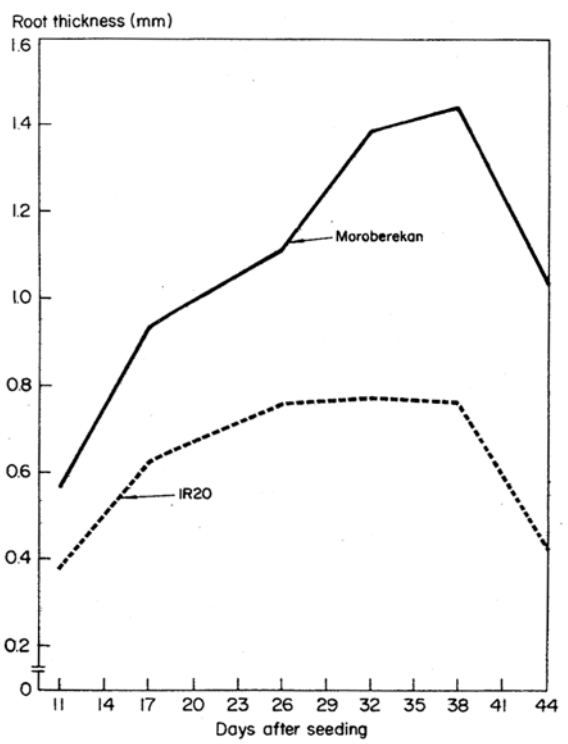
In breeding for drought tolerance and adverse soil conditions, breeders can use these findings in 1) choosing parental materials, 2) making cross combinations in wide crosses, and 3) adopting breeding procedure and selection criteria.

Root development of upland and lowland varieties in aeroponic culture (*Upland Rice Breeding*). Root and shoot development of five upland varieties, seven lowland, and one dual-purpose variety was investigated in aeroponic culture.

Most lowland varieties significantly increased root length at 20 d after seeding (DAS), while the traditional rainfed-lowland variety Salumpikit had a significant increase at 17 DAS. Only BPI-76 showed initial root growth at 14 DAS with continued elongation beyond other lowland varieties.

On the other hand, upland varieties generally grew faster after 14 DAS. Among them Kalakeri, Rikuto Norin 21, and Kinandang Patong, and dual-purpose Dular significantly increased growth at 17 DAS.

Upland varieties produced thick roots early at about 11 DAS. Studies on check varieties Moroberekan and IR20 showed fastest increase in root diameter between 17 and 26 DAS (Fig. 4). Moro-



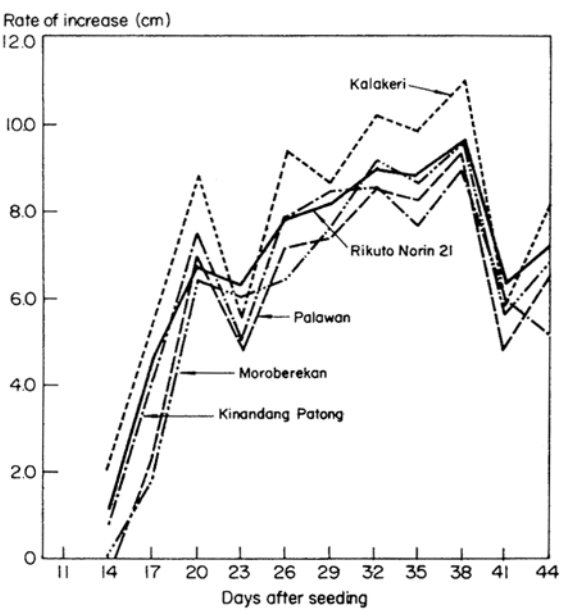
4. Growth development in root diameter of Moroberekan and IR20 grown in aeroponic culture. Upland Rice Breeding, 1984 DS.

berekan attained its maximum diameter of 1.44 mm at 34 DAS while IR20 reached 0.76 mm at 29 DAS. Root diameter declined thereafter.

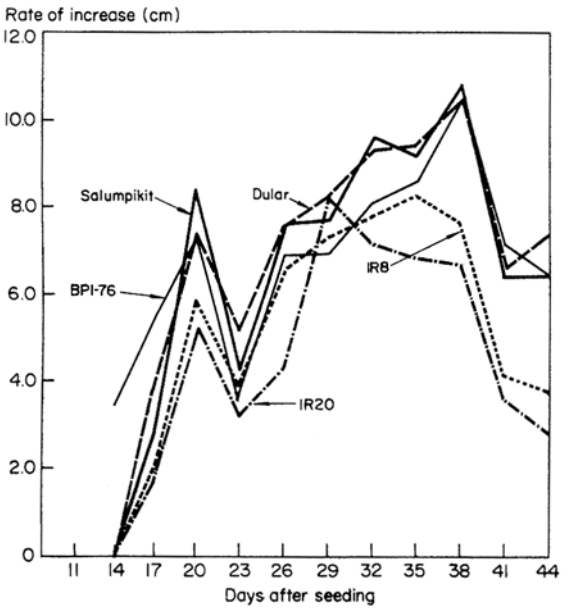
Generally, upland and lowland varieties had similar root growth pattern (Fig. 5, 6). Roots grew rapidly from 14 to 20 DAS, slowing from 20 to 23 DAS. Roots grew rapidly again after 23 DAS but slowed after 38 DAS. No evidence can explain this pattern.

In shoot development, lowland varieties generally grew slower than upland varieties. Shoot growth was greatest from 23 to 32 DAS (Fig. 7). Shoots of BPI-76 and Salumpikit grew rapidly after 20 DAS, slowed from 23 to 29 DAS, and increased again after 29 DAS. Shoots of the semidwarf IR20 did not grow significantly faster until after 41 DAS. IR8 significantly increased after 23 DAS. The overall shoot growth pattern was a series of rapid and slow intervals spaced at 3 d apart from 14 to 44 DAS. Patterns of lowland varieties varied more than those of upland rices.

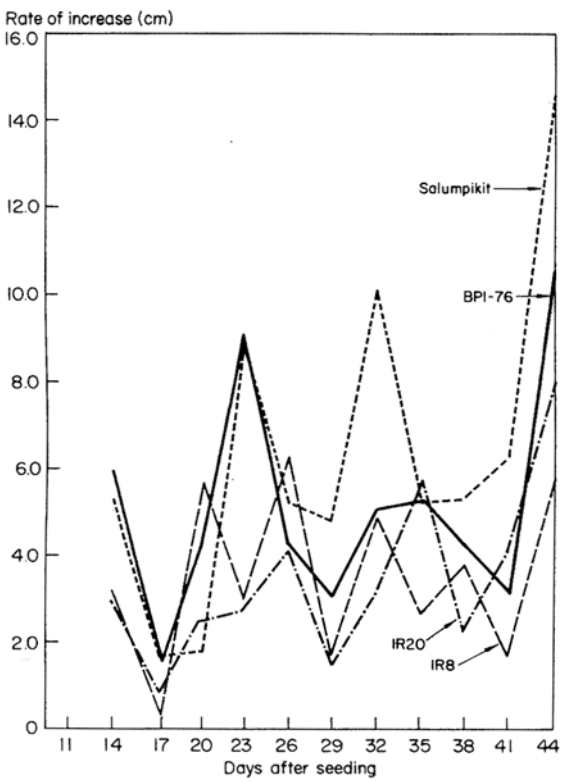
Among the upland varieties, Rikuto Norin started the fastest shoot growth at 14 DAS, followed by Kinandang Patong at 20 DAS (Fig. 8). Kalakeri and Moroberekan began significant increase at 23 DAS. Overall, upland varieties grew rapidly at an early vegetative stage, from 14 to 28 DAS. The



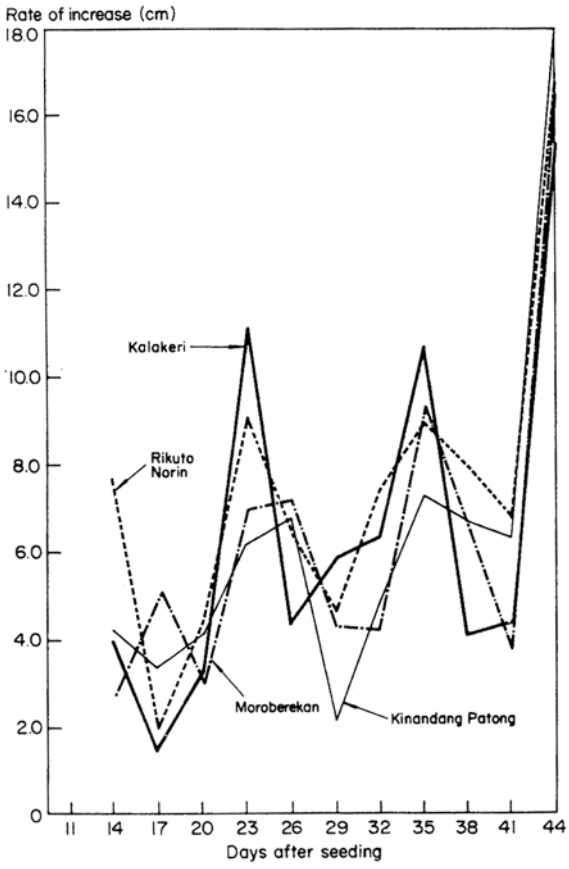
5. Rate of root growth increase of upland varieties grown in aeroponic culture. Upland Rice Breeding, 1984 DS.



6. Rate of root growth increase of lowland and dual-purpose varieties grown in aeroponic culture. Upland Rice Breeding, 1984 DS.



7. Rate of shoot growth of 4 lowland varieties grown in aeroponic culture. Upland Rice Breeding, 1984 DS.



8. Rate of shoot growth of 4 upland varieties grown in aeroponic culture. Upland Rice Breeding, 1984 DS.

intervals of rapid and slow growth were longer (about 6 d) for upland varieties than for lowland rices.

Root length was positively correlated with shoot length (0.769*). Initially, the shoot was longer than the roots in both upland and lowland varieties. But at 44 DAS, root and shoot lengths were similar for most lowland varieties. The shoots of IR20, IR8, and Guang Mao 127 were shorter than their roots. Upland variety shoots were generally longer than roots at 44 DAS.

Rapid root and shoot growth are vital attributes of seedling vigor which 1) enhance the plant's ability to withstand the rigorous turning over of seedling during harrow-weeding, 2) enable seedlings to compete with weeds, and 3) avoid severe drought stress in early growth.

A new soil-root sampling technique for rice in flooded puddled soil (*Agronomy*). Methods to quantitatively describe rice root growth and activity in puddled lowland rice culture are needed. In 1984, a new soil-root sampling technique was developed to estimate root weight and root length of rice grown in a simulated rainfed lowland condition. A large sampler (20 × 20 × 50 cm internal dimension) was fabricated with galvanized iron sheets, strong enough to collect and support a sample without distorting it (Fig. 9). The device is a modification of the soil sampler designed to take large undisturbed cores of lowland soil in the IRRI-IFDC Cooperative Project. The sliding cover makes it easy to remove the bulk sample.

The sampler is used as follows. After harvest of plant tops, surface water is removed. In a microplot, the sampler is centered over the rice hill, one-half the distance from the adjacent rows. With a sledge hammer, the sampler is pushed vertically to 40-cm depth. With the sampler at the desired depth, the soil around it is removed to reach the bottom edge. The sampler is then tipped over to break the soil at the bottom, and then lifted. Two men can collect a sample in about 15 min. (Hundreds of samples have been taken without sign of sampler wear and tear.)

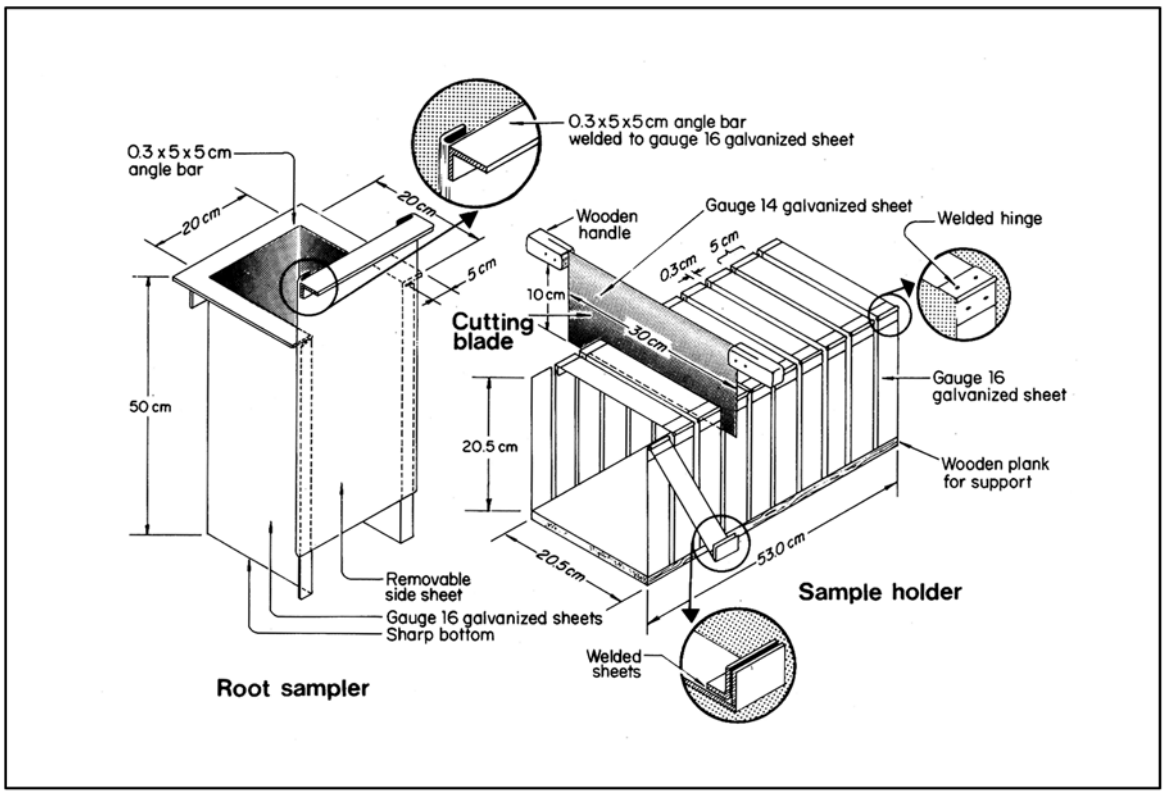
Soil cores are immediately transferred to the greenhouse. The entire monolith (20 × 20 × 40 cm) with the sampler is frozen for 12-14 h. The sliding side sheet is removed and the undisturbed soil with the roots is pushed into a sample holder and held in position (Fig. 9). The soil core is cut into 5-cm-long sections by pushing a sharp cutting blade in 0.3-cm slits (Fig. 9). These sections are washed to separate soil from roots. Root length is measured with a root length scanner.

Root lengths of plants grown in continuously flooded plots are shown in Table 9. The data are typical of Maahas clay (Andaqueptic Haplaquolls) at IRRI farm. The low coefficient of variation supports the reliability of this technique. The unit is simple to make and maintain and can be built locally and handled easily. This technique can contribute to research on rice root growth in both rainfed and irrigated lowland soils.

SOIL-PLANT-WATER RELATIONSHIPS

Agronomy Department

Drought tolerance under limited rooting depth. A total of 105 GEU elite and selected lines were



9. Root sampler, sample holder, and cutting blade showing details of fabrication. IRRI, 1984.

Table 9. Mean values of root length,[a] standard deviation, and coefficient of variation for root length estimated at 8 depths and 3 stages of crop growth. IRRI, 1984.

Depth (cm)	Panicle initiation			Flowering			Harvest		
	Length (cm)	SD (m)	CV (%)	Length (m)	SD (m)	CV (%)	Length (m)	SD (m)	CV (%)
0-5	381	18	5	446	30	7	384	22	6
5-10	184	17	9	185	5	2	174	17	10
10-15	66	6	9	154	10	6	122	10	8
15-20	35	3	9	92	6	6	68	4	6
20-25	24	2	8	70	6	9	44	4	8
25-30	12	2	15	70	11	16	36	5	13
30-35	4	1	17	43	6	15	30	4	13
35-40	1	0	14	29	3	10	20	1	7

[a] Mean of 4 replications per sample.

screened in the greenhouse for drought tolerance at limited rooting depth (45 cm) and the ability to recover from drought stress.

Three rices, including the indicator plant Leb Mue Nahng, were seeded in dry soil in steel drums and watered regularly to 30 DAS. Then water was withheld and the soil allowed to dry by evapotranspiration. When Leb Mue Nahng was apparently dead, the plants were scored for drought tolerance and then rewatered.

Table 10 shows some of the entries which recovered and have better drought tolerance than Leb Mue Nahng, the drought-tolerant check. Recovery, however, was very slow and poor.

Table 10. Drought tolerance ratings of promising entries during the vegetative phase, and recovery of entries after relief from stress. IRRI greenhouse, 1984.

Variety or line	Drought tolerance rating[a]	Tillers (%) that recovered 15 d after stress was relieved
	Dry season	
IR8608-3-2-2-3	8	21
IR21015-196-3-1-3	8	12
B44b-50-2-2-5-1-1	8	9
IR25774-3-1-1	8	6
IR43	9	7
IR15429-268-1-2-1	8	5
IR19672-155-2-1-1-3	8	4
IR29723-143-3-2-1	9	3
IR32826-59-2-3	8	4
Leb Mue Nahng	9	0
	Wet season	
IR9814-11-3	7	9
IR27316-60-3-2-2	7	9
IR10206-29-2	7	8
IR25588-7-3-1	8	6
IR45	8	5
IR6115-1-1-1	7	3
IR10011-16-3	7	3
IR21015-196-3-1-3	7	2
IR18348-36-3-3	9	2
Leb Mue Nahng	9	0

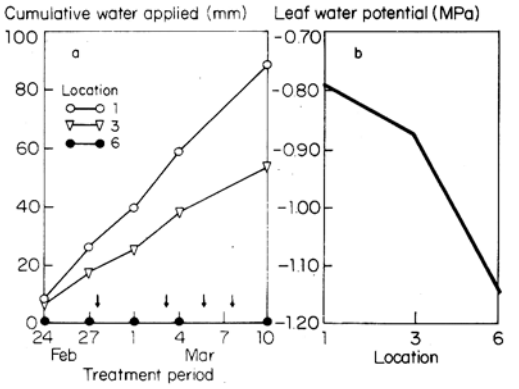
[a] By the 1980 Standard Evaluation System for Rice.

Although IR43, IR8608-3-2-2-3, and IR21015-196-3-1-3 in DS and IR9814-11-3 in WS have poor drought-tolerance ratings, they recovered well. Results show that ability to recover from drought stress is at least as important as ability to tolerate drought.

Physiological and yield responses to irrigation gradient in simulated rainfed lowland. This research examined the effects of different moisture levels on growth and yield of IR54.

Line source treatment and leaf water potential. The line source sprinkler treatment was imposed for 19 d from 42 to 61 DAS. Location 1 (continuously flooded) received the most water and location 6 (farthest from the line source sprinkler) received the least water (Fig. 10a). Locations 1, 3, and 6 were placed to conveniently represent the 6 irrigation treatments that correspondingly decreased the plant water status. Midday leaf water potential was −0.79 MPa at location 1 and −1.15 MPa at location 6 (Fig. 10b). Soil cracks were observed in locations 3 and 6 as drought progressed.

Photosynthesis. Canopy photosynthesis was sensitive to drought. It decreased by about 27% in

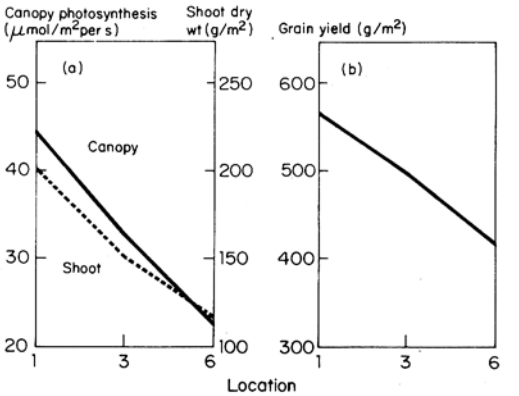


10. a) Cumulative water applied in different locations during line source sprinkler treatment. Location 1 was continuously flooded and nearest the line source, while location 6 was farthest from the line and received no irrigation. b) Midday leaf water potential on the 14th day of the treatment period. IRRI, 1984.

location 3, and 49% in location 6 (Fig. 11a). The decrease in canopy photosynthesis decreased the shoot dry weight, and consequently grain yield (Fig. 11b).

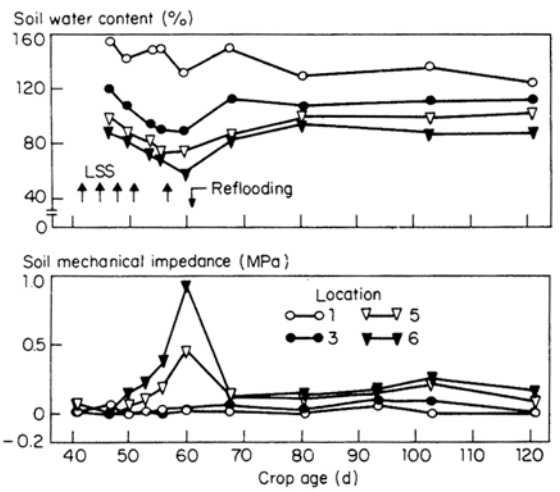
Soil mechanical impedance and root system. Root samples were taken with large samplers ($20 \times 20 \times 50$ cm^3) at irrigation levels 1, 3, 5, and 6 at 9 stages of crop development, 3 of them during drought treatment (42 to 61 DAS). The results presented are only for the upper 10 cm of soil containing 70% of total root length, although sampling went to the 40-cm depth by 5-cm increments.

The soil mechanical impedance (SMI) in the 0-10 cm soil layer is closely related to soil moisture

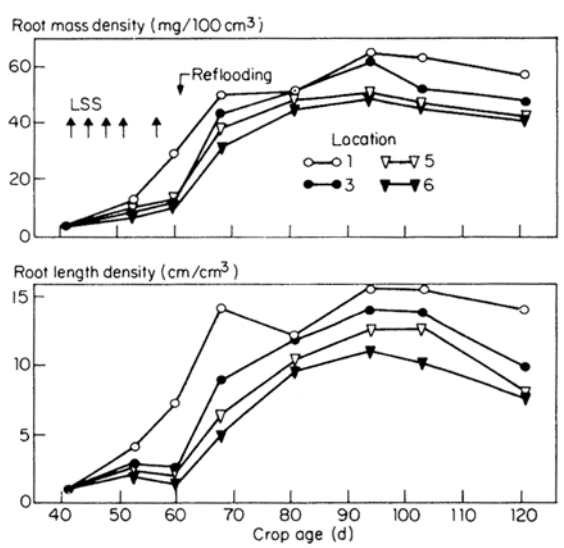


11. a) Canopy photosynthesis and shoot dry weight at the end of the 19-d treatment period. b) Grain yield at harvest in 3 locations. IRRI, 1984 DS.

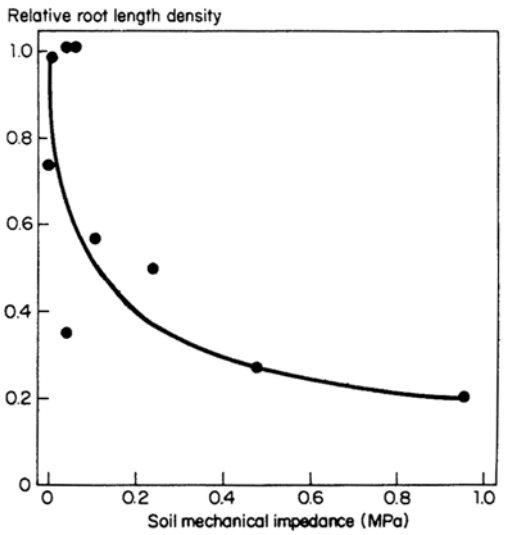
content (SMC) (Fig. 12). In locations 1 and 3, SMI remained nearly constant over time. In locations 5 and 6, SMI gradually increased until SMC reached around 70%, and increased significantly when SMC fell below 65%.



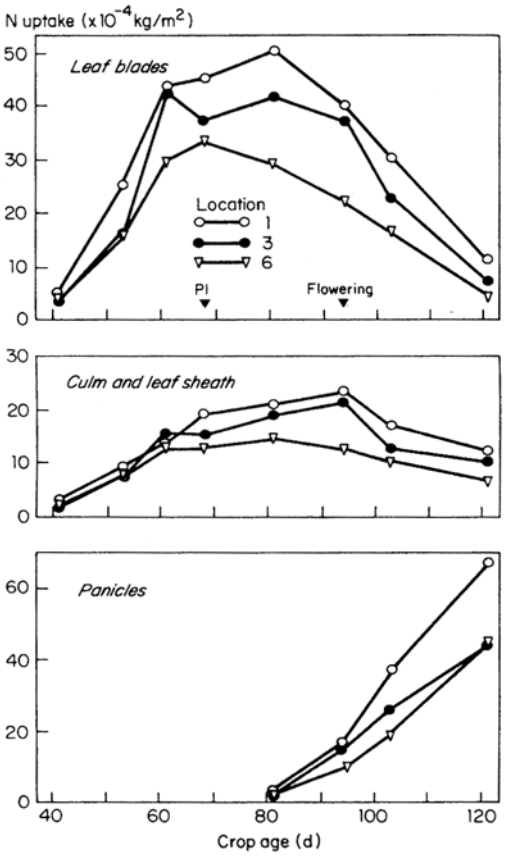
12. Effect of 4 irrigation treatments between day 42 and 61 on soil water content and soil mechanical impedance in the 0 to 10-cm zone. Irrigation level 1 was continuously flooded; levels 3, 5, and 6 were drained on day 42 and until day 61 received decreasing amounts of water applied by the line source sprinkler (LSS) irrigation system. IRRI, 1984.



13. Effect of 4 irrigation treatments imposed between day 42 and 61 on root weight and root length density in the 0 to 10-cm soil depth. Irrigation level 1 was continuously flooded; levels 3, 5, and 6 received decreasing amounts of water applied by the line source sprinkler (LSS) system. IRRI, 1984.



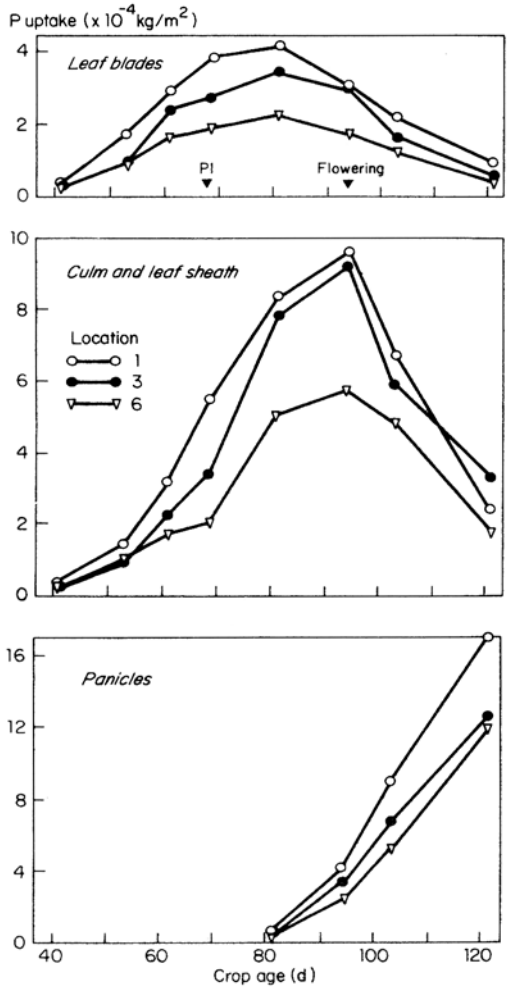
14. Relationship between root length density relative to control and soil mechanical impedance in a drying puddled lowland soil. The regression equation $Y = (1.441 + 27.27x)^{-1/2}$ describes the relationship ($R = 0.95^{**}$). IRRI, 1984.



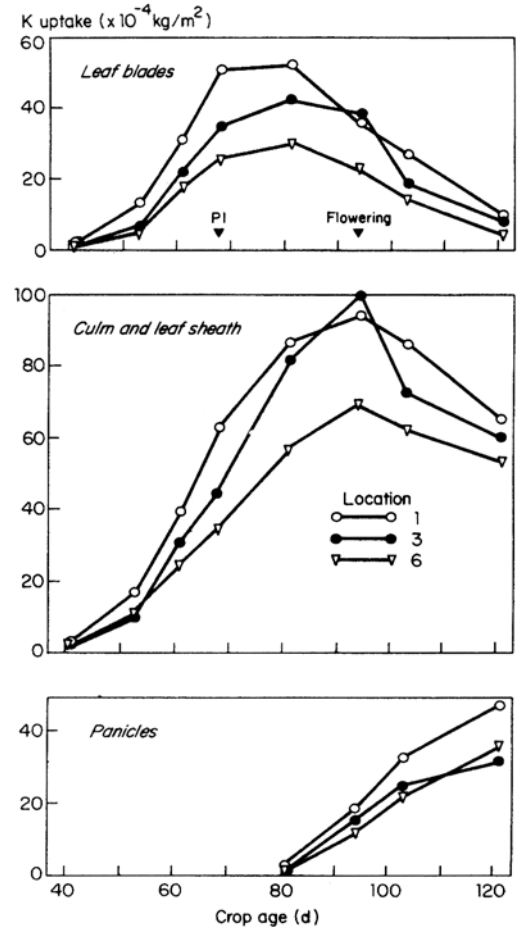
15. N uptake in various parts of IR54 at 3 irrigation levels. IRRI, 1984. PI = panicle initiation.

The root length density (RLD) increased linearly with time in the flooded control (Fig. 13). In locations 3, 5, and 6, an initial increase in RLD was followed by a decrease at the third sampling date when stress was maximum. Root weight response was similar to that of RLD in trend and timing. Root morphology changed more than root weight — roots became shorter and thicker in response to increased mechanical impedance, as is frequently observed. Reflooding the field reduced soil strength and increased root length densities. But it did not overcome effects of drought.

Increase in SMI decreases RLD relative to the control as shown in Figure 14. Under field conditions, however, SMI values as low as 0.05 MPa



16. P uptake in various parts of IR54 at 3 irrigation levels. IRRI, 1984. PI = panicle initiation.



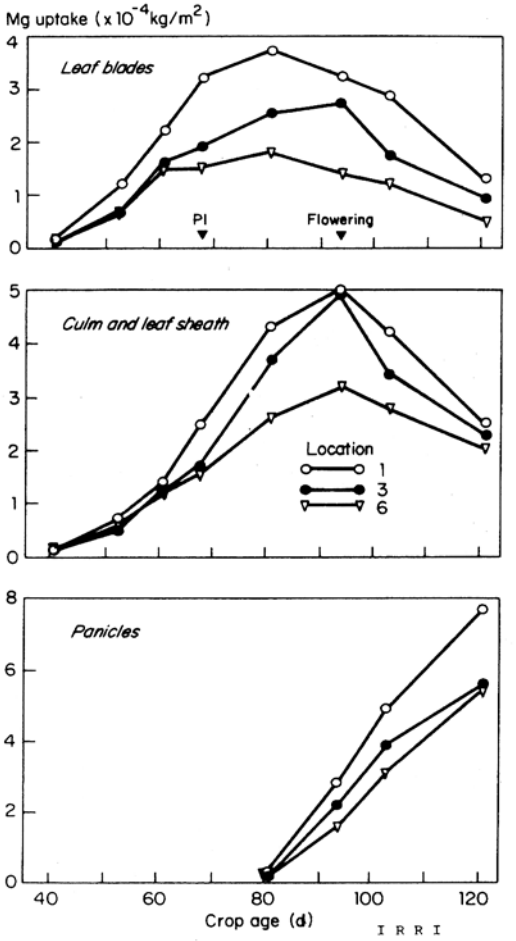
17. K uptake in various parts of IR54 at 3 irrigation levels. IRRI, 1984. PI = panicle initiation.

can inhibit root growth below control level. Values greater than 0.3 to 0.5 MPa might be critical. They consistently decreased root growth and extension to 25% of the control. Impaired root growth led to inefficient use of water and nutrients and reduced yield.

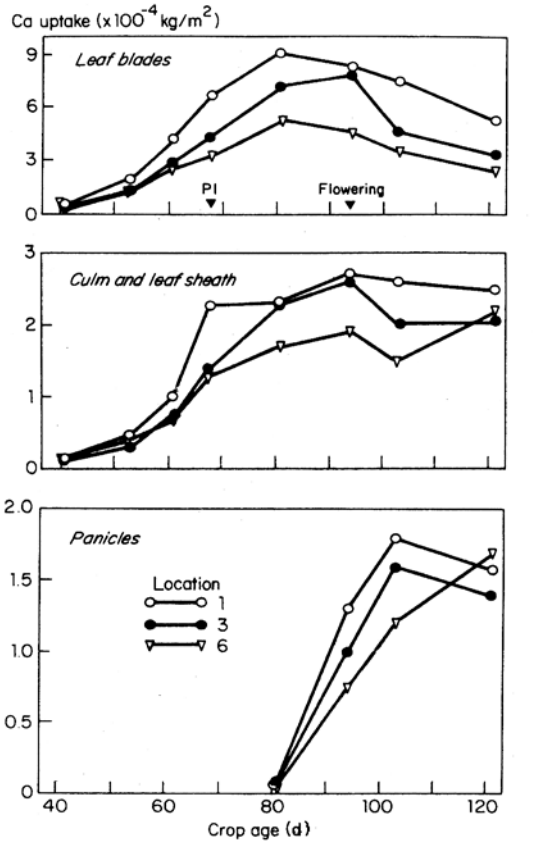
Nutrient uptake. This experiment also studied the effects of drought on nutrient accumulation and distribution among plant parts at different growth stages.

Figures 15-19 illustrate nutrient accumulation and distribution patterns in IR54 at three irrigation levels.

In general, IR54 continuously accumulated N, P, K, Mg, and Ca in leaf blades up to about 13 d before flowering, after which uptake decreased. Maximum uptake of N, P, K, Mg, and Ca in culm and leaf



18. Mg uptake in various parts of IR54 at 3 irrigation levels. IRRI, 1984. PI = panicle initiation.



19. Ca uptake in various parts of IR54 at 3 irrigation levels. IRRI, 1984. PI = panicle initiation.

sheath occurred during flowering. Panicles continuously took up these elements until maturity.

Comparing flooded control plants and stressed plants in location 6 shows that drought depressed N, P, K, Mg, and Ca uptake by about 40 to 50% in leaf blades and by about 14 to 40% in culm and leaf sheath with N and K less affected. At full maturity, panicles of stressed plants contained 25 to 37% less N, P, K, and Mg than flooded control plants. Ca in panicles of control and stressed plants in location 6 did not differ at maturity, although stressed plants reduced Ca uptake as much as 43% at flowering.

Genetic evaluation and utilization (GEU) program

Adverse soils tolerance

Soil Chemistry/Physics and Plant Physiology Departments

SCREENING **102**
- Salinity **102**
  - Mass screening **102**
  - Yield trials **102**
  - International tests **102**
- Alkalinity **102**
- Acid sulfate soils **102**
- Peat soils **102**
  - Screening **102**
  - Yield trials **102**
- Boron toxicity **102**
- Acid aerobic soils **102**
- Phosphorus deficiency **102**
  - Screening **102**
  - Yield trials **102**
- Zinc deficiency **103**
  - Screening **103**
  - Yield trials **103**

SCREENING OF CULTIVARS FOR ALUMINUM TOXICITY TOLERANCE **103**

SCREENING OF R_3 VARIANTS FROM SOMATIC CELL CULTURE FOR ALUMINUM TOXICITY TOLERANCE **103**

MULTIPLE STRESS TOLERANCE **104**

VARIETAL TOLERANCE AND YIELD STABILITY **104**

VARIETAL REACTIONS TO PHOSPHORUS AND ZINC DEFICIENCIES AND GROWTH DURATION **104**

OTHER CHEMICAL STRESSES **105**
- Low Ca to Mg ratio **105**
- K efficiency **105**
- Cold soils **105**
- Sulfur efficiency **105**

INTERNATIONAL IMPACT **106**

PHYSIOLOGICAL STUDIES ON SALT TOLERANCE **106**
- Effect of calcium ion on plant survival and uptake of Na^+ and Cl^- **106**
- Interaction of humidity and salinity **107**

EFFECT OF HIGH CALCIUM ION ON ALUMINUM TOXICITY **107**

IMPROVING A TRADITIONAL SALT-TOLERANT VARIETY BY TISSUE CULTURE **108**
- Testing advanced selections of Nona Bokra variant in saline fields **109**

SCREENING

Soil Chemistry/Physics Department

Screening for tolerance for chemical soil stresses and yield trials with promising rices in 1984 continued with greater emphasis on soil problems in rainfed environments. Of 13,438 rices screened, 1,917 were tolerant. Yield trials in farmers' fields in the Philippines showed that 32 modern rices are adapted to adverse soil conditions. IR9764-45-2 is outstanding in tolerance for multiple soil stresses.

Salinity. *Mass screening.* Of 5,726 rices from the GEU program, 1,125 tolerated a salinity stress of 9-10 dS/m. Of 832 rices in the salt tolerance hybridization program, 117 showed tolerance in field tests. Outstanding were IR15948-4-2, IR19743-25-2, IR29692-94-2, IR29723-143-3, IR31375-3-3, IR31811-35-3, IR31847-67-2, SPR7216-RST542-1, and SPR7316-30-1.

Yield trials. Of 33 rices tested in 13 replicated experiments in farmers' fields in coastal saline tracts in 6 Philippine provinces, IR9764-45-2 fared best with a yield (averaged for 5 sites) of nearly 3 t/ha.

International tests. Seven of 11 entries rated tolerant in the 1982 IRTP were nominations of the Soil Chemistry/Physics Department. Three salt-tolerant IRRI rices identified earlier are grown or used in breeding programs for saline tracts in India and Vietnam.

IR36, IR42, IR46, and IR52 have been found suited to saline soils.

Alkalinity. Of 1,415 rices tested in the greenhouse, IR32809-26-3, IR32809-67-2, and IR32814-70-2 were outstanding in alkali tolerance. In field tests of recent breeding lines, the following were rated tolerant: IR15948-4-2, IR19660-274-3, IR19743-25-2, IR28178-111-1, two IR38502-CP106-02 lines, RP975-109-2, and R909-1-2.

IR varieties suited to alkali soils are IR36 and IR46.

Acid sulfate soils. Of 369 rices tested in 1984, 20 scored 3 on the Standard Evaluation System for Rice at 8 wk after transplanting. In a performance trial of 20 rices, the top yielder was IR9764-45-2 with 4.6 t/ha in dry season (DS) and 2.9 t/ha in wet season (WS). It outyielded the resistant check (IR36) by 0.8 t/ha in DS and 0.7 t/ha in WS.

Because IR9764-45-2 also tolerates salinity and P deficiency, it should do well on saline acid sulfate soils.

The following IR varieties are now grown in acid sulfate or iron-toxic soils: IR36, IR40, IR42, and IR52.

Peat soils. *Screening.* Fifty-four GEU elite lines were tested on 2 peat soils in 1984 DS and WS with 50-25-25 NPK and ZnO. The following were visually rated as tolerant: IR13540-56-3, IR21055-196-3, IR21848-65-3, IR25588-7-3, and IR31917-31-3-2. The previously reported tolerance of IR60, IR8192-31-2, and IR9764-45-2 for peat was confirmed in concrete-bed tests.

Yield trials. A total of 27 rices was tested in WS and DS on 2 peat soils with ZnO. IR9764-45-2 was the top yielder on both soils with 2.6 t/ha.

IR varieties that are suited to fresh water peats are IR34, IR42, and IR54.

Boron toxicity. In a greenhouse test of 25 GEU rices, 9 were visually rated as tolerant of B toxicity, among them IR42 and IR50. Salt-tolerant IR9884-54 grew well in a B-toxic soil. In a test of 24 rices in a B-toxic field, yields ranged from 1.5 to 3.4 t/ha. IR42, IR54, IR21820-154-3, IR28150-84-3, and IR29723-143-3 yielded more than 3 t/ha. When B toxicity was increased by adding 10 mg B/kg soil, the yields were 0.6-3.0 t/ha. The highest yielder was IR21820-154-3. Yield reduction due to added B ranged from 12% for tolerant IR21820-154-3 to 76% for IR58.

Three IR varieties are suited to B-toxic soils: IR42, IR46, and IR54.

Acid aerobic soils. Of 224 rices screened in farmers' fields on 3 acid soils with pH values of 3.8-4.7, the following were tolerant: IR3839-1, IR5931-110-1, IR9101-124-1, IR9256-59, IR9671-1-4, IR17494-1-1, Chianung Sipi 661020, NDR96, OK165-28, and Tox 955-104-1. IR43, IR6023-10-1, and IR6115-1-1 did well on acid soils in concrete beds. IR43 and IR6115-1-1 yielded more than 3 t/ha.

IR43 and IR46 are suitable for planting in acid upland soils.

Phosphorus deficiency. *Screening.* A total of 896 rices were screened in the greenhouse. Among the 37 that tolerated P deficiency were IR32, IR54, IR58, IR21848-65-3, IR25774-3-1, and IR25916-15-3.

Yield trials. Of 30 rices grown on a P-deficient soil, IR46, IR9217-58-2, IR9764-45-2, IR13149-23-2, IR13427-40-2, IR14632-21-3, and IR15791-163-1 yielded 4-5 t/ha without P fertilizer compared with

1.5 t/ha of IR36, the susceptible check. Yield depression due to P deficiency (as measured by relative yield with and without P fertilizer) for these rices ranged from 5.0% to 24%, compared with 68% for IR36. Seven of the 8 rices suffering yield reductions exceeding 40% were early rices (112 d).

The findings indicate that early maturing rices need more phosphate than medium duration ones. P deficiency delayed maturity by 30 d, averaged for the twelve 112-d rices and by 16 d for the later rices. The advantages of early maturity are lost if P deficiency is not corrected.

Among IR varieties suited to P-deficient soils are IR26, IR34, IR42, IR44, IR46, IR48, IR52, and IR54.

Zinc deficiency. *Screening.* Of 917 entries screened in a Zn-deficient farmer's field, 35 gave tolerant scores. Among them were SR26B, Pokkali, IR36, IR50, IR8866-30-3, IR19743-25-2, IR21567-9-2, IR21367-16-2, and IR25064-99-1.

Yield trials. In a trial of 9 rices in a Zn-deficient farmer's field with and without Zn application in 1984 DS, the resistant check IR34 yielded 4.7 t/ha; IR9764-45-2, 4.5 t/ha; and the sensitive check IR26, 3.1 t/ha without applied Zn. Yield reduction due to Zn deficiency ranged from 4.3% for tolerant IR9764-45-2 to 26.2% for sensitive IR26.

IR34, IR46, IR52, and IR54 are suited to Zn-deficient soils.

SCREENING OF CULTIVARS FOR ALUMINUM TOXICITY TOLERANCE

Plant Physiology Department

Aluminum toxicity is a potential problem in growing upland rice on acid soils. A total of 352 rice cultivars from the 1983 International Upland Rice Observational Nursery and 1983 Acid Upland Soils Screening Set were screened for Al toxicity tolerance. IR45 and Cica 4 were used as susceptible checks and IAC3 and OS4 as tolerant checks. Seedlings were grown in full strength nutrient solution with and without 30 ppm Al. After 2 wk, relative root length (RRL) was measured.

RRL ranged from 0.36 to 0.97. Seven percent of the entries screened were tolerant; most tolerant was IRAT104. Azucena, an upland Philippine variety, and IR5853-196-1-P_1 and IR7812-16-1-4 were also outstanding (Table 1).

Eight improved upland lines were also screened for Al tolerance. All lines possessed intermediate tolerance, with RRL ranging from 0.66 to 0.76 (Table 2). Root growth of lines tested in the Al-free medium was less than that of the checks.

Table 1. Aluminum toxicity-tolerant varieties screened from the 1983 IURON and 1983 Acid Upland Soils Screening Set.

Variety	
IRAT104	Rau 5002-12
IRAT131	IRAT104
ITA184	ITA116
IAC1246	ITA164
ITA225	Leuang Kon Ngan
E425	IR7812-16-1-4
ITA175	OS-6 IRR DWF 16809
Azucena	IRAT133
B2991b-Tb-4-30-2-2-3	M18
Khao Daeng Rai	Niaw Prong Aew
IR5853-196-1-P1	IRAT119
Khao Daeng	IRAT142
	M55

Table 2. Screening for aluminum toxicity tolerance. IRRI, 1983.

Entry	Root length (cm)			Tolerance score[b]
	0 ppm Al	30 ppm Al	RRL[a]	
IR3839-1	9.8	6.6	0.67	2
IR3880-10	9.0	6.1	0.68	2
IR3880-17	8.3	5.7	0.69	2
IR5178-1-1-4	11.7	8.1	0.69	2
IR5929-12-3	9.3	7.0	0.75	2
IR6023-10-1-1	9.6	6.4	0.67	2
IR6115-1-1-1	8.7	6.6	0.76	2
IR9669 Sel.	8.7	6.7	0.66	2
IAC3 (check)	17.3	15.1	0.87	1
OS4 (check)	11.6	9.8	0.84	1

[a]Relative root length. [b]Tolerance score:
1 = tolerant RRL >0.80
2 = intermediate RRL 0.65-0.79
3 = susceptible RRL <0.64

SCREENING OF R_3 VARIANTS FROM SOMATIC CELL CULTURE FOR ALUMINUM TOXICITY TOLERANCE

Plant Physiology Department

From 3,991 R_2 rice seedlings representing 472 lines derived from the callus of Taichung 65, 46 Al-tolerant and 5 Al-susceptible R_2 seedlings were selected and grown in soil until maturity. The 51 R_3 variants harvested were then screened for Al toxicity using 0 and 30 ppm Al in nutrient solution.

Table 3. Most Al-tolerant R_3 variants and range of root growth. IRRI, 1984.

Line	Maximum root length (cm) in 0 ppm Al	Relative root length (30 ppm/0 ppm Al)
TNV C-9-2-1-A-1	16.3	0.83
TN II 5-8-2-A-1	15.9	0.82
TN II 5-7-1-1-C-4	16.1	0.81
Range	8.5-18.5	0.42-0.83
Parent (Taichung 65)	14.6	0.58

Table 4. Yields of IR9764-45-2 on unamended problem soils. 1984 DS, IRRI.

Problem	Yield (t/ha)
None	5.9
P deficiency	4.9
Acid sulfate	4.7
Zn deficiency	4.5
B toxicity	3.3
Peat	3.2
Salinity	2.7
Alkalinity	2.0

TNV C-9-2-1-A-1, TN II 5-8-2-A-1, and TN II 5-7-1-1-C-4 were found highly tolerant of Al (Table 3). Maximum root length of the variants in 0 ppm Al ranged from 8.5 to 18.5 cm; that of Taichung 65 was 14.6 cm. RRL varied from 0.42 to 0.83. Of 51 variants, 49 were more tolerant than their parents.

MULTIPLE STRESS TOLERANCE

Soil Chemistry/ Physics Department

IR8192-200-3 and IR9764-45-2 showed tolerance for most soil toxicities and nutrient deficiencies. The yields of IR9764-45-2 on some unamended problem soils in the 1984 DS appear in Table 4.

VARIETAL TOLERANCE AND YIELD STABILITY

Soil Chemistry/ Physics Department

Varietal tolerance for a soil stress confers a comparative yield advantage of about 2 t/ha over varieties that lack the trait (Table 5, 6). Tolerance for multiple soil stresses ensures yield stability over a range of environmental conditions. The yield of IR36, a cultivar with multiple soil stress tolerance, was compared with that of IR26, a stress-sensitive cultivar, under stresses commonly encountered in rainfed lowland rice areas (Table 7).

VARIETAL REACTIONS TO PHOSPHORUS AND ZINC DEFICIENCIES AND GROWTH DURATION

Soil Chemistry/ Physics Department

Rices can be classified into four groups according to their performance on P- or Zn-deficient soils in the absence or presence of the elements as fertilizers. The reactions of IR varieties illustrate the grouping (Table 8, 9).

Varieties of Group I give low yields under nutrient stress and do not respond positively to the applied nutrient. Such varieties either inefficiently absorb the nutrient or suffer from other yield-limiting stresses. Group II varieties are poor absorbers of soil P and Zn, but respond well to the applied elements. Cultivars in Group III efficiently use soil P and Zn, but not the fertilizer elements or they experience other limits to yield. The varieties in Group IV use both soil and fertilizer P and Zn efficiently.

Table 5. Summary of results of replicated yield trials with IR rices on unamended problem soils in farmers' fields in the Philippines, 1977-82.

Stress	Total no.			Mean yield (t/ha)		
	Tests	Sites	Rices	Min	Max	Advantage
Salinity	31	20	77	1.6	3.6	2.0
Alkalinity	4	2	79	0.7	3.3	2.6
Fe toxicity	15	4	70	2.3	4.8	2.5
Peatiness	18	6	62	1.5	3.2	1.7
Al/Mn toxicity	7	3	44	1.8	3.7	1.9
P deficiency	15	2	142	1.9	4.4	2.5
Zn deficiency	29	11	145	1.4	3.9	2.5
Fe deficiency	8	3	65	0.9	2.8	1.9

Table 6. Summary of results of replicated yield trials with IR rices on unamended problem soils in farmers' fields in the Philippines, 1983-84.

Problem	Total no.			Mean yield (t/ha)		
	Tests	Sites	Rices	Min	Max	Advantage
Salinity	18	9	34	1.0	3.0	2.0
Alkalinity	4	1	24	1.1	3.6	2.5
Acid sulfate	4	4	25	1.3	3.1	1.8
Peat	7	3	32	0.9	3.5	2.6
B toxicity	5	1	34	1.1	3.0	1.9
Acid upland	5	3	24	0.8	2.8	2.0
P deficiency	4	1	44	2.2	5.2	3.0
Zn deficiency	12	4	56	1.4	3.9	2.5

Table 7. Yields of IR36 and IR26 on some unamended problem soils in farmers' fields in the Philippines, 1984.

Problem	IR26			IR36		
	Tests (no.)	Sites (no.)	Yield (t/ha)	Tests (no.)	Sites (no.)	Yield (t/ha)
Salinity	5	5	1.6	16	8	2.6
Fe toxicity	9	2	1.9	6	2	3.1
Zn deficiency	9	8	1.0	6	5	2.7

Table 8. Yields of some IR cultivars with and without P fertilizer on a P-deficient Tropaquult, averaged for several tests. IRRI, 1984.

Group	Yield (t/ha)		Cultivars
	No P	With P	
I	<3.0	<3.3	IR22, IR24, IR28, IR29, IR30, IR32, IR43, IR45
II	<3.0	>4.0	IR36, IR58, IR60
III	>3.5	<4.0	IR20, IR40
IV	>3.5	>4.5	IR42, IR46, IR48

Table 9. Yields of some IR cultivars with and without Zn fertilizer on a Zn-deficient Hydraquept, averaged for several tests. IRRI, 1984.

Group	Yield (t/ha)		Cultivars
	No Zn	With Zn	
I	<3.0	<3.3	IR28, IR36, IR56, IR58
II	<3.0	>4.0	IR20, IR54
III	>3.5	<4.0	IR22, IR24, IR43
IV	>3.5	>4.5	IR38, IR46, IR48

Efficient utilizers of native and added P and Zn are varieties with growth durations exceeding 120 d. Varieties with durations less than 113 d are poor users of soil P. They respond well to P fertilizer.

Thus, varietal growth duration should help determine P and Zn fertilization. Early varieties will benefit more than late ones from P and Zn application on marginally deficient soils.

OTHER CHEMICAL STRESSES

Soil Chemistry/ Physics Department

Low Ca to Mg ratio. Wetland soils tend to have a low Ca:Mg. Because an exchangeable Ca:Mg of less than 2 depresses yields, screening for varietal tolerance to this stress is under way.

K efficiency. Because low K:Ca and K:Na limit rice growth on saline soils, rices are being screened in the greenhouse for K efficiency.

Cold soils. Excess Fe, CO_2, and organic acids retard rice growth in cold, acid lowland soils. In breeding for cold tolerance, incorporating tolerance for these adverse factors may improve performance.

Sulfur efficiency. Widespread S deficiency in lowland rice has stimulated interest in S-efficient rices. Because S deficiency is easily corrected by adding gypsum or ammonium sulfate, screening for this stress may be unnecessary.

INTERNATIONAL IMPACT

Soil Chemistry/Physics Department

Of 35 rices found tolerant of adverse soils in international tests in 1982, 32 were nominations by IRRI's Soil Chemistry/Physics Department. The nominations were based on greenhouse and field tests in the Philippines.

In international tests of 20 rices conducted in 53 locations in 15 countries in 1982, multiple-soil-stress-tolerant IR36 was the second highest yielder, averaging 4.6 t/ha.

In production or breeding programs, national agencies are using several rices IRRI identified as tolerant of soil stresses. They include the multiple-soil-stress-tolerant IR36 and IR42 in six countries, salt-tolerant IR4-11 and IR36 on the coastal saline soils of West Bengal, two acid-sulfate-soils-tolerant IR1529 lihes on acid sulfate soils in Vietnam, and salt- and acid-sulfate-tolerant IR2153-26 on saline acid sulfate soils in Vietnam.

PHYSIOLOGICAL STUDIES ON SALT TOLERANCE

Plant Physiology Department

To increase rice production on saline soils, we can change the environment to improve conditions for the plant, or change the plant genetically to better tolerate salinity. The varietal approach to increasing salt tolerance would be cheaper for the farmers.

Effect of calcium ion on plant survival and uptake of Na^+ and Cl^-. Membrane structure is directly affected by changes in the ionic environment. Plants need Ca to maintain membrane integrity and to transport other ions.

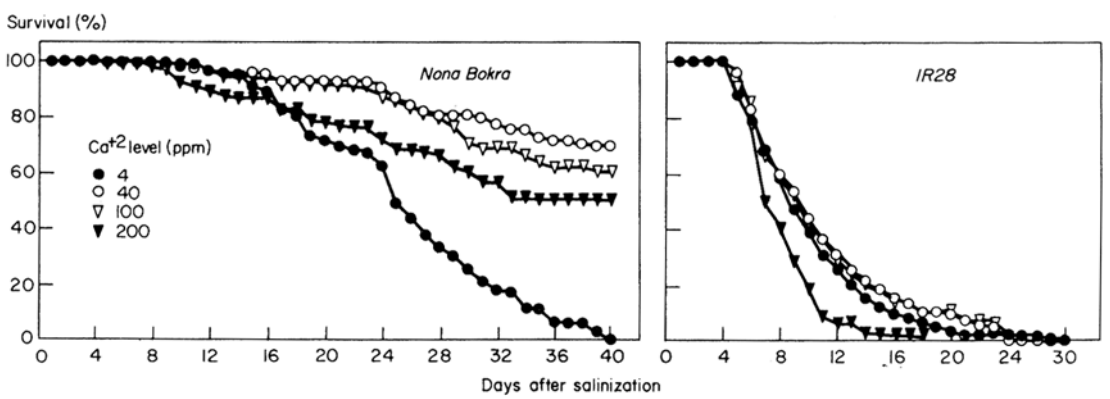
Ca is even more important in a saline environment. It can ameliorate adverse effects of salt on plant growth. An experiment was conducted to elucidate the effect of Ca ion on growth of salt-susceptible (IR28) and salt-tolerant (Nona Bokra) varieties in saline culture medium. Seedlings were grown in salinized nutrient solution containing 0.5% NaCl and Ca^{2+} ion concentration at 4, 40, 100, and 200 ppm. Plants were grown up to 40 d in salinized solutions.

Varying Ca^{2+} concentrations had very little effect on survival of IR28 plants (Fig. 1). The D50 (time in which 50% of seedlings die) from 4 ppm to 40 and 100 ppm was 9 d. Adding 200 ppm Ca^{2+}, however, decreased D50 to 7 d. Nona Bokra survived best at 40 ppm Ca^{2+}, then at 100 and 200 ppm. Plants grown in 4 ppm Ca^{2+} died after 40 d. In tolerant plants, adding Ca to the growing medium greatly increased percent survival.

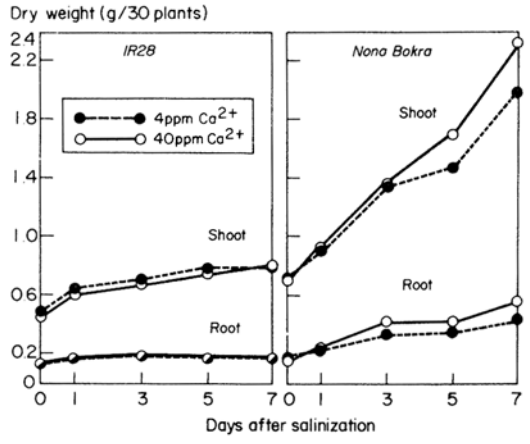
The stability of biological membranes under widely varying ratios of K^+ to Ca^{2+} and Na^+ to Ca^{2+} might be a crucial feature of salinity tolerance. Therefore the role of Ca^{2+} on uptake and transport of Na^+ and Cl^- in the two varieties was further investigated.

Seedlings were transferred to a salinized nutrient solution containing 0.5% NaCl and Ca^{2+} concentrations at 2 levels, 4 and 40 ppm. The shoot and root dry weights of IR28 did not vary at either concentration (Fig. 2). In Nona Bokra, however, 40 ppm Ca increased the shoot and root dry weight.

The amount of Na ion absorbed by plants in the shoot was higher in IR28 than in Nona Bokra



1. Effect of calcium ion on percent survival of Nona Bokra and IR28. IRRI, 1984.



2. Dry weight of shoot and root of IR28 and Nona Bokra as affected by NaCl (0.5%) and different Ca ion concentrations. IRRI, 1984.

(Fig. 3), which explains the susceptibility of IR28 to salinity. Addition of Ca ion at 40 ppm did not decrease the translocation of Na ion from the root to the shoot in IR28. In Nona Bokra, less Na ion and Cl ion were absorbed both in the shoot and in the root than in susceptible IR28.

Nona Bokra appeared to tolerate high salinity by regulating salt uptake and by accumulating little Na and Cl in the shoot. Adding enough Ca in the culture solution increases Nona Bokra's tolerance.

Interaction of humidity and salinity. Increase in ambient humidity to near saturation can either reduce water flow in the plant or reduce drought stress. Higher humidity should decrease the effect of salinity.

An experiment in the phytotron examined the growth and survival of IR28 and Nona Bokra exposed to salinization under high and low relative humidities (RH). The seedlings were transferred to a salinized nutrient solution containing 0.5% NaCl under 50 and 80% RH. Plants were grown to 40 d and the number of surviving plants was recorded daily.

In both varieties, survival was higher at low RH (Fig. 4). D50 was 8 d under high humidity and 14 d under low humidity. In Nona Bokra, most plants grown on high RH died after 28 d.

To further investigate interaction between salinity and atmospheric humidity on growth, uptake, and translocation of Na and Cl ions, another experiment used 0.5% NaCl under low and high RH.

IR28 shoot and root dry weights did not vary at low and high RH. In Nona Bokra, however, the high RH stimulated shoot growth.

Roots absorbed more Na ion at low RH than at high RH in both IR28 and Nona Bokra. More Na ion translocated to the shoots of both varieties at low RH until 3 d after salinization but then became higher at high RH after 5-7 d from salinization (Fig. 5). The same trend was observed for Cl ion absorption.

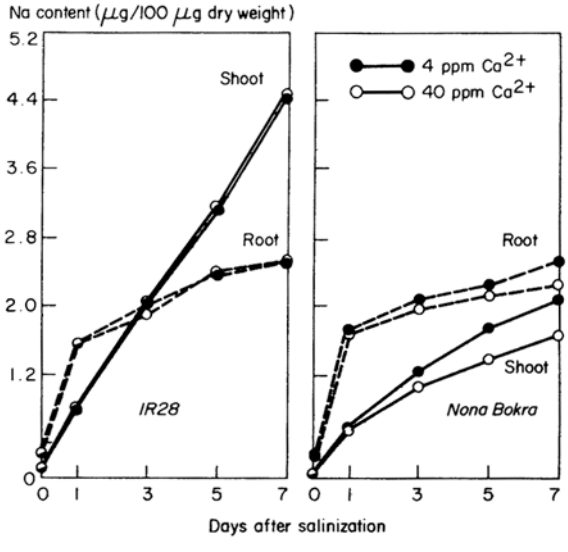
Higher translocation of Na and Cl ions to shoots of both varieties under high RH started after 5 d from salinization. Fewer plants survived under high RH. These results illustrate a complex relationship of growth with water flow, ion transport, and osmotic adjustment in the plant, requiring further research.

EFFECT OF HIGH CALCIUM ION ON ALUMINUM TOXICITY

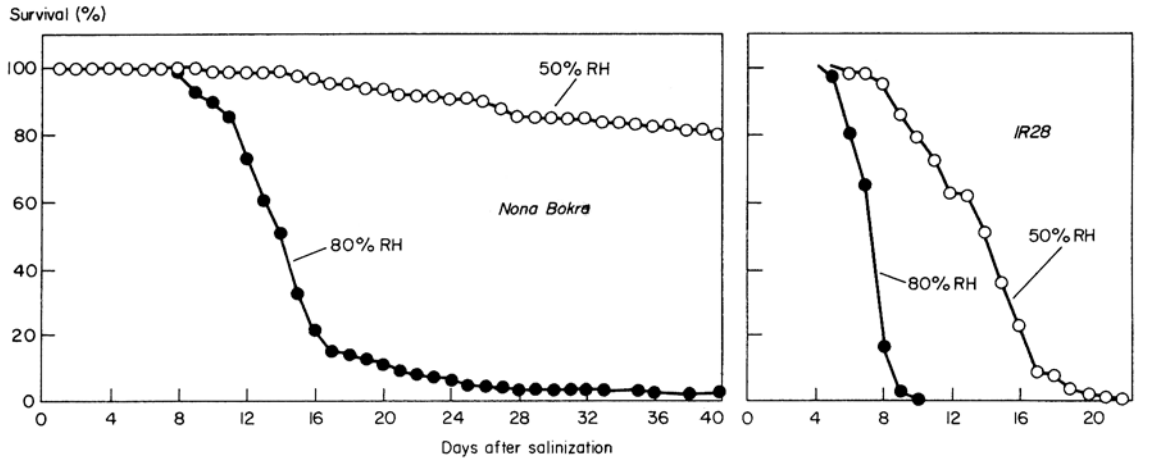
Plant Physiology Department

Ca concentration in soil solutions of acid soils studied varied from 0.5 to 653 ppm. Generally, 40 ppm Ca is adequate for normal rice growth. Excess Ca can compete with Al for exchange sites in the rice roots and hence reduce Al toxicity.

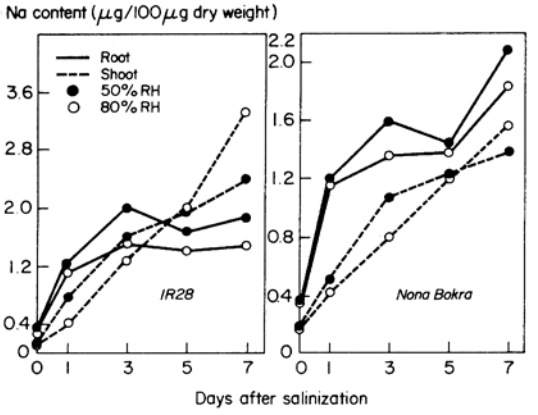
Ten-day-old seedlings of Al-sensitive IR45 and



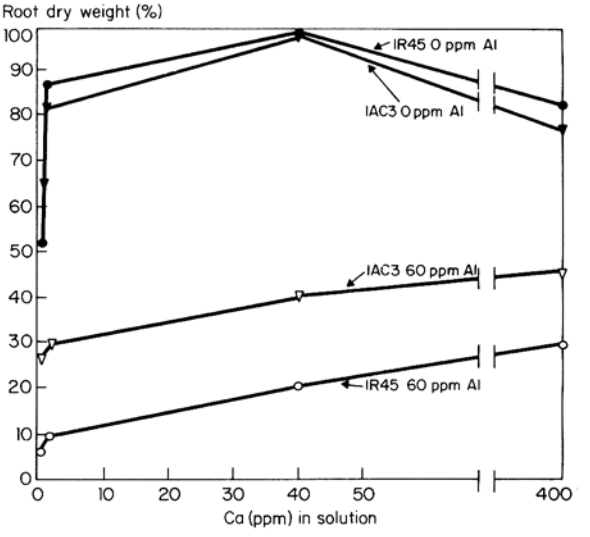
3. Na ion content in shoot and root of IR28 and Nona Bokra as affected by NaCl (0.5%) and different Ca ion concentrations. IRRI, 1984.



4. Survival of Nona Bokra and IR28 seedlings salinized with NaCl (85 mol/m^3) under different relative humidities (RH). IRRI, 1984.



5. Na ion content in shoot and root of IR28 and Nona Bokra as affected by NaCl (0.5%) and different relative humidities (RH). IRRI, 1984.



6. Effect of Ca on root growth of IR45 and IAC3, with and without Al. IRRI, 1984.

Al-tolerant IAC3 were grown in complete nutrient solution with graded levels of Ca and Al for 4 wk.

In the Al-free medium, 1 ppm Ca markedly depressed root growth of both IR45 and IAC3 (Fig. 6). Growth of both varieties was close to normal in 4 and 400 ppm Ca.

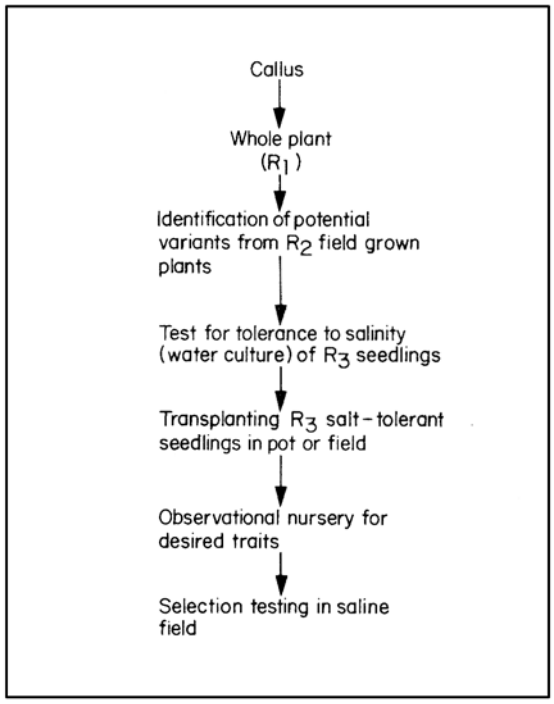
At toxic Al levels, both varieties grew slightly better with greater Ca concentration (Fig. 6). IAC3 consistently grew better than IR45. However, both varieties in the highest Ca level grew much poorer than at Al-free and low Ca levels.

High Ca has a limited alleviating effect on Al toxicity.

IMPROVING A TRADITIONAL SALT-TOLERANT VARIETY BY TISSUE CULTURE

Plant Physiology Department

Nona Bokra, a salt-tolerant rice from India, is tall, weak-culmed, and has droopy leaves and open tillers. The tissue culture technique provided variations from the Nona Bokra parent (Fig. 7). Plant lines with desirable plant type and tolerance for



7. A scheme to improve a traditional salt-tolerant variety. IRRI, 1984.

saline water culture were selected. The best variant was designated NBSC-1-1-1-1.

In July 1984, an observational nursery was set up at IRRI and 1,700 R_2 lines of Nona Bokra at 100 seedlings per line were grown to maturity. A total of 250 variants were semidwarf to intermediate in plant height. The selections were further tested for salinity tolerance. The results show that variation in salinity tolerance and thus wide variation in plant type can be obtained through somatic tissue culture.

Testing advanced selections of Nona Bokra variant in saline fields. More than 530 advanced selections of Nona Bokra variant NBSC-1-1-1-1 were tested for survival in an unreplicated field trial in a saline area in Santo Tomas, Pampanga, in August 1984. Some lines were tall but erect-leaved, thick-culmed, and semicompact in tillering with long panicles and good grain filling. Others were semidwarfs or medium tall with well-filled panicles.

Eighty-one of the 534 selections tested were more salt-tolerant than the parent Nona Bokra and 186 were slightly better or comparable to it. Seeds of harvested panicles will be included in the 1985 field test for tolerance for salinity.

Genetic evaluation and utilization (GEU) program

Deep water and flood tolerance

Plant Physiology and Agronomy Departments

SCREENING FOR ELONGATION ABILITY **112**
SCREENING FOR SUBMERGENCE TOLERANCE **112**
NITROGEN RESPONSE AND YIELD POTENTIAL OF DEEP WATER RICES **112**

SCREENING FOR ELONGATION ABILITY

Plant Physiology Department

A total of 48 crosses from the rapid generation advance (RGA) program were tested for elongation ability using the deep water tank. Outstanding selections from IR28273, IR28289, IR28319, IR37029, IR16156, IR22787, CN652, CN658, HTA FR77035, HTA FR77060, and Rau 1004 were given to plant breeders for further evaluation. Seeds were in F_5.

SCREENING FOR SUBMERGENCE TOLERANCE

Plant Physiology Department

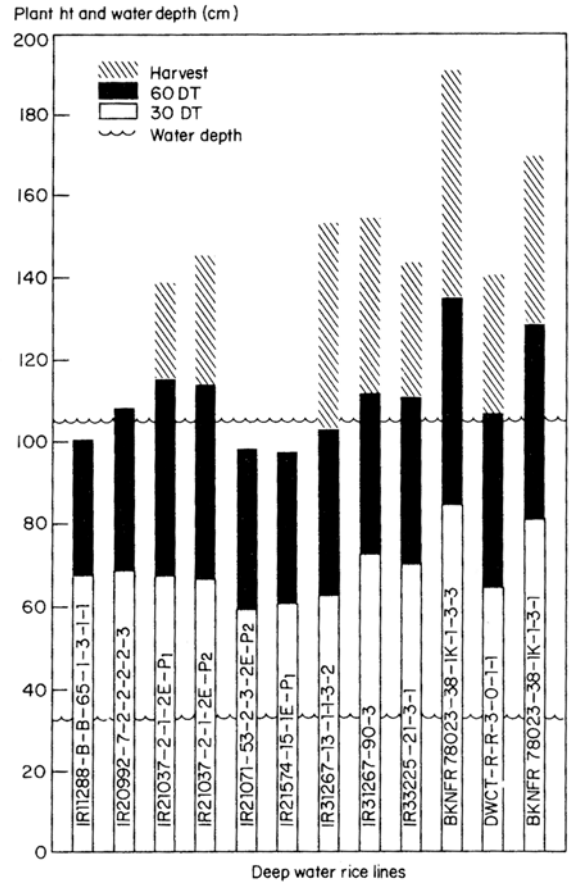
Submergence tolerance tests were conducted on more than 26,000 entries coming from the pedigree nursery, yield trials, and IRTP nurseries.

Surviving plants from 86 crosses from the RGA program were transplanted in the field and selections made for the pedigree nursery.

Table 1. Grain yield of promising deep water (maximum 100 cm) rices. IRRI, 1984 DS and WS.

Deep water rice	Yield (t/ha)
1984 DS	
IR21037-2-1-2E-P_1	0.4
IR21037-2-1-2E-P_2	0.4
IR31267-13-1-1-3-2	0.1
IR31267-90-3	0.3
IR33225-21-3-1	0.4
DWCT-R-R-3-0-1-1	0.2
BKNFR78023-38-1K-1-3-1	1.0
BKNFR78023-38-1K-1-3-3	1.0
IR11288-B-B-65-1-3-1-1	[a]
IR20992-7-2-2-2-2-3	[a]
IR21071-53-2-3-2E-P_2	[a]
IR21574-15-1E-P_1	[a]
1985 WS	
BKNFR78023-38-1K-3-3	0.2
GEU76050-0-19-4-1	0.3
IR11141-6-1-4-1	0.8
IR11288-B-B-69-1	0.1
IR33225-45-3-1-1-3-1	0.2
IR5857-16-1E-1-18	0.2
IR5857-16-1E-1-5	0.1
IR5857-4-1E-1-6	0.1
IR6370-K-23-1-2-0-1	0.4
SPR7411-7-2-1	0.4
IR28424-4-1-1-1	0.9
BKNFR76026-3-2-2-4	2.1
IR31617-19-3-3-4	[a]

[a] Because of poor elongation ability, plants did not survive at 100-cm depth.



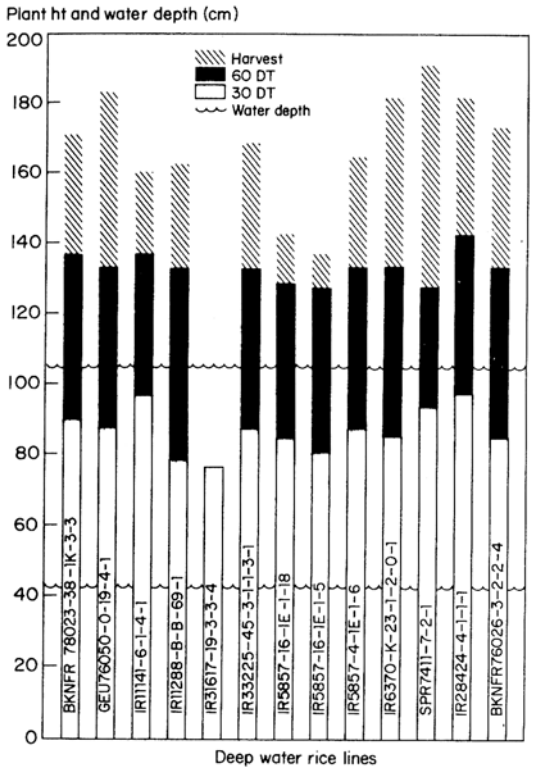
1. Plant height of some promising deep water rice lines in relation to plant growth stages and increasing water depth. IRRI, 1984 DS. DT = days after transplanting.

Many entries selected from the screening program were outstanding in the 1984 nurseries for deep water (IRDWON) and shallow water (IRSWON). The 1984 IRTP nurseries contain 40 such entries.

NITROGEN RESPONSE AND YIELD POTENTIAL OF DEEP WATER RICES

Agronomy Department

During 1984 dry and wet seasons (DS and WS), 25 promising rices were tested at IRRI in controlled water (maximum water depth 100 cm) at 0 and 87 kg N/ha (DS) and 58 kg N/ha (WS). Without fertilizer N, yields were zero. BKNFR78023-38-1K-1-3-1 and BKNFR78023-38-1K-1-3-3 yielded 1.0 t/ha during DS, BKNFR76026-3-2-2-4 yielded



2. Plant height of some promising deep water rice lines in relation to plant growth stages and increasing water depth. IRRI, 1984 WS. DT = days after transplanting.

Table 2. Some agronomic characteristics of promising deep water (maximum 100 cm) rices. IRRI, 1984 DS and WS.

Deep water rice	Tillers (no./m^2)	Panicles (no./m^2)
1984 DS		
IR21037-2-1-2E-P_1	244	173
IR21037-2-1-2E-P_2	291	163
IR31267-13-1-1-3-2	424	291
IR31267-90-3	459	260
IR33225-21-3-1	357	145
DWCT-R-R-3-0-1-1	267	189
BKNFR78023-38-1K-1-3-1	330	171
BKNFR78023-38-1K-1-3-3	350	231
IR11288-B-B-65-1-3-1-1	*a*	*a*
IR20992-7-2-2-2-2-3	*a*	*a*
IR21071-53-2-3-2E-P_2	*a*	*a*
IR21574-15-1E-P_1	*a*	*a*
1985 WS		
BKNFR78023-38-1K-3-3	77	52
GEU76050-0-19-4-1	78	61
IR11141-6-1-4-1	68	61
IR11288-B-B-69-1	101	89
IR33225-45-3-1-1-3-1	67	58
IR5857-16-1E-1-18	222	136
IR5857-16-1E-1-5	180	96
IR5857-4-1E-1-6	160	97
IR6370-k-23-1-2-0-1	127	94
SPR7411-7-2-1	90	63
IR28424-4-1-1-1	97	71
BKNFR76026-3-2-2-4	117	85
IR31617-19-3-3-4	*a*	*a*

[a] Plants did not survive at 100-cm water depth.

highest (2.1 t/ha) in WS (Table 1). Flash flooding as early as 7 d after transplanting in both seasons prevented high yields. Some lines did not elongate and remained submerged (Fig. 1, 2). Increasing water depth drastically reduced tillers and panicle production (Table 2).

To get high yield with fertilizer at maximum water depth of 100 cm, deep water rices need submergence tolerance during flash flooding, elongation capacity, and resistance to diseases, insect pests, and lodging during spikelet filling.

Genetic evaluation and utilization (GEU) program

Adverse temperature tolerance

Plant Physiology and Plant Breeding Departments

KOREA-IRRI COLLABORATIVE PROJECT **116**
COLD TOLERANCE SCREENING NURSERY **116**
- Growth duration **116**
- Spikelet fertility **116**
- Phenotypic acceptability **117**
- Nutrient uptake **117**

PEDIGREE NURSERY AND RAPID GENERATION ADVANCE BULK MATERIALS **117**
OBSERVATIONAL YIELD TRIAL **117**
SCREENING FOR TOLERANCE FOR LOW AIR TEMPERATURE AT REPRODUCTIVE STAGE **119**
NUTRIENT UPTAKE AND USE AT LOW AIR OR SOIL TEMPERATURE **119**
SELECTION FOR COLD TOLERANCE AT ANTHESIS **120**
PLANT TYPE NEEDED FOR HIGH GRAIN YIELDS AT DIFFERENT NITROGEN LEVELS **120**
- Grain yield **121**
- Yield components **121**
- Dry matter production **122**
- Harvest index **122**
- Leaf area index at flowering **123**

SCREENING FOR HIGH TEMPERATURE TOLERANCE **123**

KOREA-IRRI COLLABORATIVE PROJECT

Plant Physiology Department

In the seventh year of the Korea-IRRI Collaborative Project on Rice Cold Tolerance, eight experiments were conducted at Chuncheon.

COLD TOLERANCE SCREENING NURSERY

Plant Physiology Department

At the cold water gradient facility, 1,160 entries were screened and promising materials selected based on leaf color, growth duration, spikelet fertility, and plant type.

Growth duration. Short growth duration has several advantages in low temperature areas. It minimizes the risk of low temperature during the most susceptible stage — about 10 d before flowering until anthesis. It also allows flexibility in scheduling and preparing the next crop. Short-duration varieties, with or without cold tolerance, can avoid low temperatures. Table 1 shows the entries which flowered in <100 d at the water outlet and had 10% or less delay in heading under low water temperature. Most of them are cold tolerant in terms of leaf color and spikelet fertility at low water temperature. Four of nine entries were generated through the rapid generation advance (RGA) facility.

Spikelet fertility. Spikelet fertility at the inlet (17° C) was very low compared to previous years'.

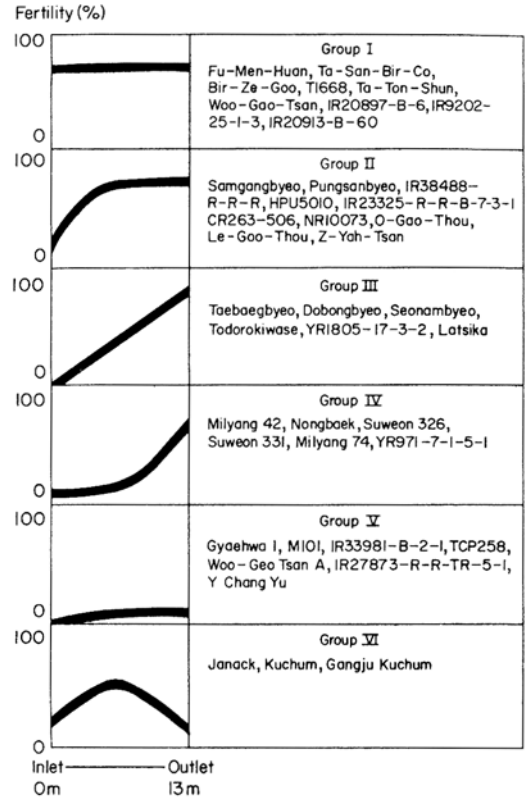
Table 1. Entries that flowered in <100 d at the outlet and with <10% delay in heading at the inlet. Chuncheon, Korea, 1984.

China 1037	K39-96-1-1-1-2
China 1039	K333[b]
IR9129-K1[a]	TK5331-R-R-R-R-28-1-B
IR29278-R-R-TR-5-1	TK5331-R-R-R-R-28-3-B
Jo80-27-R-R-C-50	

[a]Good spikelet fertility. [b]Susceptible to neck blast at Chuncheon.

Table 2. Entries with spikelet fertility >80% at the inlet. Chuncheon, Korea, 1984.

China 988	IR20910-B-67
IR9202-25-1-3	Ta-San-Bir-Co
IR18476-86-3-1	Woo-Gao Tsan
IR19746-26-2-33	YR3484-62-3
IR20897-B-6	



1. Responses to water temperature in the cold water gradient facility in Chuncheon, Korea, 1984.

Entries with 80% or higher spikelet fertility are shown in Table 2.

Based on percent fertility of spikelets at different points along the inlet-outlet gradient, six types of responses to low water temperature are recognized (Fig. 1). Group I entries have high and stable fertility along the gradient. In group II, fertility is low at the inlet, increases up to 5 m from it, and then levels off up to the outlet. Group III entries are sensitive to small differences in temperature within the gradient. Fertility increases as sampling moves away from the inlet. In group IV, fertility is low in entries near the inlet up to the middle of the gradient, then slowly rises in plants toward the outlet. Apparently group V is the most susceptible group. Fertility percentage is low from the inlet to the outlet. These entries have long growth duration. Their response to low water temperature is compounded by the low air temperature during their long growth duration. Group VI, first observed in

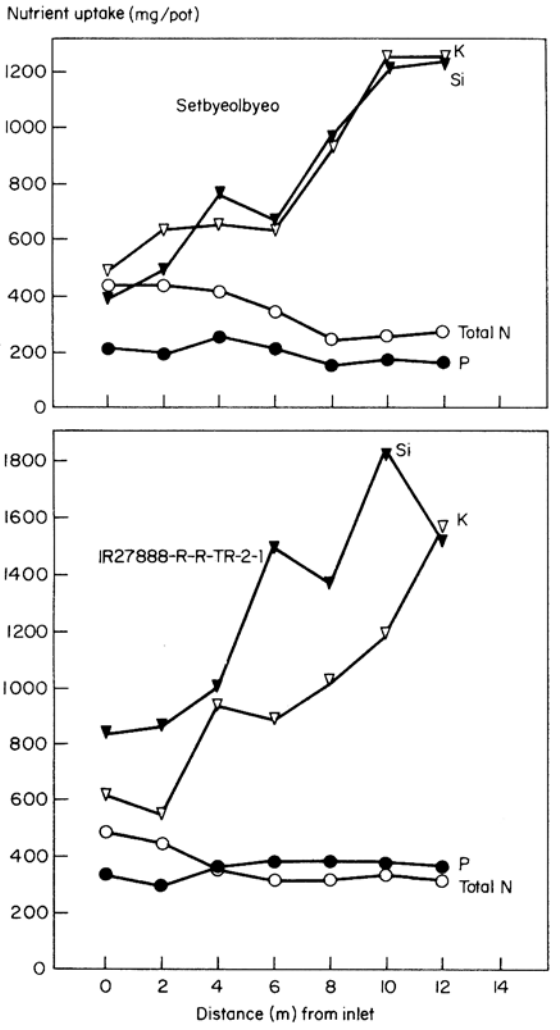
Table 3. Entries with phenotypic acceptability score of 2 and good panicle exsertion, fertility, and vigor at low temperature areas. Chuncheon, Korea, 1984.

IR9202-25-1-3	IR18476-86-3-3
IR9202-33-4-2-1	IR18476-108-1
IR13155-60-3-1-1-3-2	RPKn-2
IR13155-60-3-1-1-3-2-3-2	T1668
IR15579-24-2	Ta-San-Bir-Co
IR15579-135-3	YR1654-16-1-2-4-B-2
IR15889-113-3	YR2404-15-4-9-3
IR18476-86-3-1	

1984, has entries from Bhutan. They have higher fertility near the middle of the 13-m gradient and lower toward the outlet and the inlet. Janack and Kuchum flowered earlier at the middle and the inlet, and latest at the outlet. The delay in flowering at relatively warmer temperature is unusual for rice.

Phenotypic acceptability. Entries with phenotypic acceptability scores of 2, high fertility at the inlet, good panicle exsertion and spikelet fertility, and vigor are shown in Table 3.

Nutrient uptake. To examine nutrient uptake along the water gradient, plant samples of two entries, Setbyeolbyeo and IR27888-R-R-TR-2-1, were taken at season end for tissue analysis. Total N slowly decreased as distance from the inlet increased (Fig. 2). The two varieties differed little in P uptake with temperature gradient. K and Si contents of plants were far greater near the outlet than near the inlet. Low water temperature hindered K and Si uptake. These nutrients may accumulate in the soil in low temperature areas.



2. Nutrient uptake of 2 entries at different points along the cold water gradient facility in Chuncheon, Korea, 1984.

PEDIGREE NURSERY AND RAPID GENERATION ADVANCE BULK MATERIALS

Plant Physiology Department

The materials in a pedigree nursery were screened for low temperature at seedling stage. Only green seedlings were transplanted in the field, where water temperature was maintained at 20° C.

The nursery had 108 F_2 bulk populations, 252 F_2 families, and 869 pedigree lines from 29 crosses mostly in F_3 and F_4. From the 108 F_2 bulk populations, 869 plants from 35 crosses were selected for the pedigree nursery at IRRI and will be planted at Banaue after one generation (Table 4). Also 180 plants were selected from the 10 RGA bulk materials (Table 5). Seven early lines from IR29278 and IR29279, RGA selections from Turkey, were harvested in bulk for seed increase at IRRI.

OBSERVATIONAL YIELD TRIAL

Plant Physiology Department

The observational yield trial had 25 entries from the 1983 cold tolerance screening nursery. Some released varieties from Korea were included for comparison.

Table 4. Materials selected from the Chuncheon Pedigree Nursery for planting at IRRI and subsequent trial at Banaue, Philippines.

Designation	Cross	Plants selected (no.)
IR46747	IR50//IR20654-R-R-R-1-2/ Suweon 287	40
IR46748	IR56//IR54/Barkat	10
IR46749	IR56//IR56/K39-96-1-1-1-2	50
IR46752	IR8866-30-3-1-4-//IR20654-R-R-R-1-2/IR36	30
IR46753	IR8866-30-3-1-4//IR2298-PLPB-3-19-1-2/IR50	20
IR46555	IR20654-R-R-R-1-2//IR52/ Suweon 287	20
IR46556	IR20654-R-R-R-1-2//IR4547-4-1-2/ Suweon 300	10
IR46758	IR20654-R-R-R-1-2//IR15529-253-2-2-2/Suweon 287	59
IR46759	IR22623-12-R-4-2//AD9246/IR1848-65-3-2	20
IR46762	IR22623-12-R-4-2//IR20654-R-R-R-1-2/Milyang 23	20
IR46769	Suweon 287//IR56/IR2298-PLPB-3-19-1-2	50
IR46770	Suweon 287//IR20654-R-R-R-1-2/ Milyang 54	20
IR46774	IR52/Rikutonorin Mochi 1// IR22623-12-R-4-2	50
IR46778	IR54/Shimokita//Suweon 287	20
IR46779	IR54/Suweon 295-E2//IR22623-12-R-4-2	20
IR46780	IR54/Suweon 295-11//IR22623-12-R-4-2	20
IR46792	IR42773/IR22623-12-R-4-2	10
IR46751	IR8866-30-3-1-4//IR56/Thangone	30
IR46764	IR22623-12-R-4-2/IR42797	30
IR46766	Iri 347/IR42745	30
IR46781	IR54/TK5331-R-R-R-28-1// IR20654-R-R-R-1-2	30
IR46783	IR56/Kami-Iku 382//IR22623-12-R-4-2	30
IR46789	IR15429-268-1-2-1/Todorokiwase// IR8866-30-3-1-4	30
IR46796	IR20654-R-R-R-1-2/Suweon 295-11// IR9202-25-1-3	30
IR46799	Todorokiwase/Suweon 299// IR22623-12-R-4-2	30
IR46806	IR42793/Suweon 287	30
IR46808	SR8165-31-1-2/Milyang 57// IR20654-R-R-R-1-2	30
IR46810	Suweon 295-E2/Suweon 300// IR22623-12-R-4-2	50
IR46813	IR52/Line 62//IR52/Milyang 23	20

Table 5. RGA materials selected at Chuncheon (1984) for planting at IRRI.

Designation	Cross	Plants selected (no.)
IR38486-R-R	Guang Lu Ai No. 4/BPI-76	10
IR38487-R-R	Guang Lu Ai No. 4/IR54	10
IR38490-R-R	Qing Gang Huang/Milyang 23	10
IR38494-R-R	I31/BPI-76	30
IR38495-R-R	I31/IR54	30
IR38496-R-R	I31/Milyang 23	10
RGA 648	Fuji-chubo 36/Joiku 380// Kuiku 114	20
RGA 649	Fuji-chubo 36/Dohoku 36// Kuiku 114	20
RGA 650	Joiku 378/Kitahikari// Shimahikari	20
RGA 652	Joiku 378/Kitahikari//Kuiku 114	20

Table 6. Grain yield of top 10 yielders at 2 N levels in the observational yield trial at Chuncheon, Korea, 1984.

Designation	Grain yield (t/ha)
100 kg N/ha	
IR5716-18-1	8.00
Samgangbyeo	7.28
Pungsanbyeo	7.16
IR23325-R-R-B-7-3-1	7.12
IR8866-30-3-1-4	6.77
IR2061-522-6-9	6.77
IR27892-5-2-1-1-1	6.77
Se Lin R	6.68
Todorokiwase	6.52
SR9144-MB-378	6.34
200 kg N/ha	
Pungsanbyeo	9.16
Samgangbyeo	8.86
IR8866-30-3-1-4	7.14
IR9129-K1	6.76
HR3629-62-5-3	6.62
IR2061-522-6-9	6.56
SR9144-MB-276	6.46
Todorokiwase	6.40
ON211	6.37
Se Lin R	6.36

Yielding highest at 100 and 200 kg N levels were indica/japonica varieties Pungsanbyeo (Iri 346) and Samgangbyeo (Milyang 55) (Table 6). Samgangbyeo produced the highest yield (10 t/ha) in the rice production contest in Korea. Average grain yields at 100 kg N/ha were generally higher than at 200 kg N/ha because of higher harvest index (HI), shorter culm length, higher fertility and higher 1,000-grain weight. However some entries, e.g. IR9129-K1, Pungsanbyeo, Samgangbyeo, IR8866-30-3-1-4, SR9144-MB-276, and HR3629-62-5-3, yielded higher at 200 than at 100 kg N/ha.

IR8866-30-3-1-4 has been giving top yields in the last 2 yr at Banaue and in Korea. IR23325-R-R-B-7-3-1, with highest spikelet fertility (95% at the inlet) in the cold tolerance screening nursery in 1983, is a high yielder at 100 kg N/ha. It had high total dry matter, many spikelets per panicle, and high fertility. A tall variety, it yielded low at 200 kg N/ha because of lodging.

IR5716-18-1, IR23325-R-R-B-7-3-1, and IR8866-30-3-1-4 should be useful in low temperature areas where intermediate plant height is preferred and applied N level is low.

SCREENING FOR TOLERANCE FOR LOW AIR TEMPERATURE AT REPRODUCTIVE STAGE

Plant Physiology Department

Screening for tolerance for low air temperature at reproductive stage in the field is difficult. All entries must flower at the onset of critically low air temperatures.

To partly overcome this problem, the 175 entries in the 1984 International Rice Cold Tolerance Nursery were seeded 1 mo later than normal Chuncheon seeding date so most would flower by the end of August when night temperatures usually drop below 20° C. The relationship between heading date and spikelet fertility is shown in Figure 3. Most entries were early maturing and flowered when the air temperature was still high. Moreover, air temperature in 1984 was higher than normal until August end so only 25% of the entries were caught by low temperature the first week of September onwards. Twenty-five entries did not flower by 20 Sep.

Several varietal types had high spikelet fertility despite low night temperatures. Chang Wang Ku and Nan-Keng 32 are japonicas, San-Bir-Z-Goo and Che-Eu-Hung are indicas from China, and the two YR2379 lines are from an indica/japonica cross in Korea. The Chinese varieties were screened earlier at IRRI for cold tolerance at panicle initiation and flowering stage.

NUTRIENT UPTAKE AND USE AT LOW AIR OR SOIL TEMPERATURE

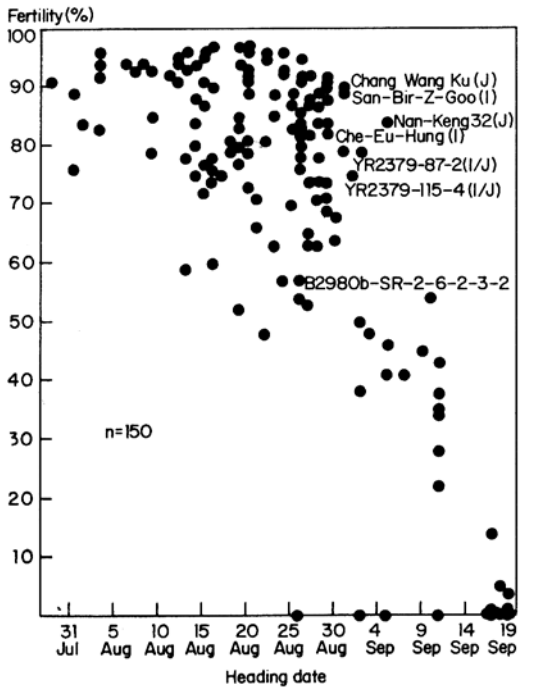
Plant Physiology Department

To study nutrient uptake and availability under various air/water temperature regimes, plants were grown for 30 d under natural conditions, then transferred to the glasshouse for these temperature regimes for 20 d: low air/low water (LA/LW), low air/high water (LA/HW), high air/low water (HA/LW). The plants were then returned to natural conditions. Plant samples were taken before treatment and after at heading and at maturity.

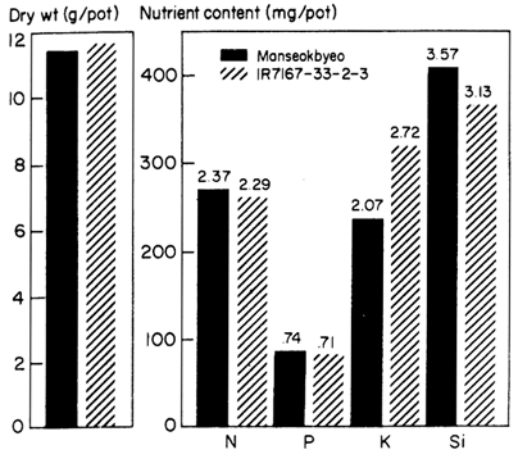
Dry weight of Manseokbyeo and IR7167-33-2-3 were similar before treatment (Fig. 4). The total N and P uptake were similar although N percentage in the tissue was higher in IR7167. In Manseokbyeo, K uptake and tissue content were less but Si uptake and content were higher than in IR7167.

After treatment, plants subjected to LA/LW had proportionately lower dry weights even at flowering and harvest (Fig. 5). The absolute dry weights of low temperature treated plants were lower than the control up to flowering.

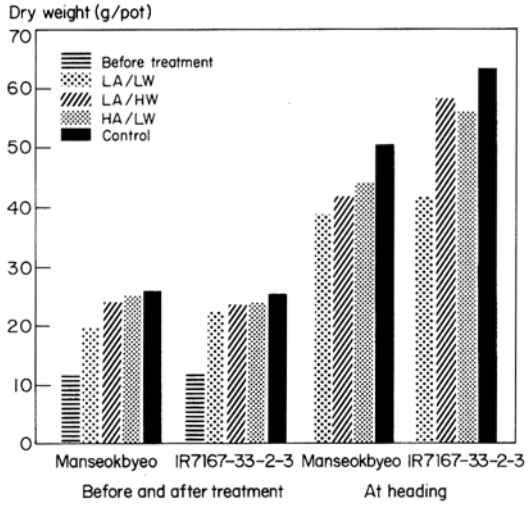
LA/LW greatly inhibited N uptake. This effect was still apparent at flowering in IR7167-33-2-3. LW slowed N uptake but later warm temperature increased N content. IR7167-33-2-3 generally had higher N uptake than Manseokbyeo at heading but lower content in the tissue.



3. Relationship between heading date and percent fertility of the 1985 IRCTN entries when planted late at Chuncheon, Korea, 1984.



4. Dry weight and nutrient content before low temperature treatment in Manseokbyeo and IR7167-33-2-3. Chuncheon, Korea, 1984. Values above the bars indicate the percent content in the tissue.



5. Dry weight before and after low temperature treatment and at heading stage in Manseokbyeo and IR7167-33-2-3. Chuncheon, Korea, 1984. LA = low air, LW = low water, HA = high air, HW = high water.

Low temperature generally lowered P uptake especially with LA/LW. Except with LA/LW, the earlier cold treatment still greatly depressed P uptake of Manseokbyeo at heading.

As with N and P, the LA/LW treatment was most inhibiting on K uptake even at flowering. At heading, IR7167-33-2-3 had generally higher K uptake than Manseokbyeo. This higher K uptake was evident even before treatment.

Uptake of Si was also depressed by cold treatment, especially LA/LW. Although Manseokbyeo had higher Si uptake before treatment, at heading it had generally lower total Si uptake than IR7167-33-2-3.

N, P, K, and Si uptake were greatly inhibited by low temperature, especially LA/LW, for 20 d during the vegetative stage. The earlier cold treatment effect was apparent even at heading, lowering dry weight and nutrient uptake.

SELECTION FOR COLD TOLERANCE AT ANTHESIS

Plant Breeding and Plant Physiology Departments

We know little about the genetics of resistance to low-temperature-induced sterility during anthesis. It is difficult to conduct such studies under field conditions because of day-to-day variability when segregating populations are flowering. Four crosses of cold tolerant by cold susceptible parents were studied using the phytotron and RGA facilities.

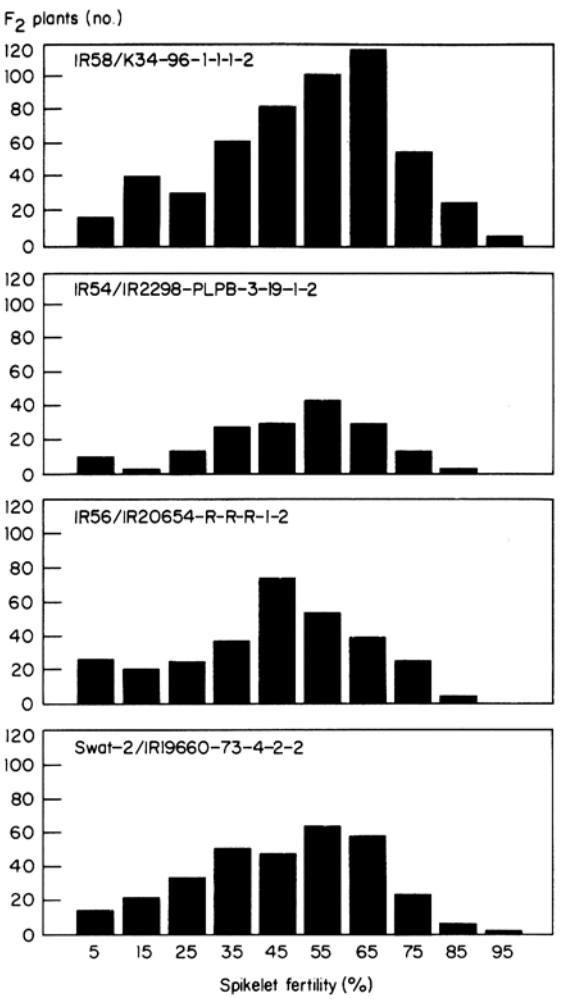
A wide range of segregation in the F_2 was found for percent fertility under a 21/21° C temperature regime for the 4 crosses (Fig. 6). A continuous distribution suggested polygenic inheritance. Broad-sense heritabilities ranged from 0.82 to 0.94, indicating high genetic control for this trait.

The F_3 progeny selected from the most tolerant F_2 plants were compared with F_3 progeny from random, nontreated F_2 plants for cold tolerance at anthesis. A 20/20° C temperature regime was used. The F_3 families from the selected F_2 progeny showed significantly better percent fertility than nonselected families (Fig. 7). The narrow-sense heritabilities calculated from response to selection ranged from 0.35 to 0.45. This indicates that additive genetic variance is sufficiently high in these crosses to give a marked response to selection in early generations.

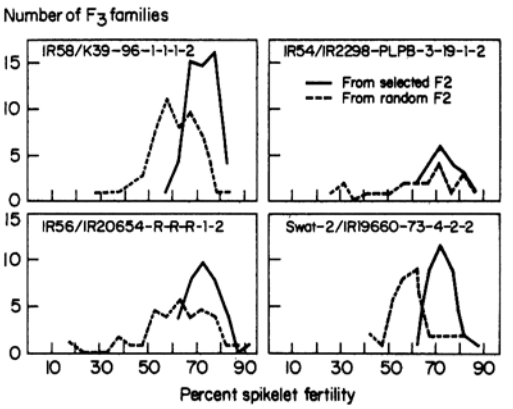
PLANT TYPE NEEDED FOR HIGH GRAIN YIELDS AT DIFFERENT NITROGEN LEVELS

Plant Physiology Department

Five cultivars of different varietal types — China 988 and IR7167-33-2-3 (indica), Manseokbyeo and Taebaekbyeo (indica/japonica), and Sangpungbyeo (japonica) — were planted under normal field conditions in Chuncheon. N levels were 75, 150, and



6. Distribution of percent fertility in F_2 populations of 4 rice crosses under 21/21°C for 5 d during anthesis. IRRI, 1984.



7. Distribution of percent fertility in F_3 families from selected and random F_2 plants under a 20/20°C temperature regime for 5 d during anthesis. IRRI, 1984.

Table 7. Grain yield of 5 varieties at 3 N levels. Chuncheon, Korea, 1984.

Variety	Grain yield (t/ha)			Mean yield (t/ha)
	75 kg N/ha	150 kg N/ha	300 kg N/ha	
Manseokbyeo	6.8	7.8	7.6	7.4
Taebaekbyeo	7.7	8.4	8.1	8.0
Sangpungbyeo	6.7	6.9	5.9	6.5
China 988	7.5	5.3	4.0	5.6
IR7167-33-2-3	8.3	5.8	3.5	5.9
Mean	7.4	6.8	5.8	

LSD (5%) 2.0 — Variety means under the same N level.
1.8 — N level means at same or different variety.

300 kg N/ha. The first 2 were applied basally; the third had 180 kg basal, and 120 kg topdressed 20 d after transplanting.

Grain yield. The mean yields of the 5 varieties were significantly lower at 300 kg N/ha than at 150 or 75 kg N/ha (Table 7), particularly for tall entries China 988 and IR7167-33-2-3, which lodged during flowering. Taebaekbyeo yielded high at all N levels and highest at 150 kg N/ha. IR7167-33-2-3 had its highest yield at 75 kg N/ha. China 988 and IR7167-33-2-3 are suited to low N only and are different plant types.

Regardless of N level, Taebaekbyeo yielded highest followed by Manseokbyeo. These varieties did not lodge at any N level.

Yield components. The 1,000-grain weight decreased with increase in N level (Table 8). That lowered yields at higher N in spite of higher dry matter production.

Spikelet fertility decreased with higher N level on all varieties (Table 8). That also accounted for lower yields at higher N. Fertility was poorest with higher N level for IR7167-33-2-3 followed by China 988, as these tall varieties lodged after flowering. Spikelet fertility of Manseokbyeo and Taebaekbyeo did not significantly differ at any N level, but was slightly lower at higher N.

Spikelets per panicle and panicles per hill did not significantly differ with N level.

Table 8. Yield components for 5 varieties at 3 N levels. Chuncheon, Korea, 1984.

Variety	75 kg N/ha	150 kg N/ha	300 kg N/ha	Mean
	Spikelet fertility (%)			
Manseokbyeo	91	89	78	86
Taebaekbyeo	93	90	85	89
Sangpungbyeo	90	84	64	79
China 988	98	88	66	84
IR7167-33-2-3	96	69	48	71
Mean	93	84	68	
	Panicles per hill			
Manseokbyeo	11	14	16	14
Taebaekbyeo	10	14	17	14
Sangpungbyeo	15	14	21	17
China 988	14	10	14	12
IR7167-33-2-3	10	9	12	10
Mean	12	12	16	
	Spikelets per panicle			
Manseokbyeo	108	103	89	100
Taebaekbyeo	116	126	112	118
Sangpungbyeo	89	88	88	88
China 988	89	102	110	100
IR7167-33-2-3	116	126	131	124
Mean	103	109	106	
	1,000-grain weight (g)			
Manseokbyeo	23.7	23.6	20.8	22.7
Taebaekbyeo	23.3	22.4	20.8	22.1
Sangpungbyeo	25.2	23.9	20.2	23.1
China 988	26.4	23.8	22.6	24.2
IR7167-33-2-3	28.4	27.1	18.4	24.6
Mean	25.4	24.1	20.5	

Table 9. Total dry matter and harvest index of 5 varieties at 3 N levels. Chuncheon, Korea, 1984.

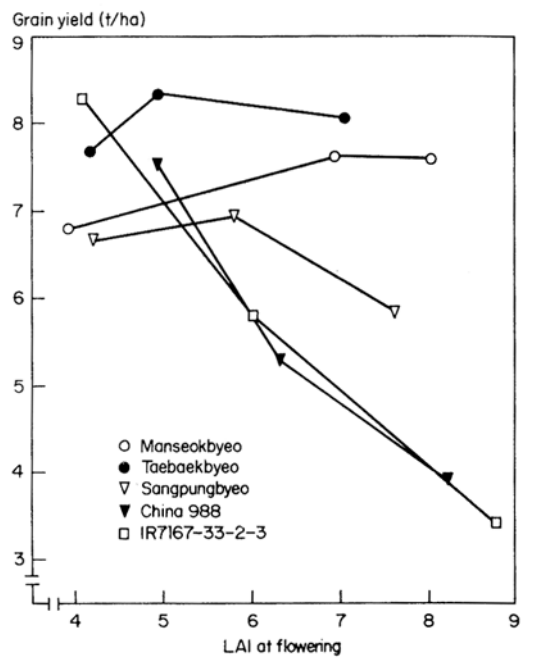
Variety	75 kg N/ha	150 kg N/ha	300 kg N/ha
	Total dry matter (t/ha)		
Manseokbyeo	12	15	17
Taebaekbyeo	13	14	14
Sangpungbyeo	14	14	13
China 988	13	11	7
IR7167-33-2-3	15	13	8
	Harvest index		
Manseokbyeo	0.56	0.51	0.46
Taebaekbyeo	0.59	0.63	0.57
Sangpungbyeo	0.50	0.50	0.45
China 988	0.59	0.48	0.54
IR7167-33-2-3	0.56	0.42	0.42

Dry matter production. Manseokbyeo had highest total dry matter at 150 and 300 kg N/ha while those of China 988 and IR7167-33-2-3 were higher at 75 and 150 kg N/ha (Table 9). Sangpungbyeo and Taebaekbyeo had similar total dry matter at all N levels.

Table 10. Leaf area index (LAI) at flowering of 5 varieties at 3 N levels. Chuncheon, Korea, 1984.

Variety	LAI			Mean LAI
	75 kg N/ha	150 kg N/ha	300 kg N/ha	
Manseokbyeo	3.9	7.0	8.0	6.3
Taebaekbyeo	4.1	4.9	7.0	5.4
Sangpungbyeo	4.2	5.8	7.6	5.9
China 988	4.9	6.4	8.2	6.5
IR7167-33-2-3	4.1	6.0	8.7	6.3
Mean	4.2	6.0	7.9	6.1

LSD (5%) 1.56 — Two N level means.
1.91 — N level means at same or different variety.



8. Relation between LAI at flowering and grain yield in 5 varieties at 3 N levels. Chuncheon, Korea, 1984.

Harvest index. Harvest index (HI) decreased with increase in N level (Table 9). Taebaekbyeo had highest HI of 0.63 and highest yield at that HI. Plants increased in plant height or culm length with increase in N level. At 300 kg N/ha, the culm length of Manseokbyeo and Taebaekbyeo remained below 100 cm. That of China 988 and of IR7167-33-2-3

were around 150 cm at 150 to 300 kg N/ha, causing them to lodge.

Leaf area index at flowering. Leaf area index (LAI) increased as N level increased (Table 10). However, high LAI at flowering did not always produce higher yields (Fig. 8). China 988 and IR7167-33-2-3 had lower yields at higher LAI because of lodging. Taebaekbyeo and Manseokbyeo reached the yield plateau at around LAI 5-6. Sangpungbyeo had highest yield at LAI 5.8, but yield decreased with higher LAI even with no lodging.

A low N level suits China 988 and IR7167-33-2-3. Relatively tall, they may lodge at higher N; therefore, they produce more dry matter at low N. Both have high 1,000-grain weight and relatively high HI at low N compared to entries adapted to high N.

SCREENING FOR HIGH TEMPERATURE TOLERANCE

Plant Physiology Department

Screening of the 1983 International Rice for Arid Regions Observational Nursery entries identified 7 entries with high temperature tolerance at 35° C: Chianung Sen Yu 13 from China, IRAT127 and IRAT128 from Malagasy, SKL17-67-11 and UPR251-101-2 from India, and IR10198-66-2 and IR19746-28-2-2. IRAT128 consistently showed a high degree of tolerance for high temperature.

Of several varieties tested from the germplasm collection, Ghraiba (Accession no. 26848), a variety from Iraq, was most tolerant, and better than tolerant check N22.

Genetic evaluation and utilization (GEU) program

Innovative breeding methods

Plant Physiology and Plant Breeding Departments and collaborators in China, India, Indonesia, and Korea

TISSUE CULTURE **126**
- Anther culture **126**
  - Cold tolerance **126**
  - Aluminum toxicity tolerance **127**
  - Isoenzyme studies **127**
  - Collaborative research **127**
- Somatic cell culture **128**
  - Plant regeneration from long-term calli **128**
  - Plant regeneration from salt-tolerant calli **128**
  - Somaclonal variation for salinity tolerance **128**
  - Somaclonal variation for *Helminthosporium oryzae* resistance **128**

HYBRID RICE **128**
- Development of an early maturing F_1 hybrid **128**
- Identification of heterotic combinations **129**
- Cytoplasmic male sterility and fertility restoration **130**
- Seed production **132**
- Wide hybridization for rice improvement **133**
- Biparental mating **135**

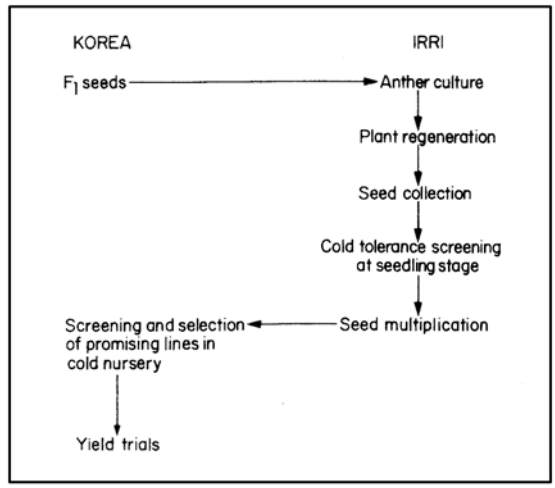
RAPID GENERATION ADVANCE **136**
- Screening RGA materials for submergence tolerance **137**
- RGA field evaluation **137**
- RGA materials in IRTP nurseries **137**

TISSUE CULTURE

Plant Physiology and Plant Breeding Departments and collaborators in China, India, Indonesia, and Korea

Anther culture (*Plant Physiology*). *Cold tolerance.* A shuttle scheme for producing cold-tolerant lines from hybrids was established in 1984 in collaboration with the Rural Development Administration, Chuncheon, Korea (Fig. 1). Thirteen crosses were tested for efficiency in regenerating plants in various callus induction and regeneration media. Crosses varied in culturability (Table 1). Some were highly responsive, others were not. From a total of 11,500 anthers plated, callus production was 53.56%. Average green plant production per callus plated for regeneration was 1.99 while 50.95% of the total green plants produced set seeds. The remaining plants were haploids and some did not survive stress when transferred to soil.

Some Korean anther culture (AC)-derived lines were tested for cold tolerance (10° C for 10 d) at the seedling stage. Lines from the same cross varied in response (Table 2). Of 278 lines from the F_1 hybrid RAC3/Ishiokamochi (SR11452), 6 were more cold-



1. IRRI-Korea collaborative program for the production of cold-tolerant lines through anther culture, 1984.

Table 1. Efficiency of callus production and plant regeneration of F_1 hybrids from Korea for cold tolerance studies. Planted in 1983 WS.

Cross	Anthers plated (no.)	Calli produced		Calli plated (no.)	Calli-producing green plants		Green plants produced		Albino plants produced		Anther culture plants with seeds	
		No.	%[a]		No.	%[b]	No.	%[c]	No.	%[c]	No.	%[d]
SR11191	857	4	0	4	0	0	0	0	3	75	0	0
SR11193	924	14	1	8	0	0	0	0	0	0	0	0
SR11238	969	0	0	0	0	0	0	0	0	0	0	0
SR11242	338	0	0	0	0	0	0	0	0	0	0	0
SR11426	476	438	92	64	2	3	11	17	31	48	1	9
SR11428	1,236	587	47	113	1	1	0	1	61	54	0	0
IR11433	678	1,266	187	192	35	18	276	144	144	75	108	39
SR11436	941	735	78	105	3	3	22	21	46	44	8	36
SR11440	491	33	7	21	0	0	0	0	0	0	0	0
SR11451	1,475	710	48	90	19	21	117	130	66	73	81	69
SR11452	1,066	1,407	132	257	68	26	979	381	225	88	439	45
SR11453	1,081	440	41	72	38	53	518	719	46	64	342	66
SR11455	968	88	9	50	6	12	16	32	28	56	9	56
Total	11,500	6,160		976	172		1,939		650		988	
Average			53.56			17.62		198.67		66.60		50.95

[a] Callus production (%) = $\frac{\text{Calli produced (no.)}}{\text{Anthers plated (no.)}} \times 100$.

[b] Calli-producing green plants (%) = $\frac{\text{Calli-producing green plants (no.)}}{\text{Calli plated (no.)}} \times 100$.

[c] Green/albino plant production (%) = $\frac{\text{Green/albino plants produced (no.)}}{\text{Calli plated (no.)}} \times 100$.

[d] Anther culture plants with seeds (%) = $\frac{\text{Anther culture plants with seeds (no.)}}{\text{Green plants produced (no.)}} \times 100$.

Table 2. Cold tolerance score at seedling stage of anther culture-derived lines from F_1 SR sexual crosses. IRRI, 1984.

Designation	Parents	Lines tested (no.)	Lines (no.) with a score[a] of				
			1	3	5	7	9
		After 10 d at 10° C					
SR11453	RAC3/Fujihikari	262	0	244	18	0	0
	RAC3			x			
	Fujihikari		x				
SR11452	RAC3/Ishiokamochi	278	6	239	33	0	0
	RAC3			x			
	Ishiokamochi			x			
SR11451	RAC3/Hamaasahi	27	0	11	16	0	0
	RAC3			x			
	Hamaasahi			x			
SR11426	Fujihikari/Fukei 126	1	0	1	0	0	0
	Fujihikari		x				
	Fukei		x				
SR11433	Chulweon 32/Fujihikari	39	16	23	0	0	0
	Chulweon 32		x				
	Fujihikari		x				
		After 13 d at 10° C					
SR11452	RAC3/Ishiokamochi	278	2	155	102	16	3
	RAC3				x		
	Ishiokamochi				x		
SR11433	Chulweon 32/Fujihikari	39	0	19	20	0	0
	Chulweon 32			x			
	Fujihikari			x			

[a] 1 = seedlings dark brown, 3 = seedlings light green, 5 = seedlings yellow, 7 = seedlings brown, 9 = seedlings dead. x marks the column of the tolerance score of the given parent.

tolerant than either parent. Cold tolerance was even greater when the seedlings were scored 13 d after cold treatments — 157 lines (56.5%) showed higher tolerance than either parent. Since these plants were homozygous diploids, cold tolerance characteristics will be maintained in future generations.

Twenty-two AC-derived lines from IR crosses and varieties found cold tolerant at the seedling stage were sent to Chuncheon, Korea, in 1984 for field evaluation. Three lines were better than the resistant check in some aspects (Table 3); for example, they had higher fertility percentage at the inlet (17° C) and were more vigorous at the end of the test period than the resistant check.

Aluminum toxicity tolerance. AC-derived lines of the direct cross Tatsumi mochi/BG90-2 and its reciprocal were tested for Al toxicity tolerance at seedling stage. The relative root length (RRL) (ratio of the average root length at 30 ppm Al to the average root length at 0 ppm Al) was the parameter for determining tolerance. Among 48 entries tested in the direct cross, 9 were tolerant (RRL $\geq$ 0.80), 23 were intermediate (RRL 0.65-0.79), and 16 were susceptible (RRL $<$ 0.65). Twenty-four lines had higher RRL than the more tolerant parent Tatsumi mochi (RRL = 0.69). One line even had a higher RRL than the resistant check IAC3. Among six lines of the reciprocal cross tested, three were tolerant, two were intermediate, and one was susceptible. Five entries had higher RRL than the more tolerant parent.

Isoenzyme studies. Isoenzyme studies among the regenerated plants of the direct cross Tatsumi mochi/BG90-2 and its reciprocal cross were conducted (Fig. 2). Recombination among nine isoenzyme loci was achieved in all the lines tested in both crosses. This shows that plants regenerated through AC originate from the pollen grains and not from maternal tissues as is often argued. These results were confirmed by field experiments since the AC-derived lines were nonsegregating.

Collaborative research. In a field experiment in Egypt, three of four AC-derived lines of Giza 170 yielded higher than the parents. The highest-yielding

Table 3. Promising anther culture-derived lines in cold tolerance test. Chuncheon, Korea, 1984.

Observed trait[a]	Location	Anther culture line no.			Check varieties	
		608-1[c]	1166[d]	1166-4[d]	Setbyeolbyeo (susceptible)	Sangpungbyeo (resistant)
Discoloration score[b]	Inlet	2	2	2	9	1
	Outlet	4	5	6	6	2
Heading (d)	Inlet	136	136	133	144	137
	Outlet	109	116	118	127	128
Fertility (%)	Inlet	7	53	51	0	8
	Outlet	90	76	78	18	91
Spikelet no.	Inlet	59	78	79	71	102
	Outlet	140	130	77	132	101
Culm length (cm)	Inlet	55	46	39	–	53
	Outlet	87	54	53	–	69
Panicle no.	Inlet	24.6	21.4	22.0	–	22.0
	Outlet	23.2	22.2	22.8	–	20.6
Panicle exsertion score		4	6	6	9	5
Phenotypic acceptability score		5	4	5	9	5
Vigor score		1	1	1	7	5

[a]Temperature was 17°C at the inlet and 25-27°C at the outlet. [b]For score explanation, see footnote *a* of Table 2. [c]Taipei 309/Tatsumi mochi. [d]Tatsumi mochi/BG90-2.

line produced 13.5 t/ha, against 10.77 t/ha of the parent (25.3% increase).

Two other lines yielded 12.8% and 12.1% more than the parents. The AC-derived lines were shorter and all four had more productive tillers.

Six AC-derived lines were tested in replicated yield trials in Suweon, Korea (Table 4). Three yielded higher than either parent. AC599A yielded 19.5% better than BG90-2 and 10% better than Taipei 309. Two lines from Suweon 290/BG90-2 were also superior to both parents. AC700 gave 2% and 21% higher yield than Suweon 290 and BG90-2, respectively, while AC683 was 1.2% and 19.6% better than the same parents. In field experiments conducted at IRRI, AC700 also yielded higher than the higher-yielding parent Suweon 290.

Somatic cell culture (*Plant Physiology*). *Plant regeneration from long-term calli.* Seed-derived calli from Taichung 65, Reiho, IR52, IR54, and Nona Bokra which were subcultured every 4 wk for 12 passages were transferred to the regeneration medium. Seventeen plants from Reiho and Nona Bokra were regenerated from long-term calli.

Plant regeneration from salt-tolerant calli. Seed-derived calli of varieties Reiho and Norin 10 kept on salt-enriched medium for 30 mo were transferred to the regeneration medium. Fifteen plantlets regenerated from Reiho and were transferred to soil.

Somaclonal variation for salinity tolerance. One hundred forty-four tissue culture-derived plant progenies of IR36 have been tested for salinity tolerance at seedling stage. Three showed somaclonal variation for increased salinity tolerance. Since progenies came from plants from the test tube (R1), further study is needed.

Somaclonal variation for Helminthosporium oryzae *resistance.* Ninety-eight R1 lines from four IR varieties were tested for resistance to *H. oryzae* in the laboratory in collaboration with Plant Pathology Department (Table 5). Only three lines showed resistance to the toxin. Since the lines tested were only first generation from somatic tissue culture, further studies are needed to ascertain field resistance and generational stability.

HYBRID RICE

Plant Breeding Department and collaborators in China, India, Indonesia, and Korea

Development of an early maturing F_1 hybrid (*Plant Breeding and collaborators in China*). Four years of collaborative research between China (Hunan Academy of Agricultural Sciences, Changsha, Hunan) and IRRI (Plant Breeding Department)

Material		Locus[a] 1	2	3	4	5	6	7	8	9
J parent		○	○	○	○	○	○	○	○	○
I parent		●	●	●	●	●	●	●	●	●
AC-derived lines										
J/1	574	●	○	●	●	●	○	○	●	○
	671	○	○	●	●	●	●	●	●	●
	672	○	○	●	●	●	●	●	●	●
	673	○	○	●	●	●	●	●	●	●
	915	●	●	●	●	●	●	○	●	●
	1055	○	●	●	●	●	○	○	●	○
	1064	○	●	○	●	●	●	●	●	●
	1065	●	○	●	●	●	●	●	●	○
	1078	●	○	○	●	●	○	○	●	●
	1083	●	○	○	●	●	○	●	●	●
	1090	●	●	●	●	●	○	●	●	●
	1124	○	○	○	●	●	○	●	●	○
	1143	●	●	●	●	●	○	○	●	●
	1165	○	○	○	○	○	●	○	○	○
	1166	●	○	○	●	●	○	○	●	●
	1183	●	●	○	●	●	●	●	●	○
	1187	○	○	○	○	○	●	○	○	○
	1188	○	○	○	○	○	●	○	○	○
	1190	○	○	○	○	○	●	○	○	○
	1198	○	○	○	○	○	●	○	○	○
	1202	●	●	○	●	●	●	●	●	●
	1204a	●	●	○	●	●	●	●	●	●
	1204b	●	●	●	○	●	●	●	●	●
	1467	○	○	○	○	○	●	○	○	○
I/J	755	●	●	●	○	●	●	●	●	●
	1152	○	○	○	●	●	●	○	●	●
	1200	●	●	●	●	●	○	○	●	○
	1230	●	●	●	●	●	○	○	●	○
	1239	●	●	●	●	●	○	○	●	○

[a] 1: Cat-A; 2: Sdh-A; 3: Pgi-A; 4: Pgi-B; 5: Lap-F; 6: Alap-A; 7: Est-Ca; 8: Est-E; 9: Acp-B

2. Recombination among 9 isozyme loci in anther culture-derived lines of reciprocal F_1 hybrids between indica (I) variety BG90-2 and japonica (J) variety Tatsumi mochi. 1984.

produced an early maturing F_1 rice hybrid: Wei You 64 in China. It was derived from a male sterile line from China (V20A) and IRRI restorer line IR9761-19-1 supplied to China in 1979. The hybrid yield is comparable to that of Wei You 6 (6-8 t/ha). The highest recorded yield of Wei You 64 in China was 11.3 t/ha, compared with 12 t/ha from Wei You 6.

Because it matures early (110-125 d), Wei You 64 is planted as a first crop in the south of Yangtze Valley where the leading hybrid Wei You 6 (derived from V20A/IR26, growth duration 135-140 d) cannot be cultivated. Even during the second crop season, Wei You 64 can be transplanted as late as first week of August without significant yield loss. Wei You 64 resists blast, bacterial blight, brown planthopper, and green leafhopper and moderately resists yellow dwarf virus in China. It also yields more seeds than Wei You 6 in seed production plots because of higher pollen production of its male parent IR9761-19-1. Wei You 64 is, however, susceptible to sheath blight, making it unsuitable for waterlogged soils. During 1984, the hybrid occupied 260,000 ha in China. It has also shown promise in cooperative trials conducted by IRRI in Indonesia, India, and Korea. At IRRI, however, it yields poorly because it is susceptible to prevailing virus diseases.

Identification of heterotic combinations (*Plant Breeding and collaborators in Korea, Indonesia, and India*). We identified F_1 combinations (derived from cytoplasmic male sterile [cms] lines and restorer lines developed at IRRI) yielding higher than check varieties of equal duration (Table 6). IR46828A/IR13524-21-2-3-3-2, and IR46828A/IR54 were superior in both crop seasons. Seeds of these combinations and those found promising during 1983 were multiplied for large-scale multi-location trials during 1985. Yields during 1984 wet season (WS) were generally lower than in previous years because of unfavorable conditions (higher rainfall, longer rainy season, higher disease and insect incidence). Besides, spacing was 25 × 25 cm compared to 20 × 20 cm in previous years.

Experimental combination V20A/Milyang 46, developed at IRRI in 1983 and found promising for Korea, again outyielded the Korean check variety Suweon 294 in 1984 trials under different fertility levels (Fig. 3). This hybrid yielded 10.3 t/ha compared to 8.1 t/ha from the check variety at 2 locations and 3 fertility levels: 120, 180, and 240. Cooperative trials in Indonesia and India led to

Table 4. Data of replicated yield trials of anther culture-derived materials.[a] Suweon, Korea, 1984.

Designation	Parents	Days to heading	Culm length (cm)	Panicle length (cm)	Panicles (no.)	Yield[b] (t/ha)		
						R_1	R_2	Mean
Taebaegbyeo		112	77	24	15	0.8	0.8	0.8
AC638	Tatsumi Mochi/Suweon 290	104	89	17	14	0.4	0.3	0.4
BG90-2		141	85	27	13	0.7	0.7	0.7
AC930	BG90-2/Taipei 309	143	84	19	16	0.5	0.5	0.5
AC599A	BG90-2/Taipei 309	116	77	22	12	0.8	0.8	0.8
Taipei 309		121	112	22	15	0.8	0.7	0.8
AC810-2	BG90-2/Tatsumi mochi	121	85	22	14	0.7	0.7	0.7
AC683	Suweon 290/BG90-2	117	83	21	12	0.8	0.8	0.8
AC700	Suweon 290/BG90-2	117	85	22	12	0.8	0.9	0.8
Suweon 290	116	116	87	21	12	0.8	0.8	0.8

[a]Seeded 15 Apr, transplanted 25 May, and fertilized with 120-40-91 kg NPK/ha. [b]Rough rice.

Table 5. Response of some R_1 plants to spores of *Helminthosporium oryzae* in IR lines of rice.

Response to the parasite	R_1 plants (no.) with indicated response				Total
	IR8	IR36	IR54	IR6023-10-1-1	
			With toxin		
Resistant	2[a]	0	0	0	2
Sensitive	7	2	23	0	32
			Without toxin		
Resistant	0	0	1[b]	0	1
Sensitive	3	12	42	6	63
Total	12	14	66	6	98

[a]With 25% H-toxin medium, shaken 2 d. [b]Cut leaf bioassay 2 d after inoculating the spores. Two measurements.

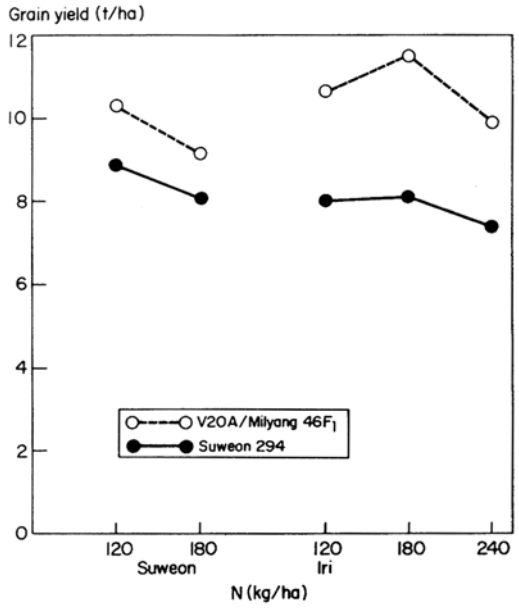
Table 6. Performance of some F_1 hybrid combinations in replicated yield trials at IRRI during 1984.

Hybrid, variety	Growth duration (d)	Lodging (%)	Yield (t/ha)
Dry season	*29 Dec seeding*		
IR19799-17-3-1-1A/IR2797-125-3-2-2	120	0	7.2
IR46828A/IR13524-21-2-3-3-2	116	0	6.9
IR46828A/IR54	121	0	6.8
IR36 (check)	120	0	6.4
IR58 (check)	117	25	6.6
	25 Jan seeding		
MR365/IR19431-72-2	118	60	6.8
MR365A/IR19083-22-2-2	116	8	6.0
MR365A/IR13429-75-3-1-1-3-2	116	50	5.6
IR36 (check)	118	25	5.3
IR58 (check)	113	0	3.8
Wet season	*28 Jun seeding*		
V20A/IR5	115	0	3.4
IR46828A/IR13524-21-2-3-3-2	112	100	3.3
IR36 (check)	115	100	2.0
IR46828A/IR2797-125-3-2-2	120	50	3.8
IR62 (check)	125	56	3.1
IR46828A/IR54	125	8	4.5
IR62 (check)	124	80	3.2

heterotic combinations V20A/IR54, V20A/IR9761-19-1, IR46826A/IR15795-232-3-3-2 (in Indonesia) and Zhen Shan 97A/IR2307-247-2-2-3, V20A/IR2307-247-2-2-3, V20A/Milyang 46, V20A/IR36, V20A/IR50, and V20A/IR9761-19-1 (in India).

Most of these combinations are based on Chinese male sterile lines V20A and Zhen Shan 97A. Therefore they are not suitable for use in the tropics and will be tested under subtropical conditions.

Cytoplasmic male sterility and fertility restoration (*Plant Breeding*). The seven new cms lines developed and designated at IRRI during 1983 were sent for evaluation in Indonesia, India, and Korea. Results are not yet available. At IRRI, all these lines, especially IR46828A, IR46829A, IR46830A, and IR48483A, have been superior to the Chinese cms lines V20A and Zhen Shan 97A in adaptability. We are testing their combining ability in crosses with elite restorer lines. Additional cms lines which are nearly stable for male sterility and uniform in agronomic characteristics are in the genetic background of breeding lines or varieties IR21845-90-3



3. Grain yield of an F_1 rice hybrid (V20A/Milyang 46) compared with that of commercial variety Suweon 294 under different N levels at Suweon and Iri, South Korea. 1984.

Table 7. New maintainer lines and varieties of 'WA' cytoplasm sterility system identified at IRRI, 1984.

Line, variety	Origin
IR15795-151-2-3-2-2	IRRI
IR18350-229-3	IRRI
IR21842-3-3-3-1	IRRI
IR22107-113-3-3	IRRI
IR24574-2-3-2	IRRI
IR24632-145-2-2-2-3	IRRI
IR27325-111-2-1	IRRI
IR28121-61-2-1-3-2	IRRI
IR28138-91-3-1-1	IRRI
IR28142-6-3-2-2-1	IRRI
IR29706-11-1-3-3	IRRI
IR29706-72-2-1-3	IRRI
IR29708-113-2-3	IRRI
IR31787-29-3-2-2	IRRI
IR37352-AC700	IRRI
Cul. 156	India
H25-54	—
HR 19	India
IET2911	India
New Sabarmati	India
Pusa 2509-3-1	India

(from IRRI), MR365 (from India), and Suweon 310 and Iri 356 (from Korea). New maintainer lines and varieties identified during 1984 are given in Table 7.

Table 8. Effect of date of seeding on pollen sterility[a] of cms lines. IRRI, 1984.

Line	Plants showing complete pollen sterility			
	Jun seeding		Jul seeding	
	Total	CS (%)	Total	CS (%)
IR46826A	40	20	39	77
IR46827A	29	66	39	100
IR46828A	44	100	46	100
IR46829A	30	100	23	100
IR46830A	30	100	13	100
IR46831A	29	97	27	100
IR48483A	88	72	79	90
97A	47	79	39	100
V20A	45	93	37	100

[a] CS = completely sterile.

Table 9. Pollen fertility behavior of F_1 to BC_4 F_1 generation plants from the cross ARC13829-26/IR10179-2-3-1. IRRI, 1984.

Generation	Plants (no.) with given pollen fertility reaction[a]					
	CS	HS	PS	PF	F	Total
F_1	0	0	10	0	0	10
BC_1 F_1	0	3	5	10	0	18
BC_2 F_1	7	7	9	4	0	27
BC_3 F_1	44	1	0	0	0	45
BC_4 F_1	38	7	3	0	0	48

[a] CS = completely sterile; HS = highly sterile, PS = partially sterile, PF = partially fertile, F = fertile.

Pollen sterility of cms lines IR46826A, IR46827A, IR48483A, and Zhen Shan 97A was affected by seeding date while cms lines IR46828A, IR46829A, IR46830A, IR46831A, and V20A were stable for complete sterility (Table 8).

Among the 1983 crosses showing cytoplasmic interaction for male sterility, the cross ARC13829-26/IR10179-2-3-1 gave highly sterile BC_4 F_1 progenies (Table 9), suggesting that ARC13829-26 does possess sterility-inducing cytoplasm. However, we need to determine whether this is a new source of cytosterility. IR10179-2-3-1 is also a maintainer of 'WA' (S_2) cytosterility system, and a cms line in its genotype has been developed and designated as IR46828A.

During the year, we identified more than 100 additional restorer lines for 'WA' (S_2) cytosterility system, bringing the total restorer lines identified at IRRI to 650.

We studied the inheritance of fertility restoration of 'WA' type cytosterility system involving three restorers: IR54, IR9761-19-1, and IR42. Results (Table 10) indicate the pollen fertility restoration ability in these restorer lines was governed by two independent dominant genes as revealed from F_2 and backcross F_1 segregation data. The mode of action of these genes varied. For example, the cross MR365A/IR54 indicated dominant epistasis gene interaction (F_2 ratio 12:3:1), 97A/IR42 showed recessive epistasis (F_2 ratio 9:3:4), and V20A/IR9761-19-1 showed semi-epistasis (F_2 ratio 9:6:1). This variation indicates that either the fertility-restoring genes are different, or their penetrance and expressivity vary with the overall genotype of the female parent. Earlier results from the cross 97A/IR54 indicated that IR54 possessed two fertility restorer genes, one stronger than the other. Allelic tests and further genetic analysis of fertility restoration are in progress.

Seed production (*Plant Breeding*). Hybrid seed (A/R) that yields up to 1.6 t/ha in DS and up to 0.6 t/ha in WS were obtained at IRRI. The cms line seed (A/B) multiplication plots yielded up to 0.8 t/ha in DS and 0.18 t/ha in WS (Table 11). Rates of natural outcrossing on cms lines ranged between 3 and 35% in A/B plots. WS yields were unusually low because of heavy rains and serious tungro interaction.

Compared to no gibberellic acid (GA), applying GA at 20-30 ppm (as in China) in seed production plots increased somewhat the seed yield and percent seed set on three cms lines (Table 12). The cms lines were planted with their respective maintainer lines 4:2. The experiment is being repeated because virus infection reduced seed yields and seed set percentage.

An experiment on flag leaf clipping effect on three cms lines (Table 13) showed genotype differences. The Chinese cms line Zhen Shan 97A yielded better with flag leaf clipping while IRRI IR46829A and MR365A showed no response. Zhen Shan 97A has longer and broader flag leaves than the two other cms lines. It should therefore, be

Table 10. Segregation pattern for pollen fertility in some crosses involving 'WA' cyto-sterile lines and their restorers. IRRI, 1984.

Generation or genotype		Total no. of plants observed	Plants (no.) with given pollen fertility reaction[a]						Level of probability
			FF	F	PF	PS	S	HS	
MR365A	(P1)	12						12	
IR54	(P2)	10	9	1					
MR365A/IR54	(F1)	12	2	10					
MR365A//F_1	(BC)	40	7	13	8	2	0	10	P > 0.99
				20		10			(2:1:1)
MR365A/IR54	(F2)	259	91	100	46	7	0	15	P 0.90-0.75
				191		53			(12:3:1)
V20A	(P1)	10						10	
IR9761-19-1	(P2)	10	6	4					
V20A/IR9761-19-1	(F1)	10	8	2					
V20A//F_1	(BC)	68	10	8	17	13	5	15	P 0.90-0.75
				18		35		15	(1:2:1)
V20A/IR9761-19-1	(F2)	256	112	38	76	10	6	14	P 0.99-0.95
				150		92			(9:6:1)
97A	(P1)	10						10	
IR42	(P2)	10	6	4					
97A/IR42	(P1)	10	7	3					
97A//F_1	(BC)	52	6	5	10	4	1	26	P 0.75-0.50
				11		15		26	(1:1:2)
97A/IR42	(F2)	224	37	86	39	6	4	52	P 0.50-0.25
				123		49			(9:3:4)

[a] FF (fully fertile) = 80-100% pollen fertility, F (fertile) = 60-80%, PF (partially fertile) = 30-60%, PS (partially sterile) = 10-30%, S (sterile) = 1-10%, HS (highly sterile) = 0.

Table 11. Seed yields obtained at IRRI farm, 1983-84.[a]

Season	Year	Production plots (no.)		Seed yield (kg/ha)		Percent seed set	
		A/B	A/R	A/B	A/R	A/B	A/R
Dry	1983	6	16	61-596	186-1578	11-13	19-43
Wet	1983	13	17	10-69	66-618	5-17	4-23
Dry	1984	14	22	36-845	37-1016	3-35	3-38
Wet	1984	16	17	12-176	18-276	5-10	3-15

[a] A/B = cms line multiplication plot, A/R = hybrid seed production plot.

Table 12. Effect of gibberellic acid (GA) application on seed yield, seed set, and panicle exsertion on cytoplasmic male sterile lines in A/B seed production plots. IRRI, 1984.

GA concn (ppm)	Seed yield (kg/ha)			Seed set (%)			Panicle exsertion (%)		
	97A[a]	IR46830A[a]	MR365A[b]	97A[a]	IR46830A[a]	MR365A[b]	97A[a]	IR46830A[a]	MR365A[b]
0	234	165	205	14	9	14	55	65	67
20	244	248	255	18	13	15	58	67	69
30	287	320	261	17	12	15	58	68	71
40	269	253	246	14	12	20	59	71	71

[a] Dry season data. [b] Wet season data.

Table 13. Effect of flag leaf clipping on seed yield and seed set on cytoplasmic male sterile (cms) lines in the A/B seed production plots. IRRI, 1984 DS.

cms line and treatment	Panicle exsertion (%)	Seed set (%)	Grain yield (t/ha)
IR46829A			
Flag leaf not clipped	71	7	0.2
Flag leaf clipped	70	12	0.2
MR365A			
Flag leaf not clipped	72	27	1.4
Flag leaf clipped	73	25	1.4
Zhen Shan 97A			
Flag leaf not clipped	59	11	0.2
Flag leaf clipped	67	11	0.3

useful in developing cms lines possessing short and narrow flag leaves.

To improve outcrossing potential of parental lines, we continue breeding to transfer long stigma and large anthers from a wild rice culture (6209-3) introduced from China into some elite lines using biparental mating. Although some new lines possess longer and more exserted stigma and larger anthers than those of cultivated varieties, their wild rice traits such as lax panicles, fewer spikelets, and awns have not been eliminated altogether. Also, the derived lines still do not possess the stigma and anther size of the wild rices. Linkage between the long exserted stigma, long anthers, and wild rice traits is quite strong and it will take more intercrossing among derived lines to break their linkages.

Wide hybridization for rice improvement (*Plant Breeding*). Several wild rice species are highly resistant to diseases and insects. They also possess genes for tolerance for drought and salinity. It is easier to transfer useful genes from the wild species with AA genome to cultivated rice. For example, grassy stunt resistance gene *Gs* was transferred from *O. nivara* to cultivated rice through conventional hybridization followed by backcrossing to the cultivated parent. However, wild species whose genomes are nonhomologous to the A genome of *O. sativa* are extremely difficult to cross with cultivated rice. Their genomes do not pair and recombine with A genome. During 1984, we attempted to establish alien monosomic addition lines having the full chromosome complement of *O. sativa* and single chromosomes of a wild species. The monosomic addition lines could be used to transfer segments of alien chromosomes bearing the useful genes to the chromosomes of *O. sativa* by radiation treatments.

We obtained 18 accessions of *O. officinalis* (CC genome) and 4 of *O. australiensis* (EE genome) from the germplasm bank (Table 14), all resistant to all known BPH biotypes. These accessions were crossed with three *O. sativa* breeding lines susceptible to BPH.

We tried crosses between *O. sativa* lines as females and wild species as males. The range of seed set was 0.5% to 30.9%. However, the seeds were imperfectly developed and started to abort 14 d after pollination. Examination revealed normal embryo development but degeneration of endosperm. To overcome this problem, 14-d embryos were excised in an aseptic condition under a stereo microscope and were cultured on 1/4 Murashige-Skoog medium devoid of auxin. The cultured embryos were incubated in darkness until germination and later transferred to a lighted incubation room. Germination varied from 33.3 to 88.2%. Data from crosses with IR25587-109-3-3-3-3 are given in Table 15. The young seedlings at three-leaf stage were transferred to liquid nutrient solution. After 10 d, they were transferred to soil. This has provided more than 450 interspecific hybrid plants.

The F_1 plants were intermediate between the two parents in some respects, but expressed several traits of the wild parents. In general, they were robust and extremely vigorous; however, they were completely male sterile.

Most F_1 plants were diploid. However, five F_1 hybrids from a cross of IR1529-680-3-2 and *O. officinalis* (Accession no. 100179) were triploid. The triploids probably came from pollination of unreduced gametes of one parent and should have two homologous genomes.

The diploid and triploid hybrids were backcrossed using breeding lines of *O. sativa* as recurrent parents. Seed set was extremely low: 0-5.2% in triploid hybrids and 0-8.6% in diploid hybrids. A few well-formed seeds germinated to produce healthy seedlings. Some of these backcross progenies, especially those from triploid hybrids, should be monosomic alien addition lines having the diploid chromosome complement of *O. sativa*

Table 14. Cultivated and wild species of rice used in wide hybridization. IRRI, 1984.

Name of species	Accession no.	Country of origin	Chromosome no.	Genome	Reaction[a] to BPH
O. officinalis	100179	Japan	24	CC	R
O. officinalis	100180	Malaya	24	CC	R
O. officinalis	101121	Philippines	24	CC	R
O. officinalis	101113	Philippines	24	CC	R
O. officinalis	101117	Philippines	24	CC	R
O. officinalis	101077	Philippines	24	CC	R
O. officinalis	101078	Philippines	24	CC	R
O. officinalis	101150	Malaysia	24	CC	R
O. officinalis	101152	Malaysia	24	CC	R
O. officinalis	101155	Malaysia	24	CC	R
O. officinalis	102385	Indonesia	24	CC	R
O. officinalis	102382	Indonesia	24	CC	R
O. officinalis	101414	India	24	CC	R
O. officinalis	101412	India	24	CC	R
O. officinalis	100947	India	24	CC	R
O. officinalis	100896	Thailand	24	CC	R
O. officinalis	100878	Thailand	24	CC	R
O. officinalis	101399	Vietnam	24	CC	R
O. australiensis	100882	India	24	EE	R
O. australiensis	101144	Australia	24	EE	R
O. australiensis	101397	USA (USDA)	24	EE	R
O. australiensis	101410	Australia	24	EE	R
O. sativa (IR1529-680-3-2)		IRRI	24	AA	S
O. sativa (IR25587-109-3-3-3-3)		IRRI	24	AA	S
O. sativa (IR31917-45-3-2)		IRRI	24	AA	S

[a] R = resistant, S = susceptible.

Table 15. Crossability and embryo rescue success rate in crosses of *O. sativa* (IR25587-109-3-3-3-3) with wild species. IRRI, 1984.

Wild species accession no.	Spikelets pollinated (no.)	Seed set		Embryos cultured (no.)	Embryos germinated		True hybrids obtained (no.)	Crossability (%)
		No.	%		No.	%		
100179	1226	113	9.2	41	21	51.2	13	1.1
100180	1413	169	12.0	19	12	63.2	5	0.4
101121	687	91	13.2	45	28	62.2	15	2.2
101113	193	24	12.4	13	6	46.2	1	0.5
101117	677	55	8.1	4	4	100.0	4	0.6
101077	110	4	3.6	1	1	100.0	1	0.9
101078	173	33	19.1	15	13	86.7	13	7.5
101150	734	80	10.9	15	5	33.3	4	0.5
101152	670	83	12.4	12	5	41.7	–	–
101155	778	65	8.4	18	11	61.1	7	0.9
102385	863	30	3.5	5	3	60	2	0.2
102382	535	29	5.4	15	12	80.0	11	2.1
101414	242	8	3.3	1	1	100.0	–	–
101412	264	27	10.2	13	9	69.2	5	1.9
100947	664	68	10.2	17	15	88.2	7	1.1
100896	352	37	10.5	3	0	–	–	–
100878	225	33	14.7	14	11	78.6	5	2.2
101399	333	68	20.4	15	12	80.0	9	2.7
100882	394	10	2.5	5	4	80.0	3	0.8
101397	984	31	3.2	7	5	71.4	3	0.3
101144	1377	36	2.6	8	4	50.0	1	0.1
101410	769	4	0.5	12	5	41.7	2	0.3

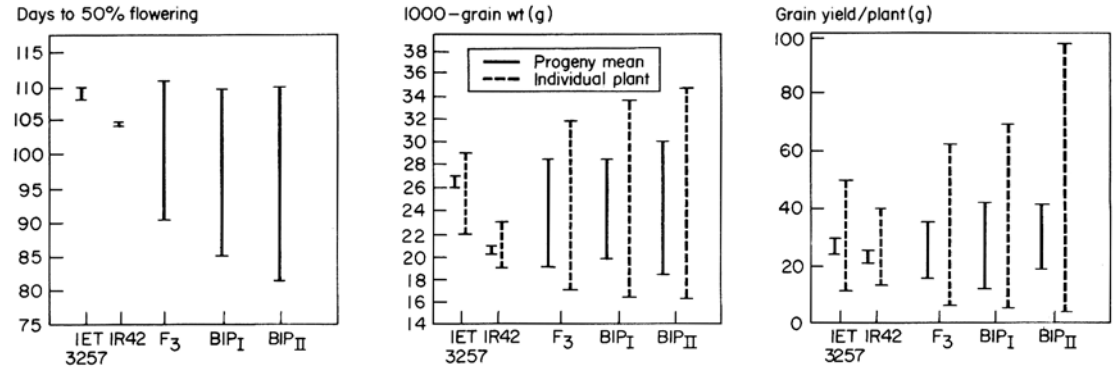
and single alien chromosomes of *O. officinalis* or *O. australiensis*.

Biparental mating (*Plant Breeding*). To develop improved varieties, most rice breeders have used the pedigree method of selection following hybridization. This method limits the opportunity for a complete reassortment of parental genes. While breeding for higher yield, we should increase physiological efficiency of the improved plant type varieties. Physiological traits bearing on yield relate to source and sink size and harvest index. Genes controlling these traits and other desirable plant characters have desirable and undesirable linkages. Breeders need approaches that will retain desirable linkages, break undesirable (repulsion-phase) ones, and improve the selection efficiency in discriminating between high and low yielding genotypes.

With varying success, biparental mating has been used to break repulsion phase genetic linkages in self-pollinated crops including wheat, cotton, and tobacco. This breeding approach involves intermating selected genotypes in segregating generations of a cross. We compared this breeding method to the conventional pedigree method in breaking linkages for genes controlling yield and yield components in the rice cross IET3257/IR42. The analysis used progenies derived from F_2, biparental I (from intermating randomly selected plants in F_2 population), and biparental II (from intermating randomly selected plants in biparental I population) using means, ranges, variances, phenotypic and genotypic correlation, and path coefficient analysis.

Examination of measures of means and dispersion showed that intermating populations gave more desirable segregation (among and within families) than F_3s for days to 50% flowering, 1,000-grain weight, and grain yield (Fig. 4). Genotypic variances for biparental progenies were significantly different from those of F_3s for days to 50% flowering and panicle number (Table 16). For plant height, grains per panicle, 1,000-grain weight, and grain yield, intermating effects were not clear, perhaps because of the higher coefficient of variability for those traits or the need for additional intermatings to break undesirable linkages.

Associations between characters tended to shift toward favorable or unfavorable values (Table 17) presumably due to new complex genic combina-



4. Range for days to 50% flowering, 1,000-grain weight, and grain yield in parents, F_3, and biparental progenies (BIP_I, BIP_{II}) based on progeny mean and individual plants. IRRI, 1984.

Table 16. Comparison of genotypic variances of F_3 and intermated populations BIP_I, BIP_{II}. IRRI, 1984.

Character	Genotypic variance[a]			
	F_3	BIP_I	BIP_{II}	CV (%)
Days to 50% flowering	10.973 b	32.411 a	36.325 a	0.8
Plant height (cm)	110.614 a	81.692 a	98.311 a	13.3
Panicle no./hill	0.441 b	0.673 a	0.302 c	31.4
Grains/panicle	127.488 a	105.464 a	146.751 a	36.6
1,000-grain weight (g)	2.080 ab	2.420 a	1.640 b	13.4
Grain yield/plant (g)	6.973 a	5.935 a	7.490 a	41.6

[a] In a row, variances followed by a common letter are not significantly different from each other at 5% level by F-test.

tions in biparental progenies. Path analysis also confirmed that intermating tended to shift the direct effects (either increased as in panicle number or decreased as in grains per panicle and 1,000-grain weight). Similarly, intermating influenced most indirect effects in different associations.

Biparental mating somewhat dissipates the initial linkage disequilibrium; consequently, the segregating generations will generate more variation. If combined with efficient selection procedures during the evolutionary phase of plant breeding, biparental mating should help select desirable genotypes for a complex inherited trait such as rice yield. We are using this breeding approach in crosses intended to transfer long stigma and long anther from a wild rice culture to selected semidwarf elite breeding lines or varieties which are useful parents in the hybrid rice breeding program. The same approach would also be useful to cross parents possessing the desired traits but for which desirable recombinants are difficult to obtain in F_2.

RAPID GENERATION ADVANCE

Plant Physiology Department

In 1984, 326 crosses consisting of 536,281 plants, the largest number ever, were sown in the RGA facilities.

F_2 seeds from 142 crosses were received this year from Kerala (India), Vercelli (Italy), Thailand, WARDA, and IITA. Of those, 20 were for low temperature and the rest were photoperiod-sensitive materials from deep water and rainfed lowland areas.

A total of 82 crosses and 132 selections were sent to 8 cooperators in Thailand, India, Sierra Leone, Indonesia, and Cameroon.

RGA facilities were used in research projects and

Table 17. Phenotypic and genotypic correlation coefficients[a] between all pairs of the 6 characters measured in F_3, BIP_I, and BIP_{II} populations. IRRI, 1984.

Character		Plant height (cm)			Panicle no./hill			Grains/panicle			Grain weight (g)			Grain yield/plant (g)		
		F_3	BIP_I	BIP_{II}	F_3	BIP_I	BIP_{II}	F_3	BIP_I	BIP_{II}	F_3	BIP_I	BIP_{II}	F_3	BIP_I	BIP_{II}
Days to 50% flowering	rp	−0.057^{ns}	−0.094^{ns}	0.100^{ns}	−0.190**	−0.152*	−0.030^{ns}	0.065^{ns}	−0.106^{ns}	0.115^{ns}	−0.020^{ns}	0.270**	0.273**	−0.089^{ns}	−0.079^{ns}	0.216**
	rg	−0.034	−0.085	0.118	−0.314	−0.241	−0.113	0.105	−0.157	0.188	−0.024	0.312	0.355	−0.115	−0.142	0.316
Plant height (cm)	rp				−0.156^{ns}	−0.192*	−0.058^{ns}	0.299**	0.124^{ns}	0.243**	0.195**	0.042^{ns}	0.090^{ns}	0.224**	0.089^{ns}	0.238**
	rg				−0.445	−0.359	−0.359	0.402	0.227	0.349	0.251	0.031	0.065	0.189	0.078	0.253
Panicle no./ hill	rp							−0.136^{ns}	−0.022^{ns}	−0.215**	−0.043^{ns}	−0.016^{ns}	0.098^{ns}	0.412**	0.507**	0.433**
	rg							−0.210	−0.346	−0.314	−0.169	−0.112	0.364	0.172	0.566	0.102
Grains/ panicle	rp										0.090^{ns}	−0.118^{ns}	−0.108^{ns}	0.606**	0.546**	0.533**
	rg										0.216	−0.217	−0.273	0.793	0.524	0.730
1000-grain weight (g)	rp													0.327**	0.185*	0.246**
	rg													0.541	0.279	0.376

[a]rp = phenotypic correlation coefficient, rg = genotypic correlation coefficient.

experiments conducted by GEU trainees, researchers, research fellows, and scholars. The facilities were used mostly to grow photoperiod-sensitive materials in F_1, F_2, and F_3 for genetic analysis.

Screening RGA materials for submergence tolerance. Seventy-six RGA crosses in F_3 up to F_6 were screened for submergence tolerance at seedling stage. A total of 120 selections were made for the 1985 pedigree nursery.

Several RGA crosses were evaluated for elongation ability.

RGA field evaluation. Eighty-five advanced RGA materials (F_5) were field planted during 1984 WS to evaluate performance against field pests and diseases. A total of 258 selections and 6 bulk populations were made from 53 crosses.

RGA materials in IRTP nurseries. The 1984 IRTP nurseries included 15 entries generated from RGA facilities.

Genetic evaluation and utilization (GEU) program

Computerized data management

Statistics and Plant Breeding Departments, International Rice Germplasm Center, and International Rice Testing Program

GERMPLASM BANK **140**
Characterization and evaluation **140**
Seed inventory system **140**
RICE GENETIC ANCESTRY SYSTEM **140**
EVALUATION OF BREEDING LINES **140**
INTERNATIONAL RICE TESTING PROGRAM **140**

GERMPLASM BANK

Statistics Department and International Rice Germplasm Center

Characterization and evaluation. In 1984, 4,148 newly registered accessions of *O. sativa* were added to the germplasm computer data bank (GB), which contained 63,490 accessions at year end. Of these, 45,502 have been completely characterized by the 45 basic morphoagronomic characters (Annual report for 1983). Data on 28 GEU traits of varying accessions were added in 1984. The number of accessions ranged from 70 for resistance to green leafhopper to 12,596 for resistance to rice tungro virus (average of 3,086 accessions over 28 traits).

In 1984 the GB data file was converted from sequential to random access. This not only eased and speeded data update and information retrieval, but increased flexibility in ordering accessions in the computer-generated data sheets that scientists use in recording screening results for various GEU traits. Random access facilitates, for example, listing accessions in the order they are planted, either in the field or in the greenhouse, rather than, say, in ascending order of accession number.

Additionally, the interactive version of the germplasm bank information retrieval system became available in late 1984. However, its use was hampered by slow response time, caused by limited power in the IBM 4331 system.

Seed inventory system. With increased seed rejuvenation and canning, more seed records were added. Of 20,417 accessions canned, the seed inventory system master file recorded 19,010 at year end.

RICE GENETIC ANCESTRY SYSTEM

Statistics and Plant Breeding Departments

The rice genetic ancestry system now includes parental records of 50,308 IR crosses and 36,510 crosses from national breeding programs in 10 countries. Requests increased for tracing parents of prescribed IR lines and especially for listing descendants.

Efforts continued to maintain uniform parent names in the rice genetic ancestry file and in all related GEU computer files. To produce uniform records, all non-IR parents of IR crosses were traced in non-IR ancestry files, in IRTP files, and in other plant breeding nursery files.

The ancestry file of IR crosses was cleaned to prepare for printing the "Parentage of IRRI crosses: IR1-50,000" in early 1985.

EVALUATION OF BREEDING LINES

Statistics and Plant Breeding Departments

In 1984, the following nurseries and trials were computerized and added to the system:

- four F_2 subnurseries: adverse soil, deep water submergence, deep water elongation, and upland;
- upland replicated yield trial; and
- field screening for drought tolerance.

A new feature of the pedigree nursery system enables automatic search and generation of pedigree numbers for a given IR cross or line. This avoids duplicate assignment of pedigree numbers as may occur when an entry appears in several nurseries and is selected by several persons.

Of 138,148 early generation lines tested in 1984, 19,332 were selected. Data on 18 GEU traits of these lines, used in selections, were updated for the nursery inventory data files.

With the increase in data files, retrieval of breeding information is more time-consuming and costly. Many users request all data of one or more varieties or lines tested in all nurseries. To facilitate such information retrieval, a study was undertaken to determine an appropriate procedure for combining data of a given breeding line over several nurseries and trials and over seasons and years. Such procedure is expected to be different for traits greatly affected by environment, such as grain yield, and for more stable traits, such as maturity, or GEU traits such as resistance to insects and diseases. A directory file was subsequently created to contain all breeding lines ever tested in a plant breeding nursery or trial; and for each line, specific nurseries or trials testing it were listed.

INTERNATIONAL RICE TESTING PROGRAM

Statistics Department and International Rice Testing Program

With the addition of the International Rice Weather Trial Nursery (IRWTN) and the International Rice

Wheat Integrated Trial (IRWIT), the system now handles 18 nurseries. For each, the system provides facilities for printing individualized fieldbooks, custom-made data analysis and summarization, and data storage for information retrieval. The International Rice Testing Program (IRTP) master entry file has 9,993 entries; 8,074 were tested in one or more IRTP nurseries.

Genetic evaluation and utilization (GEU) program

International Rice Testing Program

International Rice Testing Program

1983 NURSERY RESULTS **144**
Yield nurseries **144**
Observational nurseries **145**
Nurseries for specific stresses **145**
1984 NURSERY DISTRIBUTION **146**
Use of IRTP nursery entries **149**
MONITORING VISITS AND WORKSHOPS **149**
IRTP IN LATIN AMERICA **152**
IRTP IN AFRICA **154**

1983 NURSERY RESULTS

IRTP composed 23 types of nurseries in 1983 and sent them to 62 countries cooperating in the network. Of 2,578 entries, 1,368 came from national programs and 1,210 from IRRI.

Yield nurseries. Top ranking entries for three maturity groups of irrigated rices — very early (IRYN-VE), early (IRYN-E), and medium (IRYN-M) — are shown in Tables 1, 2, and 3. Some rices performed well in several regions. The nursery reports show yield and yield components by site and

Table 1. Best performing entries in the fourth International Rice Yield Nursery-Very Early (IRYN-VE) based on overall and regional mean yield, 1983.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall				
(47)	IR25924-51-2-3	IRRI	85	5.0
	UPR103-80-1-2	India	82	4.9
	BG367-4	Sri Lanka	86	4.8
	IR25588-7-3-1	IRRI	84	4.8
	IR25925-84-3-2	IRRI	84	4.8
	IR9729-67-3	IRRI	81	4.8
	IR50	IRRI	85	4.8
East Asia				
(9)	IR50	IRRI	93	5.3
	IR25924-51-2-3	IRRI	97	5.7
	IR25925-84-3-2	IRRI	93	5.6
	IR9729-67-3	IRRI	89	5.5
	UPR103-80-1-2	India	90	5.4
Southeast Asia				
(11)	IR9729-67-3	IRRI	72	4.5
	IR25890-5-3	IRRI	73	4.4
	IR25924-51-2-3	IRRI	75	4.3
	IR25925-84-3-2	IRRI	75	4.3
	IR29692-65-2-3	IRRI	96	4.3
	IR50	IRRI	77	4.3
South Asia				
(17)	BG367-4	Sri Lanka	88	4.8
	IR9729-67-3	IRRI	81	4.7
	IR50	IRRI	85	4.7
	IR25588-7-3-1	IRRI	84	4.6
	IR25924-51-2-3	IRRI	84	4.6
West Asia and North Africa	UPR103-80-1-2	India	104	6.5
(3)	RP1158-85-1	India	107	6.4
	IR25924-51-2-3	IRRI	105	5.5
	IR25588-7-3-1	IRRI	105	5.4
	IR28128-45-2	IRRI	104	5.4
Sub-Sahara Africa				
(3)	UPR103-80-1-2	India	73	5.8
	IR25924-51-2-3	IRRI	78	5.6
	IR25588-7-3-1	IRRI	78	5.5
	IR28210-96-4-3-3	IRRI	77	5.5
	IR29692-65-2-3	IRRI	79	5.3
Latin America				
(4)	IR25890-82-5-3	IRRI	79	6.6
	UPR231-28-1-2	India	85	6.4
	UPR103-80-1-2	India	77	6.3
	UPR254-35-3-2	India	85	6.1
	BG367-4	Sri Lanka	84	6.0
	TKM9	India	80	6.0

[a] Figures in parentheses are number of trials.

region. Climatic data allow data interpretation. Table 4 shows yields of best entries in the rainfed shallow water yield nursery (IRRSWYN), and Table 5 lists best entries in the upland rice yield nursery.

Observational nurseries. The outstanding entries in the observational nurseries (IRON, IURON, IRRSWON, IRDWON, IFRON, and ITPRON) were determined by the best overall phenotypic acceptability ratings (Table 6, 7). Many entries were resistant to or tolerant of one or more important stresses at trial locations.

Nurseries for specific stresses. Tables 8 and 9 list the best performing entries in nurseries established for specific stresses. Insect nurseries include those for brown planthopper, whitebacked planthopper, and stem borer. Disease nurseries include those for bacterial blight, rice blast, and rice tungro. Other stresses are salinity and alkalinity, acid upland and lowland soils, and cold tolerance.

Table 2. Best performing entries in the eleventh International Rice Yield Nursery-Early (IRYN-E), 1983.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall				
(37)	KAU1727	India	94	5.3
	IR18348-36-3-3	IRRI	93	5.2
	IR13540-56-3-2-1	IRRI	100	5.1
	C1322-28	Philippines	93	5.0
	IR21015-80-3-3-1-2	IRRI	95	5.0
	IR9782-111-2-1-2	IRRI	92	5.0
	IR9784-142-1-3-3	IRRI	94	5.0
	Taichung sen yu 285	Taiwan	93	5.0
East Asia				
(3)	Tainung sen 12	Taiwan	114	7.5
	Taichung sen yu 285	Taiwan	112	7.4
	Kaohsiung sen yu 252	Taiwan	113	7.3
	KAU1727	India	110	7.2
Southeast Asia				
(14)	KAU1727	India	87	4.8
	IR18348-36-3-3	IRRI	84	4.7
	IR21015-80-3-3-1-2	IRRI	85	4.6
	IR9784-142-1-3-3	IRRI	85	4.6
South Asia				
(14)	IR18348-36-3-3	IRRI	96	5.0
	KAU1727	India	97	5.0
	C1322-28	Philippines	96	4.9
	IR9782-111-2-1-2	IRRI	94	4.8
	Taichung sen yu 285	Taiwan	97	4.8
	Tainung sen 12	Taiwan	97	4.8
West Asia and North Africa	KAU1727	India	104	8.4
(2)	IR9698-16-3-3-2	IRRI	108	7.1
	BR161-2B-59	Bangladesh	111	6.9
	IR18348-36-3-3	IRRI	113	6.9
	UPR307-7-1-1	India	105	6.5
Sub-Sahara Africa				
(2)	IR21015-80-3-3-1-2	IRRI	90	5.3
	BR161-2B-59	India	93	5.0
	Kaohsiung sen yu 252	Taiwan	90	4.8
Latin America				
(2)	IR13540-56-3-2-1	IRRI	92	9.0
	IR21015-80-3-3-1-2	IRRI	89	7.4
	Kaohsiung sen yu 252	Taiwan	90	7.4
	UPR79-79	India	85	7.1

[a] Figures in parentheses are number of trials.

Table 3. Best performing entries in the eleventh International Rice Yield Nursery-Medium (IRYN-M), 1983.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall				
(30)	BG400-1	Sri Lanka	110	4.7
	IR19672-140-2-3-2-2	IRRI	107	4.7
	IR21820-154-3-2-2-3	IRRI	102	4.7
	IR28118-138-2-3	IRRI	114	4.7
	ITA 212	Nigeria	105	4.7
Southeast Asia				
(10)	IR28118-138-2-3	IRRI	105	4.9
	IR42	IRRI	107	4.8
	IR21820-154-3-2-2-3	IRRI	97	4.7
	IR19672-140-2-3-2-2	IRRI	98	4.6
	IR27325-63-2-2	IRRI	105	4.6
South Asia				
(13)	IR21820-154-3-2-2-3	IRRI	108	4.3
	BG379-2	Sri Lanka	113	4.2
	BG400-1	Sri Lanka	121	4.2
	ITA212	Nigeria	112	4.2
	IR24637-38-2-2-1	IRRI	113	4.1
West Asia and North Africa	ITA212	Nigeria	108	11.2
(1)	UPR254-85-1-TCA3	India	100	11.1
	RAU2004-6-69-2-13	India	102	10.8
	IR25560-132-2-3	IRRI	103	10.2
	RNR 74229	India	101	10.1
Sub-Sahara Africa				
(5)	ITA212	Nigeria	100	6.0
	BG400-1	Sri Lanka	105	5.5
	IR19672-140-2-3-2-2	IRRI	102	5.4
	BW295-4	Sri Lanka	108	5.3
	IR19670-263-3-2-2-1	IRRI	104	5.3
Latin America				
(1)	RNR74229	India	107	8.7
	Taichung sen 10	Taiwan	97	8.4
	BG400-1	Sri Lanka	107	7.7
	UPR254-85-1-TCA3	India	100	7.3
	RNR74802	India	105	6.9

[a]Figures in parentheses are number of trials.

Table 4. Best performing entries in the third International Rainfed Rice Shallow Water Yield Nursery (IRRSWYN). 1983.

Designation	Origin	Mean yield (t/ha)
IR19431-72-2	IRRI	3.2
BR4	Bangladesh	3.1
IR13146-45-2-3	IRRI	3.1
RP975-109-2	India	3.1
Cisadane	Indonesia	3.0
IR10781-75-3-2-2	IRRI	3.0
IR14632-2-3	IRRI	3.0
IR4819-77-3-2	IRRI	3.0

1984 NURSERY DISTRIBUTION

A total of 1,301 sets of 23 types of IRTP nurseries were composed and distributed to 55 countries in the IRTP network (Table 10). Test entry sources appear in Table 11. These include 12 nurseries for rice cultural types and 11 for stress tolerance. In 1984, 2,747 entries were distributed to scientists around the world.

In Asia, 866 sets went to national programs. Sub-Sahara Africa received 304 sets, and 104 went to WARDA for distribution to member countries. The remaining 200 sets went to IITA in Nigeria and

Table 5. Best performing entries in the tenth International Upland Rice Yield Nursery. 1983.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall (12)	UPL Ri-7	Philippines	84	3.0
	BR319-1	Bangladesh	87	2.9
	IR5931-110-1	IRRI	90	2.9
	UPL Ri-5	Philippines	94	2.9
	IR12721-24-3-1	IRRI	98	2.7
	IR43	IRRI	97	2.7
	IR6023-10-1-1	IRRI	94	2.7
	IR9782-111-2-1-2	IRRI	85	2.7
	UPL Ri-3	Philippines	95	2.7
Southeast Asia (6)	IR12721-24-3-1	IRRI	99	3.2
	IR5931-110-1	IRRI	92	3.2
	UPL Ri-5	Philippines	95	3.2
	UPL Ri-7	Philippines	85	3.2
	IR43	IRRI	99	3.1
South Asia (5)	BR319-1	Bangladesh	87	3.1
	IR9782-111-2-1-1-2	IRRI	85	3.1
	CR156-5021-207	India	90	3.0
	UPL Ri-7	Philippines	84	3.0
	UPL Ri-5	Philippines	93	2.7
Latin America (1)	C894-21	Philippines	80	2.1
	IR6023-10-1-1	IRRI	91	2.1
	UPL Ri-5	Philippines	94	2.1
	BR319-1	IRRI	78	2.0
	IR9101-124-1	IRRI	94	2.0
	UPL Ri-3	Philippines	94	2.0

[a] Figures in parentheses are number of trials.

Table 6. Entries that received best phenotypic acceptability ratings in the 1983 observational nurseries.

	Designation	Mean phenotypic acceptability score
International Rice Observational Nursery	Chianung sen yu 26	4.6
	IR18349-135-2-3-2-1	4.7
	IR28128-45-2	4.7
	C662083	4.8
	IR28128-45-3-3-2	4.8
	IR29692-65-2-3	4.8
	IR9698-16-3-3-2	4.8
	Chianung sen yu 13	4.9
	IR18349-22-1-2-1-1	4.9
	IR24632-145-2-2-2-3	4.9
	IR28154-101-3-2	4.9
	IR18348-36-3-3	4.9
	IR21015-80-3-3-1-2	4.9
International Upland Rice Observational Nursery Group		
I. Medium duration, intermediate/tall stature	B2997C-TB-60-3-3	4.8
	B3623G-TB-41	4.9
	IR3646-13-3-2	4.9
	Salumpikit	4.9

Continued on next page

Table 6 continued

	Designation	Mean phenotypic acceptability score
II. Medium duration, short stature	UPL Ri-7	4.2
	C1019-1	4.7
	IRAT 140	4.8
	IRAT 13	4.8
	C894-7	4.9
	IR3179-25-3-4	4.9
III. Short duration, intermediate/tall	B3619C-TB-8-1-4	4.3
IV. Short duration, short stature	No entry with a score better than 5.0	
International Deep Water Rice Observational Nursery	BKNFR76014-1-9-2	5
	BKNFR76014-1-9-3	5
	DWCB-B-175-1	5
	IR11141-6-1-4	6
	SPR7292-151-2-1-B-B	6
	TCA180-4	4
	RD19	8
International Floating Rice Observational Nursery	Habiganj Aman II	4
	HTAFR77043-2	4
	Leb Mue Nahng III	4
	HTAFR77068-2	4
	HTAFR7426-5-0-1-5	4
	IR4935-K103-0-2-0	4
	SPRC72-357	4
	SPR7233-44	4
	SPR7278-7-1-2-1-0	4
	SPR7282-2-0-4-2	4
	SPR7282-2-0-7	4
	SPR7290-9-1-1-0	3
International Tide-Prone Rice Observational Nursery	IR13646-55-1	4
	IR14632-65-2	4
	IR26	4
	Nazakam	4
	SPR7270-18	4

Table 7. Entries with best overall phenotypic acceptability ratings in the International Rainfed Rice Shallow Water Observational Nursery (IRRSWON). 1983.

Designation	Mean plant height (cm)	Mean flowering duration (d)	Mean phenotypic acceptability score
IR21567-18-3-1	98	103	3.8
IR21037-2-1-2E-P1	115	112	3.9
IR54	94	100	3.9
IR21567-18-3	96	104	4.0
RP975-109-2	109	117	4.0
IR4829-89-2	103	101	4.2
IR15853-89-7E-P3	93	101	4.2
IR21567-16-3	100	104	4.2
BR51-282-8	106	99	4.3
IR10781-75-3-2-2	97	108	4.3
IR21836-90-3	101	112	4.3
IR21056-9-P2	88	100	4.3
Local check (av)	106	108	4.3

Table 8. Best performing entries in the 1983 insect and disease nurseries.

Insects

- IRBPHN (Brown Planthopper Nursery). Varieties rated resistant at all locations are

BG367-2	IR19661-23-3-2-2
BG379-2	RP1756-121
IR13427-40-3-3	IR27325-111-2-1

- IRWBPHN (Whitebacked Planthopper Nursery). The following entries showed resistance at all five locations (score of 3 or better):

ASD8	IR17307-11-2-3-2
HAU2-165-3-3	IR17492-18-6-1-1-3-3
IR2035-117-3	ADR52
IR13458-117-2-3-2-3	PTB19
IR15529-253-3-2-2-2	Rathu Heenati (Acc. no. 11730)
IR15795-151-2-3-2-2	Sinna Sivappu (Acc. no. 15444)
IR15797-74-1-3-2	

- IRSBN (Stem Borer Nursery). Entries which received scores of 3 or better at all locations for resistance at flowering stage:

BPT1235	IR46
IR15314-43-2-3-3	IR48
IR17494-32-1-1-3-2	IR9288-B-B-52-1
IR29	IR9752-71-3-2
IR38	Tainung sen 12

Diseases

- IRBBN (Bacterial Blight Nursery). The following entries received the best overall phenotypic ratings:

B161-2B-59	IR13423-17-1-2-1
BR319-1-HR38	IR18348-36-3-3
BR40-300-2-1	IR21820-154-3-2-2-3
BR51-282-8	IR21848-65-3-2-2
Chianung sen yu 29	IR22082-41-2
Chianung sen yu 31	IR25840-64-1-3
IR13240-82-3-2-3-1	M61b-1-1-2

- IRBN (Rice Blast Nursery). The following entries were rated resistant (0-3 score) at more than 90% of 40 locations:

Carreon	Tetep
Suweon 300	#5287
Ta-poo-cho-z	

- IRTN (Rice Tungro Nursery). Varieties given resistant rating to rice tungro virus in 3 locations are:

Gam Pai 30-12-15
ARC11554
IR25586-36-1-2

Table 9. Entries with best phenotypic ratings in the IRTP nurseries and screening sets for soil problems and cold tolerance. 1983.

- IRSATON (Salinity and Alkalinity). The entries that were rated tolerant at both the vegetative and maturity stages were

C100	IR4595-4-1-13
C2	IR4630-22-2-17
IR14632-22-3	IR4630-22-2-5-1-3
IR4422-6-2	Pokkali
IR4422-6-2-3-1	Getu

- Acid Upland Soils

Azucena	ITA142
IRAT104	ITA235
ITA116	

- Acid Lowland Soils. The overall mean score for phenotypic acceptability (over all entries and locations and over two levels of P_2O_5) was 5.0. Entries that received the best mean phenotypic rating (score of 4.0) were as follows:

IR2153-26-3-5-2	IR5741-73-2-3
IR2797-125-3-2-2-2	IR9129-136-2
IR42	Khao Dawk Mali 105
IR4227-109-1-3-3	MRC172-9
IR44	

- IRCTN (Cold Tolerance Nursery). Entries that received the best average phenotypic acceptability ratings (scores less than or equal to 5) based on 21 tests were as follows:

HPU5010-P1$_b$21-2-1B	China 1039
IR13155-60-3-1-2-1	K31-163-3 (Kidwani)
IR22623-R-R-4-3	RP1442-4-6-1-1
IR24312-R-R-19-3-B	Barkat (K78-13)
IR9202-6-1-1	Wasetoramochi

the National Cereals Research Institute for distribution to Cameroon, Kenya, Tanzania, Uganda, Zaire, and Zambia. Forty nursery sets went to the national programs in West Asia and North Africa. Latin America received 75 sets; 4 European countries, 6 sets; and Oceania countries, 10 sets.

Use of IRTP nursery entries. National rice improvement programs continue to use IRTP materials. Often, outstanding entries in stress screening nurseries are used as donors in hybridization programs (Table 12, 13).

MONITORING VISITS AND WORKSHOPS

Site visits and workshops continued to bring together rice scientists in national and international programs to observe local and IRTP trials and to discuss action to solve rice research and production problems. Major workshops in 1984 included one in Africa, with visits to Zambia and Tanzania; an international conference on rainfed lowland rice in Bhubaneswar, Orissa, India, in October; and a breeders' workshop in Panama, 30 Sep-5 Oct, for breeders from Mexico, Guatemala, El Salvador, Costa Rica, Panama, and Centro Internacional de Agricultura Tropical (CIAT). The Panama group selected promising materials in F_2-F_4 upland populations of the Instituto de Investigacion Agropecuaria de Panama (IDIAP)-CIAT project in Rio Hato, and observed constraints on materials

Table 10. IRTP nurseries dispatched from IRRI in 1984.[a]

Region or country	Nurseries for different cultural types												Nurseries for specific stresses											Total
	Yield						Observational																	
	Y_{01}	Y_{02}	Y_{03}	Y_{04}	Y_{05}	Y_{06}	O_{01}	O_{02}	O_{03}	O_{04}	O_{05}	O_{06}	N_{01}	N_{02}	N_{03}	N_{04}	N_{05}	N_{06}	N_{07}	N_{08}	N_{09}	N_{10}	N_{11}	
East Asia																								
China	8	5	1				5	1	1				7	2	1		6	5		7	5	5	2	61
Japan													1				1							2
Korea	1	1					2	1					3	1			4	1		1	1			16
Taiwan	3						1						1				2		1	2				10
Southeast Asia																								
Burma		1	1	1				1	1	2			1	2	1	1	2	2		1	1	1		19
Indonesia	2	2		1	5	2	2	12	2	3	2	2	3	2	6	8	7		4	9	4	1		79
Malaysia	2	3	3		1	2	2	1	1						1		1	1	1	1	1	1		22
Philippines	5	3	3	6	11	7	6	18	16	5	4	5	2	11	3	4	3	1		1	1			115
Thailand	6	6	2	3	3	9	6	5	9	8	8	4	4	4	8	2	8	5	3	2	1	1		107
Vietnam	5	6	7	1	1	2	4	2	1	3	3	3	3	5	3	2	8	1	2	5	5	3	1	43
South Asia																								
Bangladesh	8	6	9	3		4	10	3	4	2	3	1	4	3		2	4	4	3	1			1	75
Bhutan	1	1					1						1											4
India	20	19	14	10	3	4	20	9	5	8	3	1	13	9	2	3	15	11	4	13	8	10	3	207
Nepal	3	2	2	2	2	4	3	2	3				3				4	2		1	1	2		36
Pakistan	4	2	2	1	1	1	3	1	1	1			2	2							2	2		25
Sri Lanka	1							2	3	1				2	2								1	12
West Asia and North Africa																								
Egypt	2	2					2							4			2					1		13
Iran	4	1	1				3							1			5			1	1			17
Saudi Arabia		1						2						1										4
Turkey	3						1							1			1							6
Sub-Sahara Africa																								
Burundi													1											1
Cameroon	3	3	4	1	1	3	2	2	2				3				3							27
Ethiopia	1		1				1	1					1											5
Guinea Bissau													1	1										2
Liberia (WARDA)	6	6	5	3	4	2	6	8	7	7	7	4	4	9	10	2	6	5		1	1	1		104
Madagascar	1			1		1	5						2									1		11
Malawi	1	1																						2
Mozambique	1	1	1		3	5																		11
Nigeria	3	4	4	4	4	3	5	5	4	2	1		5		5	3	7	4					5	68
Sierra Leone	1				1			1		1	1						2						1	8
Tanzania	1	3	3		2	1	4	3	2				3	1			3	2						28
Uganda	1	1	1			1	1																	5
Upper Volta		1	1																					2
Zaire	1	1	1			1																		4
Zambia	3	3	2		1	2	3		2	1	1		3				2							23
Zimbabwe													1	1	1									3

Latin America																									
Argentina							1								1										2
Brazil	1							1					1												3
Chile	1												1												2
Colombia	2	1	1	1			1	2	1	1			1	1	2	2	1								17
Costa Rica								1																	1
Cuba	1	1	1	1	1		1	1					1	1			1								10
Dominican Republic														1											1
Mexico	8	2	4	1	3		2	2					1	3			3						1		30
Peru	1	1	1				2	3																	8
Uruguay													1												1
Europe																									
Hungary													1												1
Italy													1				1								2
Spain	1													1											2
United Kingdom														1											1
Oceania																									
Australia	1	1	1																						3
Solomon Islands	1	1		1			1														2				6
Western Samoa					1																				1
Total	118	92	76	41	48	54	106	90	65	45	33	20	80	70	46	29	102	44	18	48	32	30	14	1301[b]	

[a] Y_{01} = International Rice Yield Nursery-Very Early (IRYN-VE), Y_{02} = International Rice Yield Nursery-Early (IRYN-E), Y_{03} = International Rice Yield Nursery-Medium (IRYN-M), Y_{04} = International Upland Rice Yield Nursery-Early (IURYN-E), Y_{05} = International Upland Rice Yield Nursery-Medium (IURYN-M), Y_{06} = International Rainfed Rice Shallow Water Yield Nursery (IRRSWYN), O_{01} = International Rice Observational Nursery (IRON), O_{02} = International Upland Rice Observational Nursery (IURON), O_{03} = International Rainfed Rice Shallow Water Observational Nursery (IRRSWON), O_{04} = International Rice Deep Water Observational Nursery (IRDWON), O_{05} = International Floating Rice Observational Nursery (IFRON), O_{06} = International Tide-Prone Rice Observational Nursery (ITPRON), N_{01} = International Rice Cold Tolerance Nursery (IRCTN), N_{02} = International Rice Salinity and Alkalinity Observational Nursery (IRSATON), N_{03} = Acid Lowland, N_{04} = Acid Upland, N_{05} = International Rice Blast Nursery (IRBN), N_{06} = International Rice Bacterial Blight Nursery (IRBBN), N_{07} = International Rice Tungro Nursery (IRTN), N_{08} = International Rice Brown Planthopper Nursery (IRBPHN), N_{09} = International Whitebacked Planthopper Nursery (IRWBPHN), N_{10} = International Rice Stem Borer Nursery (IRSBN), N_{11} = Rice Thrips. [b] As of 7 Dec 1984.

Table 11. Origin and types of entries in 1984 IRTP nurseries dispatched from IRRI.

Nursery[a]	Sets dispatched (no.)	Entries[b] (no.)	Entries from								Packets (no.)
			National programs				IRRI				
			Improved		Traditional		Improved		Germplasm bank		
			No.	%	No.	%	No.	%	No.	%	
			Yield								
• Irrigated											
IRYN-VE	118	29	15	52	1	3	13	45	0	0	10,266
IRYN-E	92	29	15	42	0	0	14	48	0	0	8,004
IRYN-M	76	29	12	41	0	0	17	59	0	0	6,612
• Rainfed Upland Yield											
IURYN-E	41	23	20	86	0	0	3	13	0	0	2,829
IURYN-M	48	25	12	48	0	0	13	52	0	0	3,600
• Rainfed Lowland Yield											
IRRSWYN	54	27	6	22	0	0	21	77	0	0	4,374
			Observational								
• Irrigated											
IRON	106	395	204	52	10	3	181	45	0	0	41,870
• Rainfed											
IURON	90	205	134	65	3	1	67	33	1	1	18,450
IRRSWON	65	226	77	34	5	3	144	63	0	0	14,690
IRDWON	45	124	72	58	4	3	48	38	0	0	5,580
IFRON	33	28	19	68	5	18	4	14	0	0	924
ITPRON	20	66	41	62	9	13	13	20	3	5	1,320
			Stress screening								
• Diseases											
IRBN	102	344	200	58	29	8	112	32	3	1	35,088
IRBBN	44	235	113	48	8	3	114	48	0	0	10,340
IRTN	18	140	64	46	7	5	66	47	3	2	2,520
• Insects											
IRBPHN	48	183	42	23	7	4	118	64	16	9	8,784
IRWBPHN	32	82	7	9	4	5	46	56	25	30	2,624
IRSBN	30	79	24	30	2	3	44	55	9	11	7,110
Rice thrips	14	41	10	24	10	24	11	27	10	24	1,722
• Problem Soils											
IRSATON	70	103	21	20	2	2	80	77	0	0	7,210
Acid Upland	29	63	27	43	3	4	32	51	1	2	3,654
Acid Lowland	46	96	26	27	3	3	67	70	0	0	8,832
• Temperature											
IRCTN	80	175	63	36	14	8	35	20	63	36	14,000
Total	1,301	2,747	1,224	1,004	126	113	1,263	1,054	134	121	220,403

[a]See footnote to Table 10 for explanation of acronyms. [b]Local check is not included.

planted in the David and Alanja stations and commercial planting in Chiriqui Province.

A monitoring tour 2-16 Aug observed rice research status of national programs, performance of IRTP germplasm, and constraints on commercial plantings in Venezuela, Colombia, Ecuador, Panama, and Costa Rica.

IRTP IN LATIN AMERICA

IRTP work in 1984 focused on providing national programs with improved germplasm to overcome major constraints.

Table 14 shows the number of sets distributed in Latin America in 1983 and the number for which

Table 12. Use of 1984 IRTP nursery entries.[a]

Region or country	Used for			
	Hybridization	Yield testing		
		Local	State	National
East Asia				
China	99	15	3	1
Korea	14	–	–	–
Southeast Asia				
Thailand	62	55	22	42
Vietnam	–	38	–	3
South Asia				
Bangladesh	–	4	–	–
India	85	235	42	7
Nepal	5	19	–	–
Pakistan	12	59	–	–
West Asia and North Africa				
Egypt	8	–	–	16
Iran	5	2	–	–
Turkey	–	4	–	–
Latin America				
Colombia	–	–	4	252[b]
Europe				
Italy	1	–	–	–
Oceania				
Solomon Islands	9	17	–	–

[a]Based on data received as of 7 Feb 1985. [b]International testing in Latin America for 1985.

data were returned to IRTP. The yield nursery with medium duration varieties (VIRAL-T) was planted in 13 irrigated sites; 5 entries yielded 6.1 to 6.7 t/ha. In 11 favored upland sites of Central America, the top 5 entries yielded 4.7 to 5.2 t/ha and showed tolerance for neck blast, leaf scald, and brown spot.

The observational nursery (VIOAL) comprising 184 entries was planted in 25 locations: 10 irrigated, 13 favored upland, and 2 unfavored upland. Eight entries resisted leaf scald, 93 sheath blight, 30 brown spot, and 22 blast.

In the nursery for unfavored upland (VIOAL-SNF) in seven locations, several lines resisted blast but were susceptible to leaf scald or brown spot. In upland savanna (strongly acid soils, good rainfall) of ICA-La Libertad, Colombia, 10 entries yielded 3.1 to 4.5 t/ha.

The hoja blanca observational nursery (VIOAL-HB) of 87 entries was planted and evaluated in ICA-Nataima (Colombia), Araure (Venezuela), and Bagua (Peru). Five entries were tolerant of hoja blanca virus.

Table 13. IRTP 1984 entries frequently used in further yield testing in different countries.[a]

ADT36	IR29692-99-3-2-1
AD9246	IR29725-3-1-3-2
ARC10372	IR31805-20-1-3-3
AS19789	IR31834-77-3-1-2
AS688	IR31847-67-2-1-1-2
BG367-4	IR50
BG380-2	IR58
B2978B-SR-2-6-2-2-2	IR60
B3981C-PN-165-2-1	KAU1727
C1158-7	Mallika Sel.
C702015	NR10045-20-3-2
DR92	Palghar 31-1-3
HPU741	PDR76-D10-D8-D1
IR13240-82-2-3-2-3-1	P33-C-30 (HPU71)
IR13539-100-2-2-2-3	RAU4004-127-3
IR18348-36-3-3	RNR1446
IR19083-22-2-2	Si-pi 692033
IR19735-5-2-3-2-1	TKM9
IR21015-72-3-3-3-1	TOX475-NIB1-NK1-LS3-B1
IR21820-154-3-2-2-3	UPR103-80-1-2
IR22083-75-3-3-1-3	UPR231-28-1-2
IR25588-7-3-1	UPR231-28-1-2-TCA2
IR25670-15-2-3	Y. R. L.
IR25898-57-2-3	
IR25924-51-2-3	
IR25924-92-1-3	
IR27316-6-2-2	
IR28128-45-2	
IR29692-34-1-3-2-2	
IR129692-65-2-3	

[a]Based on data received as of 7 Feb 1985.

Table 14. Data returned from IRTP nurseries for Latin America distributed in 1983.

Nursery[a]	Entries (no.)	Number of sets	
		Seed dispatched	Data returned
Yield			
VIRAL-T	30	59	31
VIRAL-F	21	6	1
Observational			
VIOAL	234	52	24
VIOAL-SNF	62	28	12
VIOAL-HB	90	13	5
Climate and Soil			
VIOSAL	36	9	1
VITBAL	52	12	5
Total	525	179	79

[a]VIRAL-T = International Rice Yield Nursery-Medium Maturity, VIRAL-F = International Rice Yield Nursery-Semi-Deep Water, VIOAL = International Rice Observational Nursery, VIOAL-SNF = International Rice Observational Nursery-Unfavored Upland, VIOAL-HB = International Rice Observational Nursery-Hoja Blanca, VIOSAL = International Rice Salinity and Alkalinity Observational Nursery, VITBAL = International Rice Low Temperature Nursery.

Table 15. IRTP nurseries for Latin America distributed in 1984.

Nursery[a]	Sets (no.)	Entries (no.)	Origin of entries	
			CIAT	IRTP-IRRI
Yield				
VIRAL-T	45	24	22	2
VIRAL-F	6	21	–	21
Observational				
VIOAL	56	191	127	64
VIOAL-SNF	31	49	43	
VIOAL-HB	11	83	62	21
Climate and Soil				
VIOSAL	8	61	–	61
VITBAL	10	37	–	37
Total	167	466	217	249

[a]For explanation of acronyms, see footnote to Table 14.

In April and September, 167 sets of 7 IRTP nurseries were distributed to national programs of 24 countries (Table 15). This included 466 entries originating mostly from CIAT and the global IRTP nurseries.

From 525 germplasm entries distributed in 1983, cooperators selected 445 lines for further yield trials and 41 for hybridization in the rice program of Instituto Rio Grandense do Arroz, Brazil.

IRTP IN AFRICA

In 1984, 304 nurseries were dispatched to Africa for evaluation in 16 countries. Promising entries from the 1983 African trials appear in Table 16.

Table 16. Promising entries from 1983 IRTP trials in Africa.

Nursery		Promising entries
Irrigated		
Yield	– Very Early	UPR103-80-1-2, IR25924-51-2-3, IR25588-7-3-1
	– Early	BR161-2B-59, KAU1727, IR21015-80-3-3, IR36
	– Medium	ITA212, BG400-1, IR19672-140-2-3
Observational		IR29637-21-1-2, IR13525-43-2-3-1-3-2, IR25861-153-1, B3988E-PN-164-6 IR25916-42-3-3, M57B-146-1
Rainfed Upland		
Observational		
	– General	Sein Ta Lay, IRAT132, IRAT13, M55, P1274-6-8M, TOX502-1-SLR1, IR2053-436-1
	– Acid Upland	Azucena, IAC25, IR5440-1-1-3, IRAT104, IRAT112, ITA142, ITA235, Salumpikit
Rainfed lowland (shallow)		
Observational		Cisadane, IR10781-75-3-2-2, IR9217-58-2-2
Stress Screening		
Blast		IR4744-295-2-3, IR10028-26-2, IR25912-63-2-2, IR8098-41-3, ITA118, ITA175, ITA183, Milyang 55, Milyang 58, Milyang 61, Milyang 68, P1377-1-15M-4-1M-1, P1429-8-9M-2-1M-5, Ram Tulasi, Toride 1

Genetic evaluation and utilization (GEU) program

Integrated GEU program

Plant Breeding Department

IRRI RICES NAMED IN SIX COUNTRIES **156**
BREEDING OPERATIONS **156**
IRRIGATED RICE **156**
COLD-TOLERANT RICE **157**
UPLAND RICE **157**
- Upland rice breeding **157**
  - Yield trials at Santo Tomas, Batangas **158**
  - Yield trials at IRRI **158**
  - Performance in unfavorable environments **159**
- Crosses and studies of progenies **159**
- Varietal screening at IRRI **159**
- Varietal screening at Caliraya, Laguna **160**
- Screening results **160**

RAINFED LOWLAND RICE **160**
- Survey of rice breeders **160**
- Drought-tolerant breeding lines **161**
- Yield trial in medium-deep water **162**
- Thai-IRRI shuttle breeding project **162**

DEEP WATER RICE **163**
- Hybridization **163**
- Selection during F_2 **164**
- Pedigree lines **164**
- Field testing **167**
- Contacts abroad **167**
  - Thailand **169**

RICES FOR ADVERSE SOILS **169**
- Breeding objectives **169**
- Crossing **169**
- Selection **169**
- Pedigree selection **170**
- Field selection **170**
- Salinity screening technique **170**
- Element uptake under salinity **172**
- Reselection for salinity tolerance **173**
- Increasing salt tolerance **173**

IRRI RICES NAMED IN SIX COUNTRIES

In 1984, 6 national programs named 10 IRRI breeding lines as varieties. That brought the number of IRRI lines named as varieties to 137.

- IR13427-45-2, a short-duration variety with multiple resistance, including resistance to all known brown planthopper (BPH) biotypes, was released in Pondicherry and Tamil Nadu, India. Designated PY3, it also carries the popular name Bharathidasan.
- IR930-67-2-2, a high yielding line with excellent, long, slender grains, was released in Bihar, India, under the name Sita.
- IR2058-78-1-3-2-3 was released as IR46 in Indonesia. This line was released as IR46 in the Philippines in 1977, and has also been released in Brazil and Cameroon.
- IR13543-66 was given the name Kelara in Indonesia. It has very high yield potential and resists all known BPH biotypes.
- IR2053-261-2-3 was named DR83 in Pakistan and released for general cultivation in Sind Province. It has excellent grain quality and is suitable for late plantings.
- IR21836-90-3 was named Hmawbi 2 in Burma. It has excellent, long, slender grains and high yield potential.
- IR21841-91-2-3-3 was named Hmawbi 3 in Burma. It is a long-duration variety with excellent grain quality.
- IR8423-132-6-2-2 was released as CR203 in Vietnam. I is suitable for growing on the Red River Delta.
- IR19746-11-3-3 was recommended as CN2 in Vietnam. It very quickly matures and is suitable for intensive cropping systems in Vietnam.
- IR13525-43-2-3-1-3-2 was recommended as IR62 by the Philippine Seed Board. It matures in 115 to 120 d and has multiple resistance to major diseases and insects including all known BPH biotypes. It has excellent grain quality and high yield potential.

BREEDING OPERATIONS

We made 3,477 crosses in 1984, grew F_2 populations from 2,081 crosses, evaluated 145,339 pedigree nursery rows, tested 1,075 breeding lines in the replicated yield trials, and sent 115,373 seed packets of IRRI breeding lines abroad. Of the total, 45,705 seed packets filled 261 seed requests and 65,778 packets went through IRTP nurseries.

IRRIGATED RICE

Of 840 crosses for irrigated rice made in 1984, 494 were single crosses and 346 were multiple crosses. F_2 populations from 330 cross combinations were grown, and 67,185 pedigree nursery rows evaluated. A total of 840 advanced generation breeding lines were evaluated in replicated yield trials. From IRRI tests, Philippine Seed Board trials at 12 locations, and IRTP yield nurseries, several promising lines were identified.

- IR18348-36-3-3 matures quickly (112 d) and resists all major diseases and insects. It has long, slender, translucent grains with intermediate amylose content and intermediate gelatinization temperature. It outyielded IR36 by as much as 25% in Philippine Seed Board trials in 1983-84.
- IR28150-84-3-3-2 is very high yielding and matures in 130 d. It resists all known BPH biotypes and other major diseases and insects. It has long, slender, translucent grains with intermediate amylose content and intermediate gelatinization temperature. It has excellent tolerance for salinity and alkalinity.
- IR29723-143-3-2-1, a very high yielding, sturdy-stemmed selection, performed well in all coordinated trials. It matures in 135 d. It has long, slender, translucent grains with high amylose content and low gelatinization temperature. It resists most major diseases and insects.
- IR31868-64-2-3-3-3 matures in 105 d. It has excellent, long, slender grains with intermediate gelatinization temperature and intermediate amylose content. Milling recovery is excellent. It resists all major diseases and insects.
- IR32429-47-3-2-2 matures in 105 d. It resists all known BPH biotypes and other major diseases and insects. It has long, slender, translucent grains with intermediate amylose content and intermediate gelatinization temperature. Grain quality is highly acceptable.

Other promising lines from the irrigated rice breeding program are listed in Table 1.

Table 1. Some promising breeding lines with multiple attributes and suitable for irrigated lowland culture. IRRI, 1984.

Designation	Cross	Growth duration (d)	AC[a] (%)	GT[b]	Reaction[c] to							
					BI	BLB	RTV	GSV	GLH	BPH biotypes		
										1	2	3
IR18348-36-3-3	IR5657-33-2-1/ IR2061-465-1-5-5	112	23	I	4	1	3	1	3	1	5	1
IR21820-154-3-2-2	IR1529-680-3/IR4432-52-6-4//IR7963-30-2	130	23	I	6	1	3	1	3	1	1	7
IR25587-133-3-2-2-2	IR19657-37-3/IR54	125	26	L	7	1	3	1	3	1	1	1
IR28222-9-2-2-2-2	IR19660-73-4/IR1416-1-131-5//IR4570-74-2-2-3-3	125	27	L	1	1	3	1	3	1	1	7
IR29658-43-3-2-1	IR13471-71-2/IR13429-196-1	110	28	L	1	1	3	1	3	1	1	1
IR29723-88-2-3-3	IR19661-131-1-2/IR4570-124-3-2-2-2	130	27	L	7	1	3	1	3	1	1	1
IR29723-143-3-2-1	IR19661-131-1-2/IR4570-124-3-2-2-2	135	27	L	7	7	5	1	3	1	1	1
IR31802-48-2-2-2	IR13168-143-1/IR32140-10-1//IR9129-209-2-2-2-1	107	22	I	3	1	3	1	3	1	1	1
IR31851-63-1-2-3-2	IR17491-5-4-3-3/IR2415-90-4-3-2//IR9129-209-2-2-1	110	22	I	1	1	3	1	3	1	1	7
IR31868-64-2-3-3-3	KDM105/IR50//IR9129-209-2-2-2-1	105	22	I	1	1	3	1	3	1	1	7
IR32429-47-3-2-2	IR19058-143-2-3/IR9129-209-2-2-2-1	110	23	I	1	1	3	1	3	1	1	1

[a]Amylose content. [b]Gelatinization temperature. I = intermediate, L = low. [c]BI = blast, BLB = bacterial leaf blight, RTV = tungro, GSV = grassy stunt, GLH = green leafhopper, BPH = brown planthopper.

COLD-TOLERANT RICE

To develop improved germplasm for low temperature areas, 104 single crosses were made between cold-tolerant varieties and elite breeding lines. Banaue varieties were also used as parents in some crosses.

Field evaluation and selection continued at Banaue in collaboration with the Philippine Bureau of Plant Industry. In dry season (DS), 1,110 plant selections were produced from F_2 populations from 11 single and 9 multiple crosses. Selection criteria included early maturity, disease and insect resistance, seed fertility, plant type, good panicle exsertion, and moderately firm threshability.

From 167 cross combinations, 4,791 pedigree lines in the F_3-F_7 generations were evaluated. In wet season (WS), prolonged cloudy weather and heavy rainfall caused considerable spikelet sterility. Even so, about 2,400 plants with good spikelet fertility were selected. One hundred sixty-four varieties and lines selected mostly from the pedigree nursery were evaluated in the unreplicated observational yield nursery. Similarly, agronomic characteristics were evaluated in 175 varieties and lines of the International Rice Cold Tolerance Nursery and 295 advanced breeding lines of the observational yield nursery.

Several lines evaluated in replicated yield trials during DS (fertilizer rate of 80-30-30 kg NPK/ha) and WS (40-20-20 kg NPK/ha) continued to show promise compared with local check variety Pinidua (Table 2). Despite the bad weather conditions and tungro infection in WS, IR9202-5-2-2-2, IR8866-30-1-1-4-2, IR13155-60-3-1-3, and IR5716-18-1 yielded better than the local check.

UPLAND RICE

Upland rice breeding. In 1984, 131 single crosses and 222 topcrosses and double crosses were made to incorporate drought resistance into improved germplasm. Using an adapted improved variety such as C22, IR3839, and Sew Maew Jan, we made 45 backcrosses to recombine blast (Bl) resistance with drought tolerance and other desired characteristics. Crosses were produced for collaborators in national and regional centers, with 84 cross-combinations for Thai breeders.

Table 2. Grain yield and other characteristics of promising lines grown in replicated yield trials. Banaue, Ifugao, Philippines, 1984 DS & WS.

Variety or line	Dry season				Wet season				Reaction to		Amylose content (%)
	Yield (t/ha)	Days to flowering	Height (cm)	Sterility (%)	Yield (t/ha)	Days to flowering	Height (cm)	Sterility (%)	Bl[a]	BLB[b]	
IR9202-33-4-2-1	5.7	123	120	20					8	3	28
RPKn-2	5.6	122	144	22					6	3	27
IR9202-5-2-2-2	5.5	120	96	28	3.0	97	81	39	8	3	27
IR15579-135-3	5.5	121	117	11	0.9	103	84	39	8	5	26
IR13155-60-3-1-3	5.4	118	115	18	2.2	93	103	34	8	3	27
IR9758-K2	5.3	112	77	16					7	3	27
B2980b-Sr-2-1-1-1	5.3	120	93	11					8	3	28
IR13155-60-3-1-2-1	5.1	118	111	23					6	3	27
IR5716-18-1	5.0	127	92	32	3.0	107	80	37	7	3	28
IR8866-30-3-1-4-2	4.9	125	86	22	3.5	100	75	17	7	3	27
Pinidua (local check)	4.2	139	134	20	0.8	113	123	49	1	7	26

[a]Blast. [b]Bacterial leaf blight.

In WS, 333 F_2 bulk populations were grown at IRRI. Of those, 126 populations produced plants having most of the desirable traits. Of another 310 F_4 bulk populations grown, 210 showed plants having promising characters.

About 1,125 F_5, F_6, F_7 lines selected for deep and thick roots were grown under intermittent irrigation in DS. Of those, 3,067 lines which had shown promise in agronomic traits and field resistance to drought and diseases were grown in upland pedigree nurseries at Santo Tomas, Batangas, during WS. They were exposed to natural infections of leaf and glume Bl by planting spreader rows of TN1 between blocks. This identified 101 promising lines to evaluate in performance tests.

Two cycles of random crossing were made from a composite for population improvement, using a genetic male-sterile IR36. Seeds are available to collaborators for selection and testing outside the Philippines.

Field trial of 80 upland varieties and lines was continued at a farmer's field at Santo Tomas and on the IRRI upland farm to determine yield potential and stability and reaction to biotic and environmental stresses during WS. Two groups of entries received fertilizer at 60-30-30 kg NPK/ha.

Yield trials at Santo Tomas, Batangas. The crop received 1,693 mm rainfall from seeding to harvest, with abundant rains during reproductive stage. However, the crop experienced short stress periods at early vegetative stage. The major diseases were neck Bl and sheath blight (ShB) at later stage of growth. The average crop yield was 2.1 t/ha.

Among the breeding lines in Group A, IR6115-1-1-1 yielded 2.7 t/ha, followed by IR5931-113-1 and IR12979-24-3-4 at 2.6 t/ha. These yields were not significantly different from those of check varieties UPL Ri-7 and IR43. IR6115-1-1-1 matured in 137 d, and IR5931-113-1 and IR12979-24-3-4 in about 125 d. Check variety UPL Ri-7 yielded 3.3 t/ha and matured in 119 d. It had very slight ShB infection. The semidwarf IR43 yielded 2.7 t/ha and matured in 137 d. Check variety UPL Ri-5 yielded only 2.0 t/ha because of neck Bl and ShB infections.

Group B contained more promising lines. The highest yield of 2.8 t/ha was obtained from IR5420-1-1-2-3, IR10147-113-5-1-1-5, IR12979-24-1-8, and IR13754-5-2, all with at least one upland parent. These lines matured in 124 to 138 d. They resist or moderately resist neck Bl and ShB in the field. Check varieties UPL Ri-7 and IR43 both yielded 2.8 t/ha. The marked difference in yield of UPL Ri-7 in Groups A (3.3 t/ha) and B (2.8 t/ha) was due to difference in panicle number.

In both groups, yield was significantly and positively correlated with panicle number (0.436** and 0.341*).

Yield trials at IRRI. Frequent June rains delayed seeding at IRRI until 11 Jul. The crop went through a series of short stress periods at both vegetative and reproductive stages. Precipitation totaled 1,412.5 mm from seeding to harvest. The crops had shorter plants and matured earlier than in former years. Yields were 50% less (averaging 1.2 t/ha) than those in the farmer's field at Batangas.

The highest yield was 1.8 t/ha from IR13574-12-3, UPL Ri-7, and Polbarae/Maynapacha, an

introduced variety from Sri Lanka. TOX515-58-NK5-NIB and several IR lines yielded 1.7 t/ha. Both Polbarae/Maynapacha and TOX515-58-NK5-NIB, however, are susceptible to Bl and ShB, especially when grown in environments that favor those diseases.

Table 3 shows yields, agronomic traits, and field disease reactions of promising lines at both locations. These lines generally have field resistance to neck Bl, ShB, and to bacterial blight race PXO 61.

Performance in unfavorable environments. Trials were conducted at 2 upland Philippine sites low in soil fertility, and with contrasting pH values of 4.0 and 7.0. Several breeding lines with upland parentage, such as IR6023-10-1-1-1, IR13754-12-3, and IR26957-45-1, showed more vigorous growth and well-filled grains than many lowland lines and other land races. Only some traditional upland varieties such as Kinandang Patong, Dinorado, Brown Gora, and Sew Mae Jan grew well at the sites.

Crosses and studies of progenies. We made 338 crosses, using traditional cultivars, such as Azucena, Dinorado, Moroberekan, OS6; strictly upland improved varieties such as IRAT13, IRAT104, IAC25, IR43, ARC10372; and upland aus varieties such as N22 and Dular because they mature early and tiller well. Three *O. glaberrima* and 3 *O. breviligulata* rices were crossed with 25 *O. sativa* in 1984 DS, and the 2 outstanding *O. glaberrima* and *O. breviligulata* were crossed again with 6 different *O. sativa* rices in 1984 WS.

One hundred ninety-five F_1 were studied, 29 coming from IRAT crosses in Guadeloupe.

In DS, 29 F_2 populations were grown in unprotected plots with low input. Plant selections were derived from only seven populations; the rest were discarded because of severe ShB lesions and lateness.

In WS, 63 F_2 populations were grown. Twenty-eight were eliminated for susceptibility to diseases and pests. From the 35 most promising populations, 1,478 plant selections were obtained for F_3 evaluation. From the 469 plants selected in the 7 F_2 during DS, only one F_3 looks very promising. It derives from Moroberekan/Bansi and shows very high adaptability to difficult conditions and severe stresses.

Varietal screening at IRRI. In 1984 DS, 1,246 entries were evaluated for drought tolerance and phenotypic acceptability. Irrigation was maintained at a minimal 40-50 mm/wk, and N applied at 30 kg/ha to simulate low input common in upland

Table 3. Promising lines (Group B) with good yield potential and stability and their related agronomic traits in upland yield trials. Santo Tomas, Batangas, Philippines, and IRRI, 1984 WS.

Designation	Cross	Santo Tomas			IRRI			Mean yield (t/ha)	Field reaction		
		Yield (t/ha)	Maturity (d)	Plant ht (cm)	Yield (t/ha)	Maturity (d)	Plant ht (cm)		Neck Bl[a]	ShB[a]	BB[b]
IR5420-1-1-2-3	N22/IR1561-228-3-3	2.8	129	101	1.7	121	105	2.2	1	5	1
IR10004-1-1-2	IR1746-F_5B-24/IR2992-27//BPI-76*9/Dawn	2.5	133	122	1.7	123	116	2.1	3	3	1
IR10147-113-5-1-1-5	KN-1b-361-1-8-6/IR1750-F_5B-3//BPI-76*9/Dawn	2.8	133	115	1.3	124	108	2.0	3	5	5
IR12979-24-1-8	IR3179-25/K. Patong//IR26///IR879-314-2	2.8	124	115	1.4	121	112	2.1	3	3	1
IR13754-5-2	IR3880-10/IR2823-179-5-4	2.8	138	120	1.5	131	109	2.2	3	3	1
IR13754-6-4	IR3880-10/IR2823-179-5-4	2.7	138	116	1.7	131	107	2.2	1	3	1
IR13754-12-3	IR3880-10/IR2823-179-5-4	2.7	138	121	1.8	135	108	2.2	1	1	3
UPL Ri-5 (check)		2.2	135	118	1.2	129	113	1.7	3	3	5
UPL Ri-7 (check)		2.8	119	117	1.6	117	98	2.2	1	3	5
IR43 (check)		2.8	135	73	1.3	133	70	2.0	3	7	1
Kinandang Patong (check)		2.2	126	142	0.7	127	136	1.4	1	3	5

[a]Santo Tomas data. Bl = blast, ShB = sheath blight. [b]Bacterial blight. Inoculant was PXO 61.

rice regions. Weed control was practiced as often as necessary. To allow stem borer (SB) pressure, no insecticides were used. The entries were also evaluated for Bl resistance in nursery screening. From these evaluations, 483 entries were selected for further testing.

The 483 entries were evaluated in similar unprotected plots in WS. From them, 130 were retained as prospective parents and prepared for seed increase. The rest were discarded because of neck Bl, sheath rot (ShR), and susceptibility to SB. Screened similarly were 231 new accessions with 62 selected for further evaluation. The 483 entries and 43 accessions were evaluated in Bl nurseries.

As of end of 1984,

- 192 entries were promising for low cash input conditions, Bl, ShR, SB, and panicle discoloration tolerance; and
- 92 entries were promising for good and stable level of tolerance for Bl during 2 successive screenings.

Varietal screening at Caliraya, Laguna. An upland screening site at Caliraya, close to IRRI, was selected for its typical infertile upland conditions. The pH is 4, total CEC is 23 meq/100 g, and Al saturation is 75%. Total N is 0.2% and available P is less than 5 ppm.

The sowing of 345 entries from the 483 selected previously at IRRI during DS affirmed site suitability for identifying genotypes adapted to soils with low pH, low N and P, and high Al saturation. In WS, 192 entries were selected for promising behavior in those conditions.

Screening results. Of 353 entries selected for new evaluation in 1985 DS at IRRI, 92 are promising for Bl resistance, and 261 for associated characters.

Of the 261, 56 at both Caliraya and IRRI showed tolerance for glume discoloration, SB, and ShR (Table 4).

Six *O. glaberrima* — Papa Chef, Zakpale IV, CG 18, Casamance V2, C, and Zakpale Man — showed very high Bl resistance. They will preferably be used for further *O. sativa*/*O. glaberrima* crosses.

Research so far shows that Malanding Puti, Aus 197, Aus 198, Aus 257, Aus 454, and Kinandang Patong are promising for leaffolder tolerance; Secano Brasil, Mimaoasha, Dang Go E, India Dular, and Khao Tam show good seed set under difficult environments; and some Aus and Gora entries, such as Finjah and Kinandang Patong, are highly adapted to that environment.

Table 4. Best promising entries for upland infertile conditions. IRRI, 1984.

ARC13277	Lakhsnikajal
Aus 122	Lep Xang
Aus 197	Makouta
Aus 257	Malanding Puti
Aus 454	Manik Mundu
Balit	Mimaoasha
Berlin	Misarang Gitchak
Bico Branco	Moroberekan
Black Gora S. N. 106	Non-non (N)
Black Gora S. N. 107	Padi Babarau
BPI 9-33	Padi Tatakin
Chandarhat	Paikjata
Dang Go E	Rajbhog
DB 1	R 66
Dinorado	Saket 1
Filly	Saraya
Finjah	Secano Brazil
Iguape Cateto	Seka Kpobo
India Dular	Sereke
Jabahulo	Singbassi
Kele	Speed 70
KH. Dodeng A.	Taburse
Khao Kinon	Tangkilan Kapur
Khao Tam	VL 206
Kinandang Patong	62-441
Kogbagui A	62-448
KU91	257
	423
	483

RAINFED LOWLAND RICE

In collaboration with national programs, the breeding program on rainfed lowland rice continued improving drought and submergence tolerance of breeding lines. Drought-prone, submergence-prone, and medium-deep stagnant rainfed lowland situations were the main focus.

F_1 populations from 350 single crosses and 485 multiple crosses, and F_2 populations from 393 crosses were grown; and 33,253 pedigree rows were evaluated. Seventy-five advanced lines were tested in replicated yield trials and several hundred breeding lines evaluated in observation nurseries at rainfed Philippine sites.

Survey of rice breeders. Rice breeders in South and Southeast Asia working on rainfed lowland rice were surveyed to specify varietal constraints and rank breeding objectives. Table 5 shows the common stresses in rainfed lowland areas of Asia. Only 11% of the area surveyed did not have a score below 4 for all stresses (i.e. was not hurt by the stresses).

The breeding objectives are ranked in Figure 1. The leading objective is drought tolerance, also the most serious environmental stress. Phosphorus deficiency and salinity were most important soil problems. Disease and insect resistance and tolerance for drought and flood will be leading breeding objectives for rainfed lowland rice.

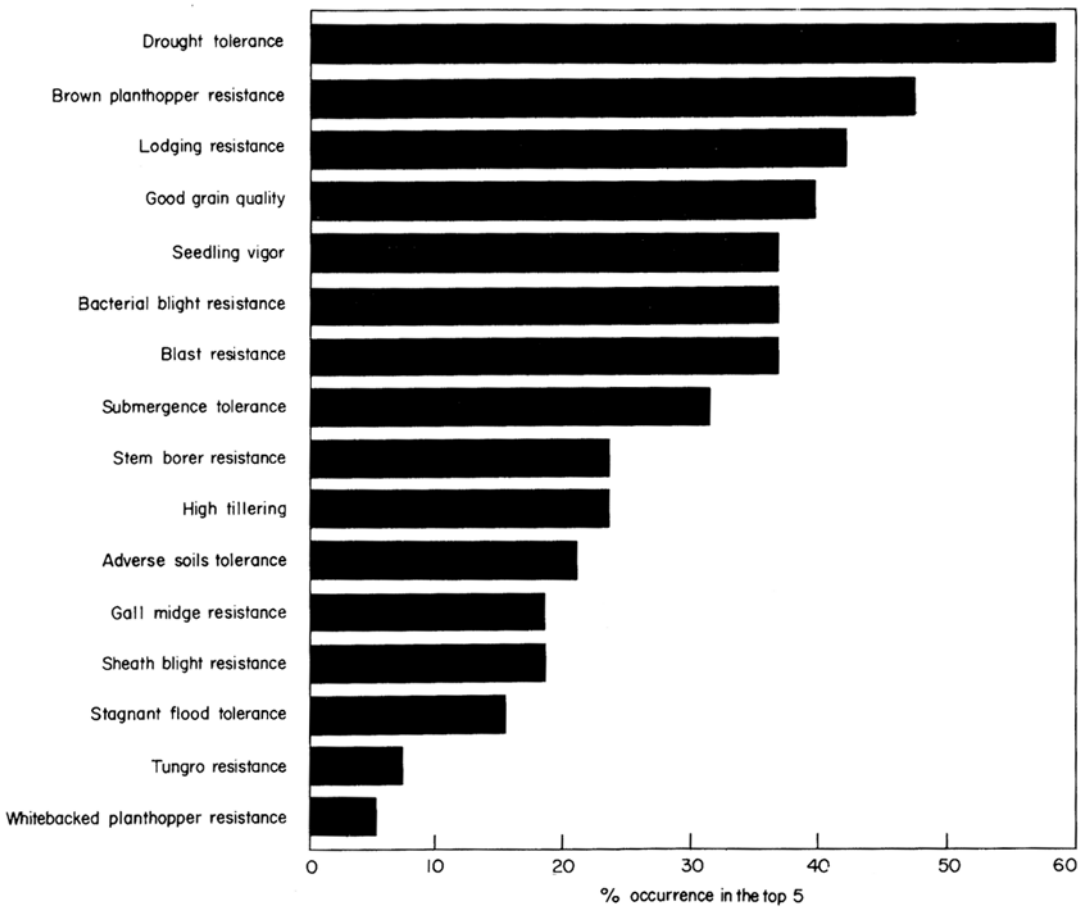
Drought-tolerant breeding lines. Drought is the major stress for rainfed lowland rice. Drought tolerance is not easily measured; therefore results from several types of tests are necessary to understand how different rices perform under drought stress.

Breeding lines from the rainfed lowland pedigree nursery are evaluated for drought tolerance in DS and WS tests at IRRI under direct seeded (upland) and transplanted (lowland) conditions. They are also tested at several Philippine drought-prone rainfed lowland sites during WS. Table 6 shows promising lines and their important traits. Most are medium duration with intermediate height. Some lines performing well in direct seeding did not do as

Table 5. Frequency of occurrence of 5 stresses in rainfed lowland areas of South and Southeast Asia.[a] 1984.

Stress	Percent of area of occurrence of each stress score[b]				
	1	2	3	4	5
Submergence	11	4	23	24	38
Drought (vegetative stage)	15	20	20	20	25
Drought (reproductive stage)	2	24	15	32	27
Stagnant flood	13	7	17	13	50
Delayed transplanting	34	8	18	24	16

[a]Total area considered is 33,779,000 ha. [b]1 = occurs regularly in most fields, 2 = occurs occasionally in most fields, 3 = occurs regularly in some fields, 4 = occurs occasionally in some fields, 5 = rarely occurs.



1. Breeding objectives listed by rice breeders in South and Southeast Asia for rainfed lowland rice improvement ranked by percent of occurrence in the 5 most important objectives, 1984.

Table 6. Rainfed lowland breeding lines showing drought tolerance in the Philippines, 1984.

Designation	Parentage	Maturity (d)	Height (cm)	Resistance[a] to					Amylose content (%)	Grain		Chalkiness	Drought tolerance[b]	
				BB	BPH			GLH		Length	Shape		I	II
					1	2	3							
IR21178-43-1-2-2-2	CR146-7055-225/IR2061-465-1-5//IR42	130	125	1	1	3	3	3	26	3	1	1	++	
IR21188-15-2-2-3-3-3-1-1	RP825-70-7-1/IR9710-192//IR52	130	110	1	1	2	2	2	25	5	5	0		++
IR21188-87-3-3-2-2	RP825-70-7-1/IR9710-122//IR52	150	120	1	1	1	1	3	25	5	3	1		+
IR24400-R-511-1-1	Sein Ta Lay/IR42//IR9264-324-1	130	160	1	5	5	5	3	26	3	1	1	++	+
IR28350-49-2-3-1-5	X69-2-27-2/S32C-46-1//IR42	120	110	1	1	3	1	6	26	3	1	0	++	
IR28878-R-R-27-3	Ratnagiri 9-5-3-2/BKN6986-108-2//IR42	125	150	9	3	3	7	7	25	5	5	0	++	
IR29341-85-3-1-3	IR52/IR46	130	110	1	1	3	9	3	27	3	1	5	+	+
IR30168-63-1-5-2	GH33/IR52	135	120	1	3	3	1	7	26	3	1	1		++
IR30213-7-2-2-3	IR52/IR13168-143-1	125	100	1	1	3	3	5	25	3	1	0		+
IR33353-64-1-2-1	IR52/IR36//IR52	125	110	5	1	1	3	3	26	3	1	1	+	+
IR33438-20-1-2-3	IR13419-35-1/IR19661-131-1-2//IET3257	140	110	1	1	1	5	5	25	5	5	1	+	

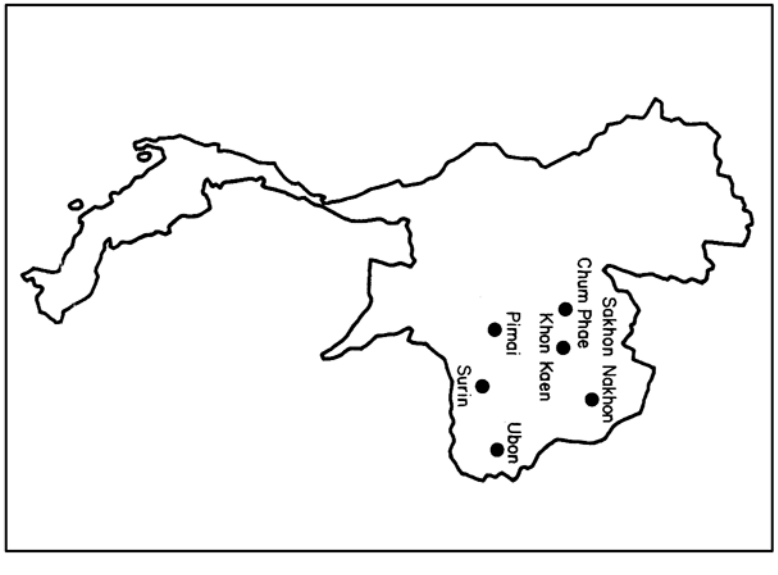
[a]BB = bacterial blight, BPH = brown planthopper, GLH = green leafhopper. [b]Observations are from trials by the Agronomy Department and the International Rice Germplasm Center under direct-seeded (I) and transplanted (II) conditions. + = good, ++ = excellent.

well when transplanted and vice versa. Good rainfed lowland varieties require tolerance in both conditions. The hybridization program is using such varieties to incorporate drought tolerance into varieties with superior agronomic traits and higher insect and disease resistance.

Yield trial in medium-deep water. In a replicated yield trial under medium-deep conditions, water was maintained at 25 to 40 cm from 3 wk after transplanting until harvest. The 75 entries were divided into three maturity groups. Table 7 shows the four highest yielding entries from each group.

The yields were low, ranging from 1.01 to 3.01 t/ha. Lodging was severe. Several high yielders also performed well in 1983.

Thai-IRRI shuttle breeding project. The Thai-IRRI Collaborative Breeding Project continued at the six research stations in Northeast Thailand (Fig. 2). Seventy-three F_2 populations and 4,527 F_4 lines harvested from F_3 plants at IRRI plus the F_3 lines



2. Six rice research stations in Northeast Thailand where pedigree nurseries for the Thai-IRRI Collaborative Breeding Project are grown under rainfed lowland conditions.

Table 7. Highest yielding breeding lines in the medium deep water replicated yield trial. IRRI, 1984.

Designation	Parentage	Height (cm)	Duration (d)	Yield (t/ha)
	Group I			
IR13149-71-3-2-3[a]	BG90-2/IR46//IR4417-177-1-4	131	130	2.86*
IR13149-43-2-P1	BG90-2/IR46//IR4417-177-1-4	130	132	2.75*
B4259-39-2-3	IR46/IR4422-98-3-6-1	132	135	2.65*
IR28384-21-2	B737KN-10-3-1/IR2797-105-2-2//IR42	137	130	2.65*
IR36 (check)		101	119	1.02
	Group II			
IR33209-22-1-1-1[a]	BG367-7/IR4744-295-2-3//IR11248-131-3-2-2	130	126	2.71
IR26916-13-1-1-2-1-1	Cheriviruppu/IR5657-33-2//IR42	124	123	2.70
IR19319-5-3-3-2-1	IR3372-44-1-2/IR4816-70-1//IR46	143	131	2.60
IR26760-76-2-1-2-3	Jaganath/IR2797-105-2-2-3//IR48	132	136	2.47
IR48 (check)		135	135	2.41
	Group III			
IR24705-11-3-2-3-3[a]	CSR1/IR52//IR5657-33-2	121	137	3.01*
IR13365-253-3-2	IR42/Mahsuri//IR42	133	133	2.65*
IR26760-27-1-3-2-1[a]	Jaganath/IR2797-105-2-2-3//IR48	133	141	2.61*
IR26702-204-2-2-1-1-3[a]	FR13A/IR48	124	136	2.50
IR42 (check)		118	133	1.76

[a] Among the four highest yielding lines per group in 1983.

Table 8. The most frequently[a] used parents in the crossing program for deep water rice, 1984.

Designation	No.	Attributes[b]
Baisbish	54	Floating rice, elongation ability, RTV resistance
BKNFR76026-3-2-1-2	41	Deep water rice, elongation ability, resistance to BPH and GLH
BKNFR76106-16-0-1	33	Shallow-water rice, submergence tolerance, short height
Chenab 64-117	79	Deep water rice, submergence tolerance, adaptation to Bihar
DWCT156-1	50	Deep water rice, elongation ability, semidwarf stature
HTAFR77022-14-157-6-1	117	Deep water rice, good intermediate plant type
HTAFR79130-1-2-1-2	34	Submergence-tolerant rice, good MV plant type
IR11141-6-1-4	81	Deep water rice, MV plant type, excellent elongation ability
IR11288-B-B-118-1	36	Floating rice, elongation ability, resistance to BPH
IR11288-B-B-65-8-3	75	Deep water rice, MV plant type, resistance to BPH and GLH
IR21037-2-1-2E-P3-6	36	Deep water rice, MV plant type, resistance to GLH
IR21567-9-2-2-2-1	46	MV type, submergence tolerant, resistant to BPH, GLH
IR26702-25-1	51	MV type with superior submergence tolerance
IR29012-4-1-3	56	Good MV plant type with submergence tolerance
IR31406-333	30	MV, with very good submergence tolerance
TCA177	56	Floating rice with adaptation to Bihar, very good elongation in fast rising water
TOX896	67	Upland rice, very stiff straw, and firm rooting

[a] In 30 or more crosses. [b] RTV = tungro, BPH = brown planthopper, GLH = green leafhopper, MV = modern variety.

harvested in 1983 by Thai breeders were grown.

Nursery conditions ranged from highly favorable at Pimai to highly unfavorable at Ubon. Severe prolonged floods destroyed all nurseries at Sakhon Nakhon station. Plant selections numbered 1,620 F_2 plants, 357 F_3 plants, and 387 F_4 plants. In DS, their progeny will be grown at IRRI for generation advance and screening.

DEEP WATER RICE

Hybridization. Of the 700 crosses made for deep water in 1984, 487 were for elongation ability and 213 for submergence tolerance. Crosses were almost equally divided between single and multiple crosses. Table 8 gives the most frequently used parents and their attributes.

Table 9. Most important donor varieties for deep water adaptation in F_2s selected in deep water at IRRI, 1984.

Designation	F_2s (no.) with good survival
Elongation	
RD19	19
IR11141-6-1-4	18
Baisbish	16
BKNFR76014-1-9-2	15
HTAFR77022-14-157-6-1	15
CN540	14
DWCT156-1	13
IR11288-B-B-118-1	11
IR11288-B-B-65-1	11
IR11288-B-B-69-1	7
HTA7406-111-0-0-2	4
BKNFR77004-5	3
Submergence	
IR26702-25-1	7
BKNFR76106-16-0-1	3

Selection during F_2. We subjected F_2 populations to flash floods or to slowly increasing water levels, depending on breeding objective and parents. Selection intensity was spectacular, with two-thirds of the F_2s completely destroyed after flash floods and half in the case of slowly rising water. Parents responsible for good performance of their descendant F_2s are listed in Table 9. Note that donors are now mostly improved plant types instead of traditional varieties.

Pedigree lines. We harvested hundreds of pedigree lines in bulk. Some 80 had outstanding combinations of elongation ability and other desirable traits (Table 10), and 70 excelled in submergence tolerance (Table 11). Those lines will be channeled to appropriate sites in the Philippines and abroad.

Table 10. Promising elongating pedigree lines for adaptation to deep water, IRRI, 1984.

Parentage and designation	SES score[a]											Comments
	HT	BB	BI	BPH			GLH	GrL	GrS	Clk	Sub	El	
				1	2	3							
BKN6987-92-2/Rayada #7													
BKNFR76045-85-1-1-1-1-2-1	135	1	5				3	3	1	1	1		
IR2070-414-3-9/LMN 111													
IR11185-R-R-R-419-1-1-3		1										3	
IR11185-R-R-R-440-3-1-2				9	9	9	9	3	1	5		3	
IR11185-R-R-R-440-3-1-3				9	9	9	9	3	1	1		3	
*Bhadoia 233/2*IR4422-51-1-1*													
IR18968-16-0-1-1-2-1	165	1					3	5	5	5		3	Red pericarp
BGD5-6-3PE-1/IR2071-586-5-6-3//IR4683-54-2													
IR21038-77-P2-5-2-3-1-1-1-1	120	1		1	1	1	3	3	3	1	6	7	
Chakia 59/IR44//IR42													
IR26662-196-2-1-1-3-3-2	133	1					7	5	5	1	1	3	
Joli Amon/BR116-313-19//IR48													
IR28333-10-2-3-1		7	9	1	1		7	5	5	5	9	5	
Beguamon 202/IR13426-19-2//IR9764-45-2-2													
IR33188-8-2-1-3-2-1-2	149	1	8	1			4	3	1	4	9	5	Heavy panicles
IR33188-8-2-1-3-2-1-3	153	1	7				4	3	1	2	9	5	Heavy panicles
IR33188-8-2-1-3-6-1-3	166	1	9	3			3	4	2	6	9	5	Heavy panicles
FRG2/IR13168-143-1//RD19													
IR33280-1-503-1-1-1-1-1	145	1		1			4	4	2	9	8	6	
IR11288-B-B-294/IR17494-32-3-1//IR42													
IR35710-5-1-1-3-21	86	1		4	2	3	3	3	2	1	5	9	
Chenab 64-117/IR7732-B-A96-3													
IR38685-7-2-3-3	103	1	9	3	1		6	5	5	7	5	5	Red pericarp
Mahsuri/IR11288-B-B-288-1													
IR38730-88-3-1-1							7	5	5	1	9	5	
IR38730-88-3-3-1							9	5	5	1	9	5	
RD19/IR50													
IR38784-137-2-1-3	89	1	5	3	5		3	3	1	0		5	
IR38784-137-2-1-5	99	1	6	3	3		3	3	1	0		5	
IR38784-137-2-3-5	87	1	6	3	3		4	3	1	0		5	
IR38784-137-2-3-6	96	1	6	3	3		4	3	1	1		5	

Continued on opposite page

Table 10 continued

Parentage and designation	SES score[a]										Comments
	HT	BB	BI	BPH			GLH	GrL	GrS	Clk	Sub	El	
				1	2	3							
IR38784-137-2-5-2	98	1	6	1	3		3	3	1	0		5	
IR38784-137-2-5-5	103	1	6	3	3		3	3	1	0		5	
IR38784-137-2-6-3	95	1	6	3	3		3	3	1	0		5	
IR38784-137-2-6-6	99	1	6	3	3		3	3	1	1		5	
IR38784-137-5-3-4	95	1	6	1	3		3	3	1	0		5	
IR38784-137-5-3-6	95	1	6	3	3		3	3	1	0		5	
RD19/IR7732-RGA-A96-1													
IR38787-26-2-1-2	99	1	5	1	9		3	3	1	0	9	5	
IR38787-26-2-2-1	101	1	5	1	9		3	3	1	1	9	5	
IR38787-26-2-2-3	92	1	1	1	3		3	3	1	0	9	5	
IR38787-26-6-1-1	91	1	4	1	3		5	3	1	0		5	
IR38787-26-6-1-3	97	1	3	1	5		3	3	1	0		5	
IR38787-26-6-4-2	93	1	4	1	3		3	3	1	1		5	
IR38787-26-6-6-1	92	1	4	3	3		3	3	1	0		5	
IR38787-26-6-6-3	93	1	1	3	7		5	3	1	1		5	
IR38787-27-2-3-1	156	1	0	1	3		5	3	1	5	9	5	
IR38787-27-2-3-2	140	1	1	1	3		5	3	1	5	9	5	

[a]HT = high temp, BB = bacterial blight, BI = blast, GrL = grain length, GrS = grain shape, Clk = chalkiness, Sub = submergence, El = elongation.

Table 11. Promising submergence-tolerant pedigree lines for adaptation to deep water. IRRI, 1984.

Parentage and designation	SES score[a]										Comments
	HT	BB	BI	BPH			GLH	GrL	GrS	Clk	Sub	El	
				1	2	3							
IR8234-OT-9-2/FRG2													
BKNFR80024-1-506-1-2-1-2-3	151	1	1				3	3	3	9	5		
FR13A/IR48//IR42													
IR26702-25-42-2-1-3-2-1	122	1		3			3	3	1	5	7		
IR26702-25-42-2-1-3-3-1	126	1		3			3	3	1	1	5		
IR26702-25-42-2-1-3-3-2	124	1					3	3	1	3	5		
IR26702-175-4-2-3-3-1-2	103	1		5			3	5	5	1	6		
IR26702-175-4-2-3-1-2-1	100	1		5			3	5	5	1	5		
IR26702-175-4-2-3-3-1-1	104	1		3			3	5	5	1	5		
FRG10/IR4219-35-3-3//IR42													
IR28832-37-3-1-1	116	1		3			5	5	5	1	7		
IR28832-37-3-1-2	111	1		7			5	5	5	1	7		
IR28832-37-3-1-3	104	1		3			7	5	5	0	7		
IR28832-37-3-2-2	107	1		5			5	5	5	1	7		
IR28832-37-3-4-1	108	1		3			7	5	5	0	5		
IR28832-37-3-4-2	107	1		3			7	5	5	5	5		
IR28832-37-3-4-3	109	1		3			5	5	5	5	5		
G. Heenati/IR2797-105-2-2-3//IR48													
IR28844-R-R-50-1-1-1-1		5		5			7	5	5	9	1		
G. Heenati/BKNBR1031-7-5-4//IR13419-113-1													
IR31086-12-1-3-1-3	169	1					3	5	5	5	1		
IR31086-12-1-3-3-1	159	1					3	5	5	5	1		
G. Heenati/IR4563-52-1-3-6//IR13292-5-3													
IR31142-14-1-1-3-1-1-2	83	7		7			3	5	5	5	4		
IR31142-14-1-1-3-1-1-3	93	7		9			3	5	5	1	4		
IR31142-14-1-1-3-1-1-4	84	7		3			3	5	5	5	4		
IR31142-14-1-1-3-1-1-5	89	7		3			3	5	5	5	4		

Continued on next page

Table 11 continued

Parentage and designation	SES score[a]											Comments
	HT	BB	BI	BPH			GLH	GrL	GrS	Clk	Sub	El	
				1	2	3							
IR31142-14-1-1-3-1-1-6	90	7					5	5	5	1	4		
IR31142-14-1-1-3-1-1-7	88	7		5			5	5	5	5	4		
IR31142-14-1-1-3-1-1-8	94	1		7			3	5	5	9	4		
IR31142-14-1-1-3-1-1-9	95	1		5			3	5	5	5	4		
IR31142-14-1-1-3-1-3-1	97	1		5			5	5	5	1	4		
IR31142-14-1-1-3-1-3-3	98	1		5			5	5	5	1	4		
IR31142-14-1-1-3-1-3-5	100	1		5			5	5	5	1	4		
Kurkaruppan/IR4422-98-3-6-1//IR13419-113-1													
IR31442-1-502-1-2-3-1	161	1					3	2	1	5	3		
IR4568-86-1-3-2/BKNFR76023//IR13415-9-3													
IR31176-141-2-1-1-3-1	78	1	4	3	9	9	3	1	1	3	5		
B3897C-8/G. Heenati//IR9765-45-2-2													
IR33167-1-501-1-2-3-2-2	148	1		9			5	5	5	9	4		
IR33167-1-501-1-2-3-2-5	145	1		7			5	5	5	9	3		
IR33167-1-501-1-2-3-2-6	134	1		7			5	5	5	9	3		
IR33167-6-2-3-1-3-1-3	164	1		3			4	3	1	2	4		
FR13A/IR9129-209-2-2-1//IR9224-117-2-3-3-2													
IR33277-1-507-1-1-2		1		5		3	3	5	5	5	1		
IR33277-1-507-1-1-3		1		5		3	3	5	5	5	1		
FRG2/IR48//IR9764-45-2-2													
IR33279-1-501-1-1-1-1-3	113	4		3			3	3	5	9	6		
FRG2/IR13168-143-1//IR11248-131-3-2-2													
IR33282-4-504-1-2-1-2-2	165	4		5			5	4	5	6	5		
IR33282-4-504-1-2-1-2-3	160	1					4	4	4	5	5		
IR33282-4-504-1-2-1-3-2	160	1					5	3	2	5	5		
FRG2/IR13426-19-2//IR9764-45-2-2													
IR33284-503-1-1-2-2-3	157	1		3			3	5	5	1	6		
IR33284-503-1-1-2-3-2	141	1		5			3	5	5	1	6		
IR33284-503-1-1-3-1-2	160	1		1			4	4	5	2	6		
IR33284-503-1-1-3-2-1	158	1		1			4	4	5	6	6		
IR33284-503-1-1-3-2-3	152	1		5			4	4	4	1	6		
IR33284-504-1-1-3-2-3	155	1					3	5	5	9	6		
IR33284-505-1-2-2-3-2	159	1		3			3	3	1	9	6		
IR8234-OT-9-2/BKNFR77004-5-3-4//IET5656/BKNFR77004-5-3-4													
IR38459-5-1-3-3		1	7	5			3	3	1	5	6		
IR38459-5-2-3-2		1	1				3	3	1	0	7		
Chenab 64-117/DWCT156-1													
IR38682-1-1-1-3	117	7		3			6	3	1	3	5		Red pericarp
IR38682-27-6-2-3	162	4		5			7	4	5	9	5		Red pericarp
Chenab 64-117/IR4744-295-2-3													
IR38683-19-1-3-3	108	1	4	3			7	5	5	9	6		Red pericarp
IR38683-35-2-9-10	98	1					5	5	5	1	1		
IR38683-35-2-9-12	98	1					6	5	5	1	1		
Chenab 64-117/DWCT156-1													
IR38682-1-1-1-3	117	7		3			6	3	1	3	5		Red pericarp
IR38682-27-6-2-3	162	4		5			7	4	5	9	5		Red pericarp
Chenab 64-117/IR15314-43-2-3-3													
IR38691-27-6-1-3	103	3	4	1	3		3	3	5	9	6		Red pericarp
IR38691-27-6-3-1	98	3	4	3	1		6	3	5	9	6		
IR38691-27-6-1-1	102	3	5	3	1		4	3	5	9	5		
IR38691-27-8-1-2	113	3	3	1	3		6	3	3	9	6		
Chenab 64-117/IR19661-131-1-3-1-3													
IR38692-33-3-3-4	153	4	5	3	5		5	4	3	5	8		
IR38692-33-3-3-6	131	4	5	3	1		6	4	4	7	7		
CR1009/IR48//CR1002/FR43B													
IR39536-5-2-3-2		7					3				1		
IR39536-5-2-3-3		7					3				1		

[a]For explanation of abbreviations, see footnote to Table 10.

Field testing. We obtained feedback from sites in the Philippines, Thailand, Vietnam, Indonesia (Kalimantan), and India (Bihar). The results (Table 12) largely corroborated previous results obtained at IRRI and other stations, including Huntra, Thailand. However, floods in Pusa, Bihar, habitually destroy lines developed at IRRI because they lack ability to survive a long-term flood after complete submergence, a trait which the local varieties possess. We have increased emphasis on this requirement for survival in sudden surges of water that subsequently linger, as in our use of TCA177 in the crossing program (Table 8).

Contacts abroad. We sent F_2 populations and breeding lines to programs in India (Bihar, West Bengal, Orissa), Bangladesh (Bangladesh Rice Research Institute), Thailand (Rice Research Institute [RRI]), Vietnam (Red River Delta, Mekong River Delta), Indonesia (Kalimantan), Mexico and

Table 12. Some of the best deep water rice lines in field tests outside IRRI, 1984.

Submergence tolerance	
BKNFR78022-44-506-1-1-2	Pili, Iloilo, Philippines
BKNFR80021-1-501-1-3-1-1	Pili, Iloilo, Philippines
BKNFR80021-1-501-1-3-2-1	Pili, Iloilo, Philippines
IR21037-2-1-2E-P2	Pili, Iloilo, Philippines
IR21567-9-2-2-2-1-3	Red River Delta, North Vietnam
IR21567-9-2-2-3	Red River Delta, North Vietnam
IR21567-R-16-2-2	Red River Delta, North Vietnam
IR21567-R-27-2-2	Red River Delta, North Vietnam
IR26702-175-4-2-3-2-2	Pili, Iloilo, Philippines
IR26702-25	Red River Delta, North Vietnam
IR26707-78-2-1-1	Red River Delta, North Vietnam
IR26708-2-2-3-1-P3	Solana, Northern Luzon, Philippines
IR26708-2-2-3-1-P5	Pili, Iloilo, Philippines
IR26708-2-2-3-1-P6	Pili, Iloilo, Philippines
IR26708-2-2-3-2-P1	Pili, Iloilo, Philippines
IR26708-2-2-P1	Pili, Iloilo, Philippines
IR26716-12-2-1	Pusa, Northern Bihar, India
IR26716-12-2-1-2-3-2	Pili, Iloilo, Philippines
IR26716-12-2-1-3	Red River Delta, North Vietnam
IR26716-12-3-3	Pusa, Northern Bihar, India
IR26717-139-2-17-2-P1	Solana, Northern Luzon, Philippines
IR26722-537-3-3-2-3-3	Pili, Iloilo, Philippines
IR31142-14-1-1	Solana, Northern Luzon, Philippines
IR31239-81-6-3-P5	Solana, Northern Luzon, Philippines
IR31429-13-2-2	Pusa, Northern Bihar, India
IR31449-7-5-3	Pusa, Northern Bihar, India
IR33188-8-2-1-2-2-2	Pili, Iloilo, Philippines
IR33284-4-509-1-1-1	Pili, Iloilo, Philippines
IR35644-12-6-2-1	Pili, Iloilo, Philippines
IR35644-16-P2	Solana, Northern Luzon, Philippines
IR35710-10-1-2-3	Pili, Iloilo, Philippines
IR4819-77-3-2	Solana, Northern Luzon, Philippines
IR7691-OT-4-2-2-1	Red River Delta, North Vietnam Pusa, Northern Bihar, India
IR8067-41-1E-P1	Pili, Iloilo, Philippines
IR8234-11T-4-2	Red River Delta, North Vietnam
IR8234-11T-4-2-0-5-1	Pili, Iloilo, Philippines
Deep water	
IR11141-6-1-4	Prachinburi, Central Plain, Thailand, South Buluh, South Kalimantan, Indonesia
IR11185-B-B-850-1	Prachinburi, Central Plain, Thailand
IR11185-R-R-R-88-2	Concepcion, Iloilo, Philippines, BRRI, Joydebpur, Bangladesh
IR21071-53-2-2-1E-P1	Concepcion, Iloilo, Philippines
IR23426-R-R-50-1-1	Red River Delta, North Vietnam
IR26662-29-3-2	Red River Delta, North Vietnam
IR28932-9-3-3	Concepcion, Iloilo, Philippines Huntra, Central Plain, Thailand
IR31338-30-2-1	Prachinburi, Central Plain, Thailand
IR31339-6-1-6	Prachinburi, Central Plain, Thailand
IR31340-7-2-3	Prachinburi, Central Plain, Thailand
IR7732-RGA-B-A96-1	Prachinburi, Central Plain, Thailand
Floating rice	
BKNFR76042-18-1-1	Hambuku, South Kalimantan, Indonesia
HTAFR77043-2	Hambuku, South Kalimantan, Indonesia
IR11288-B-B-118-1	South Buluh, South Kalimantan, Indonesia Hambuku, South Kalimantan, Indonesia Prachinburi, Central Plain, Thailand
IR4935-K103-0-2	Prachinburi, Central Plain, Thailand Hambuku, South Kalimantan, Indonesia
SPR7274-0-0-1	Hambuku, South Kalimantan, Indonesia
SPR7411-7-2-2	South Buluh, South Kalimantan, Indonesia Concepcion, Iloilo, Philippines

Table 13. Some soil problems and associated chemical stresses, IRRI, 1984.

Stress	Soil problems													
	Saline					Sodic	Acid sulfate			Peat			Aerobic	
	Arid		Acid	coastal										
		Sodic		pH <5	pH >7		Coast	Peat	Inland	Acid	Inland	Coast	Acid	Calcareous
Factors addressable by breeding														
EC >4 dS/m	√	√	√	√	√		√					√		
P deficiency	√	√	√	√		√	√	√	√	√	√	√	√	√
Acidity			√	√			√	√	√	√			√	
Deep water			√	√	√		√	√	√					
Hydrogen sulfide toxicity		√					√	√	√	√	√	√		
Fe toxicity			√	√			√	√		√				
Al toxicity			√				√		√				√	
Mn toxicity			√										√	
Fe deficiency		√				√							√	√
Zn deficiency	√	√			√	√				√	√			√
High pH		√			√	√								√
ESP >15		√			√	√								
B toxicity		√			√	√						√		
Organic toxicity				√				√		√	√	√		
Factors addressable by agronomy														
N deficiency	√	√				√		√	√	√	√		√	√
K deficiency								√	√	√	√			
Si deficiency								√		√				
Low base			√	√			√	√	√	√			√	

Table 14. Donor parents in crossing for adaptation to soil factors. IRRI, 1984.

Non-IRRI parent and descendants	Cross frequency	Tolerance for or resistance to[a]
N. Bokra		Sal, P
IR9884-54-3	31	Sal, Zn, BB, BPH 1, GLH
IR10198-66-2	17	Sal, Bl, BB, BPH 1
IR10205-25-1-2	3	Sal, Zn BB, BPH 1, 2
IR10205-37-1-3	5	Sal, Zn, BB,
SR26B		Sal, P
IR10206-29-2-1	19	Sal, BPH 1, 3, BB
Pokkali	5	Sal, Alk, Zn
IR4595-4-1-13	41	Sal, Alk, Zn, Drt 2, BB, WBPH
IR4630-22-2-17	21	Sal, Alk, Zn, P, Drt 2, BB, GLH
IR4630-22-2-5-1-3	51	Sal, Zn, GLH, BB, WBPH
Cheriviruppu	10	Sal, Zn, BPH 1, WBPH
IR26916-13-1-1	3	Sal, BPH 1, 2, BB, GLH
Others		
IR4432-52-6-4	12	Zn, BPH 1, 2, 3, BB, Bl
IR13419-113-1	48	Sal, Alk, Zn, P, BB, BPH 1, 2, 3, Yld
IR14632-22-3	30	Sal, Alk, Zn, BB, BPH 1, 2, 3, WBPH
Kuatik putih		Sal, Zn
IR31361-8-3-1-1	19	Sal, BPH 1, 2, 3, BB, GLH
Mahsuri	60	P
IR9764-45-2-2	35	Sal, Alk, Zn, P, BB, BPH 1, GLH
Patnai 23	5	P
Damodar	2	Sal, P
Kalarata 1-24	17	Sal, P, BB, GLH
Jhona 349	3	P, BPH 1, Bl
IET1444	5	Sal, Zn, P, Drt 2

[a] Abbreviations of traits are those of SES for rice traits.

West Africa (Mali). They answered requests specifying the type of deep water problem or the specific parent desired. With IRTP, we alerted recipients of deep water nurseries to F_2 populations with these IRTP entries for a parent, and filled subsequent requests.

Thailand. Our collaboration with Thailand's RRI continued, mainly in elongation screening of pedigree lines from IRRI, supply of breeding and crossing block materials, design of farmer field observation nurseries and yield trials, and seed multiplication of promising lines adapted to acidic soils.

RICES FOR ADVERSE SOILS

Breeding objectives. Soil problems and associated chemical stresses which breeding can at least partly resolve are shown in Table 13, along with problems more appropriately solved by soil amendments.

The key to successful breeding to resolve any soil problem is to consider tolerance for a combination of soil-related traits rather than for a single trait. For each soil type these can be read as the listed traits on top of each column (Table 13).

Based on problem soil prevalence and the feasibility of breeding for selected traits, we have concentrated on developing materials for saline soils and for potentially acid sulfate rice lands.

For compatibility with field testing needs, we used parent varieties adapted to specific saline areas, and arranged for farmer field testing of large numbers of breeding lines.

Crossing. Table 14 lists parents, frequency of use, and traits to explain their use. Using derived IR lines provides quicker gain in resistance to insects and diseases. A second crossing strategy is combining various IR lines having tolerance for soil factors into one cross combination. A third strategy is recombining modern variety (MV) salt-tolerant donors from IRRI with locally adapted, but susceptible MV types from interested countries. We made 26 such crosses with IR28, 6 crosses with IR1626-203 for Egypt and 44 crosses with IR6 for Pakistan.

Selection. Selection at IRRI centered on resistance to prevailing diseases and pests, supported by salinity tests. We planted 70 F_2s in salinized and alkalinized fields at IRRI. From 37 of the crosses, we harvested 1,382 plants from saline and 933 plants from alkaline fields. The F_2s for most selections (Table 15) clearly illustrate the strategy of

Table 15. Best-surviving F_2 populations in salinized fields at IRRI, 1984.

Parents and cross[a]	Possible traits (tolerance for or resistance to)
Pelita I-1/IR17525-114-2-1//IR21841-81-3-3-2 IR43513	Sal, P, BB, BPH 1, 2, 3, Alk, Grs
IR4595-4-1-13/IR37234-MS1//IR14632-22-3 IR43606	Sal, Alk, Zn, Drt, WBPH, BB, BPH 1, 2, 3
IR4630-22-2-17/IR37240-MS1//IR18348-36-3-3 IR43607	Sal, Alk, Zn, P, Drt, BB, GLH, BPH 1, 3, Grl, Grs
Cheriviruppu/IR10205-25-1-2 IR45571	Sal, Zn, BB, BPH 1, WBPH
CN540/IR9764-45-2-2 IR45619	Sal, Alk, Zn, P, BPH 1, GLH, BB, Elon, Sub
IR21313-36-2-2//IR9884-54-3/Pokkali IR46707	Sal, Zn, Alk, BB, BPH 1, 2, 3, GLH, Grs, Clk
IR21313-36-2-2//IR60/IR4432-52-6-4 IR46708	Zn, Bl, BB, BPH 1, 2, 3, GLH, Grs, Clk
IR21313-39-3-2//IR4630-22-2-17/IR13419-113-1 IR46709	Sal, Alk, Zn, P, Drt, BB, BPH 1, 2, 3, GLH, Grs, Clk, Yld
IR9764-45-2-2//IR9884-54-3/Pokkali IR46712	Sal, Alk, Zn, P, BB, BPH 1, GLH
IR4630-22-2-17/IR13419-113-1//IR9884-54-3/Pokkali IR46716	Sal, Alk, Zn, P, BB, BPH 1, GLH, Drt, Yld

[a] Donors for soil-related traits are underlined.

recombination among soil-factor-tolerant lines from distinct original-donor parentage.

Pedigree selection. We harvested hundreds of lines in bulk for further trial in problem-soil areas. The best lines are listed in Table 16.

Field selection. To identify lines with superior performance on saline and potentially acid sulfate soils, we cooperated with Philippine agencies in sending advanced lines to Iloilo, Philippines, and to various research stations for problem soils in Thailand. Table 17 lists the most promising lines from the 1,026 entries tested at 3 sites near Iloilo and the 68 entries tested at Ongkarak, Thailand. Noteworthy are lines performing well in both Thailand acid soils and in Philippine saline soils.

Salinity screening technique. For repeatable salinity screening in genetic experiments, a solution-culture procedure has been used: an equal mixture

Table 16. Promising pedigree lines for adaptation to one or more soil factors. IRRI, 1984.

Parentage and designation	SES score[a]														Comments
	HT	Sal	Alk	Zn	P	BB	Bl	BPH			GLH	GrL	GrS	Clk	Sub	
								1	2	3						
IR46/IR2061-522-6-9//IR4432-84-3-1																
IR15810-260-1-3-1-1-3	92			*b*				3	8	1	4	3	1	4		Good at Iloilo
IR2823-399-5-6/IR46//IR4417-177-1-4																
IR15865-430-3-1-3-1	89			*b*			6	1	3	3	3	5	3	0		
IR15865-430-3-1-3-3	86			*b*			6	1	3	3	3	5	3	0		
IR4219-35-3-3/IR46																
IR18189-1-1-2-1	125	3		*b*		1	8	2	3	3	5	3	1	1	9	
IR18189-1-1-2-3	127	3		*b*		1	8	2	5	3	4	3	1	1	9	
IR18189-1-1-3-1	130	3		*b*	5	1	8	1	7	3	4	3	1	5	9	Good at Iloilo
IR3372-44-1-2-1/IR4816-70-1//IR46																
IR19319-1-2-1-3	76			*b*	5		6	3	7	3	3	3	1	0		
IR19319-1-2-3-2	90			*b*	3			3	7	3	3	3	1	0		
IR19319-17-1-3-3	90			*b*	3			3	9	3	3	3	1	1		
IR19319-5-3-3-2-2	84			*b*	5			3	9	3	3	3	1	5		Good at Iloilo
CSR1/IR52//IR5657-33-2																
IR24705-116-2-3-1	87			*b*			6	6	1		3					R:BLS
Cheriviruppu/IR5657-33-2//IR42																
IR26916-13-2-1-2-1-1-3	107	3				1	4		3	1	3	5	5	0		
Goda Heenati/BKNBR1031-7-5-4//IR13419-113-1																
IR31086-4-2-1-1-1-1-3	145	5			2	1	8	2	1	5	3	3	3	5		
IR4568-86-1-3-2/BKNFR76023//IR13415-9-3																
IR31176-141-2-1-1-1-1	138	3			3	1	7	1			3	5	5	3		
Kuatik Putih/IR34//IR13419-113-1																
IR31363-1-1-3-3-1-1	87	3				1	6	3	8	7	3	5	3	1		
IR31363-1-1-3-3-2-1	82	4				1	8	3	9	7	3	5	4	0		
IR31363-1-1-3-3-2-3	91	3				1	8	3	6	7	4	5	4	0		
IR31363-1-1-3-3-3-2	85	4				1	8	3	5	7	3	5	3	1		
IR31363-9-2-3-1-2-1	148	4				1	7	1	2	2	4	5	5	1		
IR31363-9-2-3-1-2-2	110	3				1	6	3	9	3	3	3	4	0		
Pinangkara/IR46//IR13426-19-2																
IR31476-71-1-2-1-2-2	112	4				1	3	3	6	9	7	3	1	5		
T1242/X69-2-27-2//IR34																
IR31619-14-2-2-3-3	160	3				1	6	1	1	3	3	5	5	1		
B2797B-MR-24-1-5/IR19657-87-3//IR9764-45-2-2																
IR33158-17-1-1-1-3-3	135	3				1	8	2	3	3	5	5	5	7		
BR52-282-8/IR46//IR9764-45-2-2																
IR33238-47-1-2-1-1		3				1					3					Good at Iloilo
GH34/IR17494-32-3-1-1-3//IR13426-19-2																
IR33306-146-1-2-3-1-1	140	3				1	7	1	1	3	3	3	5	1		
IR33306-146-1-2-3-3-3	160	3				1	7	1	1	3	3	3	1	1		
IR11297-158-1-1/IR4744-295-2-3//IR54																
IR33417-36-3-3-3-1-3	100	3				1	5	1	1	5	3	3	1	5		

Continued on opposite page

Table 16 continued

Parentage and designation	SES score[a]													Comments
	HT	Sal	Alk	Zn	P	BB	Bl	BPH			GLH	GrL	GrS	Clk	Sub	
								1	2	3						
IR13419-35-1/IR50//IR9764-45-2-2																
IR33434-125-3-3-1-1-2	123	3				1	4	1	7	3	4	3	1	0		
*IR13419-113-1/2*IR54*																
IR33450-25-2-1-2-2-2-1	97	3				1	4	1	1	1	3	3	1	1		
IR33450-25-2-1-2-2-2-2	105	2				1	4	1	1	1	3	3	1	0		
IR33450-25-2-1-2-2-2-3	108	3				1	4	3	3	3	3	3	1	0		
IR13426-19-2/IR5853-213-6-1//IR2307-247-2-2-3																
IR33463-47-2-3-3-3-2	107	3				1	5	3	1	3	3	3	1	3		Good at Iloilo
IR33463-55-3-1-1-3-3	95	3				1	6		1		4	3	1	5		Good at Iloilo
IR13426-19-2/IR13168-143-1//IR9764-45-2-2																
IR33477-37-3-2-2-3-3		3				1	8	1	3	2	3	3	1	2		
IR15315-6-2-1/IR50//IR13365-353-3-2																
IR33495-52-1-3-6-3	125	3				1	0	1	1	1	3	3	1	2		
IR4215-301-2-2-6/BR51-91-6//IR13146-41-3																
IR33621-3-2-2-2-1-1	120	3				1	7	3	1	1	3	3	1	1		
IR33621-3-2-2-2-1-3	116	3				1	7	3	2	1	3	3	1	1		
IR52/IR13419-113-1//IR9129-209-2-2-2-1																
IR33628-23-2-1-2-1-3	119	3				1	8	2	1	1	4	5	5	1		
IR13419-35-1/IR50//IR48																
IR33638-4-2-1-2-1-1	123	3				1	6	1		3	3	4	5	0		
*Niaw SanPah Tawng *2/IR48*																
IR33658-1-6-1-2-1-2	106	3				1	4	3	5	5	5	3	1	1		
IR9764-45-2-2/CR1002//IR52																
IR35664-42-1-2-2-2	140	3				1	4	1	1	3	3	5	5	5		
IR35664-42-1-2-3-3	137	3				1	6	1	1	1	3	5	5	3		
IR9764-45-2-2/IET3257//IR42																
IR35665-104-1-2-2-1	120	3				1	4	1	2	5	3	5	5	0		
IR35665-104-1-2-2-2	121	3				1	5	2	1	3	3	5	5	0		
IR9764-45-2-2/IET3257//IR52																
IR35667-30-1-2-2-2	135	3				1	5	3	3	1	3	3	1	0		
Mahsuri/IR9274-B-B-50-2-3-1//IR9884-54-3																
IR35734-1-1-1-5-3	111	3				1	4	3	6	3	3	5	5	0		
Pankiraj 1170/IR13146-41-3//IR42																
IR35851-8-1-2-5-2	130	3				1	8	1	1	3	3	3	1	0		
IR35851-8-1-2-5-3	135	3				1	8	1	1	3	3	3	1	0		
IR36(MS)/IR4683-54-2																
IR37203-40-2-3-1	113	3				1	4	3	7	3	3	3	1	1		
IR36(MS)/IR9129-136-2-2-1-2																
IR37218-24-2-2-1	120	3				1	7	3	1	1	3	4	3	1		
IR4630-22-2-17/IR9884-54-3																
IR37255-12-1-2-2	105	3				1	4	3	3	7	5	5	5	3		
IR37255-20-2-2-1	100	3				1	4	1	3	7	3	6	5	4		
IR4630-22-2-17/IR10229-3-2																
IR37257-83-1 2-1	97	3				1		1	1		3	3	1	2		
IR37257-83-1-3-2	108	3				1	5	1	1		3	3	1	0		
*IR36(MS)*2/IR19362-174*																
IR38152-34-1-3-1	92	3				1	4	1	1		3	3	1	0		
Pokkali/IR19661-131-1-3-1-3																
IR38851-19-1-1	87	3				7					3	5	5	1		
IR38851-19-1-2	93	3				7					3	5	5	0		
IR38851-22-1-3	104	3				1					3	5	5	1		Good at Iloilo
IR38851-22-3-1	120	3				1					3	5	5	0		WBPH 1

[a] HT = high temp, Sal = salt injury, Alk = alkali injury, Zn = zinc deficiency, P = phosphorus deficiency, BB = bacterial blight, Bl = blast, BPH = brown planthopper, GLH = green leafhopper, GrL = grain length, GrS = grain shape, Clk = chalkiness, Sub = submergence. [b] Good in field observation.

Table 17. Advanced lines with good appearance in at least three problem soils sites in the Philippines and Thailand, 1984.

Line	Location and adverse soils[a]
GEU76043-0-2K-3-17-2	P1 CC A1
IR10232-17-2-1E-P1	P1 CC PTN
IR11141-6-1-4-1	CC P1 A2
IR13146-158-1	BP1 PTN ONG
IR13149-43-2-P1	A2 P1 PTN ONG
IR20992-7-2-2-2-2-3	P1 A1 KLG
IR21037-2-1-2E-P2	P2 A2 P1 KLG
IR21038-73-P3-8-2	A2 CC P1
IR23426-R-R-50-1-1	CC A1 KLG
IR26708-2-2-3-2-P1	P2 A1 KLG
IR26916-13-1-1-2-1	A1 CC PTN
IR31220-20-2-2-2	A2 CC PTN BP1
IR31238-446-2-3-5	CC P1 A1 BP1 PTN
IR33306-93-6-3-3-3	P1 A2 BP1
IR33360-36-3-1-2-3-2	P1 CC A1
IR33451-12-1-1-1	A1 CC P2 BP1
IR33461-13-3-1-1-2-1	CC P2 A1
IR33545-46-1-3-1-2-1	CC P2 A1
IR33552-12-1-2-1	A2 A1 P1
IR34337-2-4-1-2-1	CC P1 A2
IR35662-40-1-3-3	CC P1 A2
IR54	KAL BP2 PTN
IR8192-200-3-3-1-1-1E-P1	P1 P1 CC ONG PTN

[a] *Iloilo, Philippines*
A1 = Ajuy, saline
A2 = Ajuy, saline
CC = Concepcion, saline
P1 = Pili, saline
P2 = Pili, saline, acidic, flash flooding
Thailand
PTN = Pattani, saline peat
KAL = Kalasin, saline, sl acidic
BP1 = Bang Pakong-1, slightly saline & acidic
BP2 = Bang Pakong-2, very saline, very acidic
ONG = Ongkarak, very acidic
KLG = Klong Luang, acidic

of sodium- and calcium-chloride salinizes the standard nutrient solution to an EC of 12 dS/m. The temperature is 29/21° C and relative humidity is kept at 70%.

Calcium chloride prevents sodium toxicity and allows prolonged survival of salinity-tolerant types such as Nona Bokra. Six rice varieties with reputation for salt tolerance, and susceptible IR28 were grown in the medium to compare growth. Rating was done as follows:

<30% setback = resistant,
30-70% setback = moderately resistant,
>70% setback = susceptible.

Results are in Table 18. Although IR6 had poor survival, it rated among the best entries for growth traits in saline soil; therefore, hybridization with Nona Bokra might provide valuable recombinants.

Element uptake under salinity. To support future breeding activities, we assessed varietal reactions in uptake of major elements during salinization. Eight varieties were grown in salinized nutrient solution. Two varieties died. Contents of N, P, K, Ca, and Na for the other varieties were compared with those of the control at salinization of EC 10 and 12 dS/m, respectively.

Except for Na, concentrations of elements were always higher in shoots than in roots. K content declined with higher levels of salinity. Except for Na, concentrations of elements in the shoot did not change among varieties during salinization. Highly

Table 18. Resistance[a] of rice varieties to salinity by different criteria. IRRI, 1984.

Designation	Survival	Roots		Shoots		Leaves[c]	
		Length	Weight	Length	Weight[b]	No.	Symptom
Nona Bokra	R	R	R	R	R	R	R
Pokkali	MR	R	R	R	R	R	MR
Jhona 349	R	MR	MR	R	MR	R	MR
IR6	S	R	R	R	R	R	S
Damodar	S	MR	MR	MR	MR	R	S
IR4630-22-2-5	S	R	R	MR	R	R	S
IR9884-54-3	S	MR	S	MR	S	R	S
IR28	S	S	S	S	S	S	S

[a] R = resistant, MR = moderately resistant, S = susceptible. [b] Dry weight. [c] Resistance by leaf analysis used 2 criteria: number of affected leaves and visual symptoms.

tolerant Nona Bokra had least increase in Na concentration in shoots as salinization increased.

Reselection for salinity tolerance. Simulating growing conditions, we are reselecting for increased salinity tolerance in IR6, a leading rice variety in Pakistan. We used a salinized (EC 12 dS/m) nutrient solution for 6 wk, and continued salinity after transplanting into pots. We have found genetic variability for survival, for number of tillers, and for panicle weight and seed set.

Increasing salt tolerance. At the University of Sussex, England, 193 salt-tolerant varieties and lines from IRRI were analyzed for seedling performance in a salinized culture solution. Cheriviruppu, Nona Bokra, and IR4563-52-1-3-6 accumulated least Na. Some rices survived well even with high Na accumulation. Further research will seek to recombine sources of distinct salt tolerance mechanisms for higher levels of tolerance.

Control and management of rice pests

Diseases

Plant Pathology Department

VIRAL DISEASES **176**
- Virus epidemiology **176**
  - Virus disease survey in the Philippines **176**
  - Virus disease monitoring in Laguna **176**
  - Light trapping of rice virus vectors **177**
  - Detection of tungro-associated viruses in seedlings **177**
- Vector-virus interaction **177**
  - Multiplication of rice ragged stunt virus in brown planthopper **177**
  - Serological blocking of tungro-complex transmission **177**
- Etiology **179**
  - Etiology of orange leaf **179**
- Physiology and biochemistry **180**
  - RNA segments of ragged stunt virus **180**
  - Distribution of rice ragged stunt virus in infected TN1 plants **181**
  - Purification and serology of rice tungro spherical virus **181**

FUNGAL DISEASES **181**
- Cultivar mixtures for blast control **181**
  - On-farm trials **181**
  - Mixture response across a drought-stress gradient **182**
- Ecology of *Pyricularia oryzae* **182**
- Bacterization of rice plants for sheath blight control **182**

BACTERIAL DISEASES **184**
- Seed transmission of bacterial blight pathogen **184**
- Bacteriocin of bacterial leaf streak **186**

VIRAL DISEASES

Virus epidemiology. *Virus disease survey in the Philippines.* Tungro (RTV) broke out in several Philippine provinces in 1984. With assistance of the Ministry of Agriculture and Food, leaf samples were randomly collected and tested by latex to detect RTV-associated viruses.

The survey covered 169 fields in 52 municipalities of 21 provinces in 8 regions. IR36 and IR42 were commonly planted. Most plants were examined at early and late tillering stages. RTV was the prevalent virus disease, with high incidences in Isabela, Tarlac, Nueva Ecija, Antique, and Iloilo Provinces. Both RTBV (tungro bacilliform virus) and RTSV (tungro spherical virus) were detected in most leaves sampled in highly infected fields; however, RTSV appeared alone frequently, suggesting independent transmission (Table 1).

To confirm possible RTSV independence, leaf samples from healthy-looking plants from RTV-affected fields were also collected and tested by enzyme-linked immunosorbent assay (ELISA). Results showed most healthy-looking plants contained RTSV alone. RTSV is apparently distributed in the Philippines as an independent disease aside from RTSV + RTBV complex.

Virus disease monitoring in Laguna. We continued biweekly observation of rice virus diseases, green leafhopper (GLH) and brown planthopper (BPH) density, and other epidemiological information in 16 farmers' fields in Laguna. Insects were collected by sweep net and tested for infectivity in the greenhouse.

IR varieties were planted in 82% of the fields; IR42, IR36, and IR56 predominated. Adult RTV vectors were generally collected. More *Nephotettix nigropictus* were collected in seedbed than *N.*

Table 1. Incidence of RTV-associated viruses in Philippine areas, 1984.

Location and variety	Plants tested (no.)	Plants infected (%)			
		RTBV + RTSV	RTBV	RTSV	None
Los Baños, Laguna (IRRI)					
IR8[a]	80	4	0	5	91
IR36	60	83	12	5	0
IR36	100	71	1	12	16
Guimba, Nueva Ecija					
IR42	40	50	3	28	20
IR42	38	37	3	37	24
IR42	20	50	5	25	20
Capas, Tarlac					
IR36	40	40	3	20	38
IR36	20	50	0	50	0
Tagbilaran, Bohol[b]					
IR36	14	29	7	14	50
IR42	10	30	20	40	10
IR58	11	9	0	0	91
IR60	10	0	0	0	100
Cainte	10	50	0	50	0
Lubang Red	12	83	17	0	0
Gamu, Isabela					
Unknown	10	40	0	50	10
IR62	25	52	0	20	28
Tumauini, Isabela					
Unknown	28	58	21	7	14
Lagawe, Ifugao					
Native	21	86	9	0	5
Banaue, Ifugao					
Native	7	100	0	0	0
Native	19	16	21	10	53
Native	14	29	0	21	50
Native	11	18	9	0	73

[a] Infected mostly with grassy stunt virus and ragged stunt virus. [b] Leaf samples sent to IRRI for testing.

Table 2. Percentage of RTV vectors collected by sweep net at different rice stages in 16 farmers' fields, Laguna, Philippines, Mar 1983-Aug 1984.

Vector species	Insect stage	RTV vectors (%)				
		Seedbed	Early tillering	Late tillering	Ratoon	Idle field
Nephotettix virescens	Nymph	0	7	23	13	0
	Adult	30	38	44	39	0
N. nigropictus	Nymph	0	9	3	9	0
	Adult	60	40	37	31	100
Recilia dorsalis	Nymph	0	0	0	1	0
	Adult	10	6	4	7	0

virescens and *Recilia dorsalis*. The *Nephotettix* species prevailed during the tillering and ratoon stages (Table 2), but only *N. nigropictus* was collected in idle fields. Few GLH were obtained and RTV rarely appeared in study sites in 1984. BPH population, ragged stunt virus (RSV), and grassy stunt virus (GSV) incidence were very low throughout the year.

Light trapping of rice virus vectors. The weekly 2-h light trapping of rice virus vectors at IRRI farm continued. Vectors were tested for infectivity by 3-d serial transmission.

The number of trapped and infective insects fluctuated monthly, with low collection in December, January, and February. The percentage of infective RTV vectors was generally low, but was relatively high in wet season (Fig. 1). Few BPH were collected. RSV-infective BPH were obtained in dry season and wet season, but no GSV-infective insects were recorded.

Detection of tungro-associated viruses in seedlings. Nine- to 12-d-old TN1 seedlings were inoculated by 3-5 RTV-viruliferous GLH for 24 h. Individual seedlings were tested by ELISA 2, 4, 6, and 8 d after inoculation (DAI) to detect RTV-associated viruses. The virus was detected as early as 2 DAI. Most seedlings reacted to anti-RTBV immunoglobulin gamma (IgG) (Table 3). The proportion of plants infected with RTBV + RTSV increased tremendously from 39% (9:23) to 81% (47:58) from 2 to 8 DAI; then infection with RTBV alone declined. These results indicate RTBV is easier to detect than RTSV.

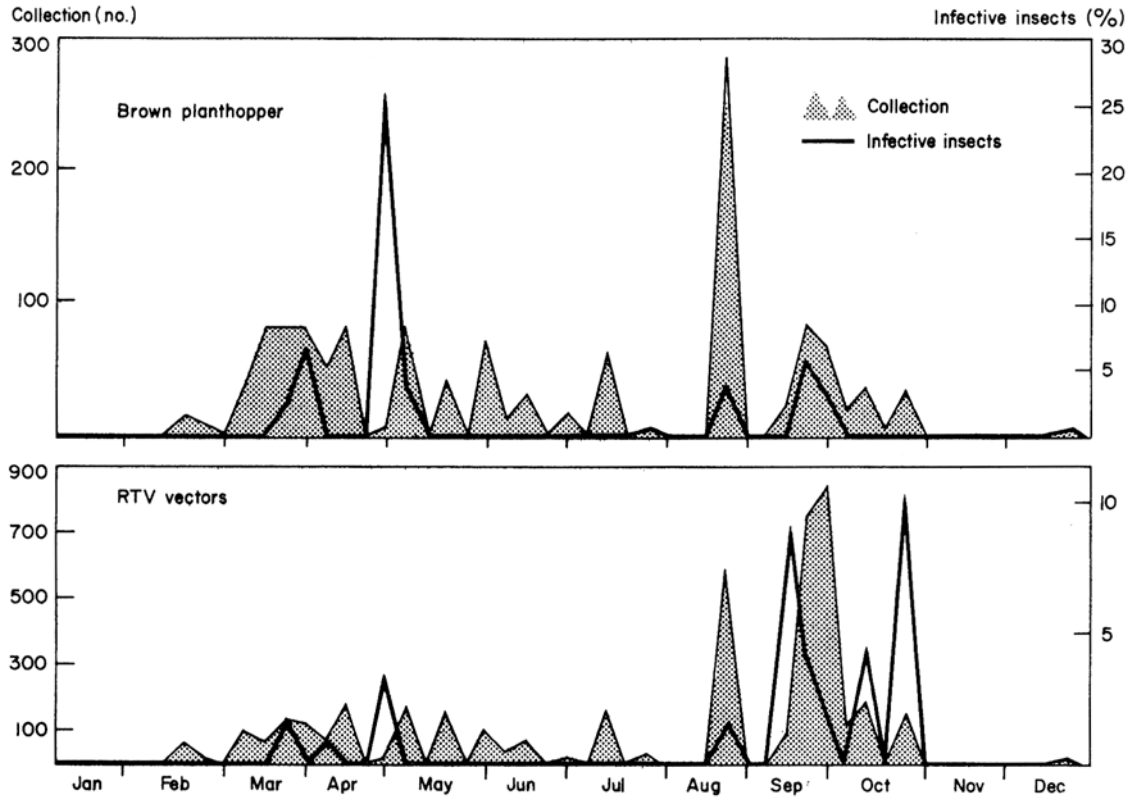
RTSV was detected up to 1/640 dilution and RTBV up to 1/1280. One RTV-infected seedling at 15-20 DAI was mixed with varying numbers of healthy seedlings and each batch processed for ELISA. The viruses were detected even when 1 infected seedling was mixed with 500 healthy seedlings (Fig. 2). Viruses can be efficiently detected in early stages when seedlings show no symptoms.

Vector-virus interaction. *Multiplication of rice ragged stunt virus in brown planthopper.* Virus-free BPH nymphs at 1st and 3d instar were allowed to feed separately on RSV-infected plants for 4 d and then transferred to healthy TN1 seedlings. Insects were collected every 2 d and were homogenized with 0.02 M phosphate buffered-saline (pH 6.5) containing 0.05% Tween plus 2% polyvinylpyrolidone at 0.05 ml/1st-instar insect and 0.1 ml/3d-instar insect. Extracts were directly tested in ELISA using polystyrene microtitre plate (immulon) for RSV antigen. Relative amount of RSV antigen was indicated as absorbance at 405 nm.

Significantly high RSV was detected in extracts soon after 4-d acquisition access. On the 2d day, however, RSV was not detected in 1st-instar nymphs and was low in 3d-instar nymphs (Fig. 3). RSV in the insect body increased up to 6 d and then declined.

Results show RSV acquired by BPH retains its antigenicity for 2 d; RSV multiplication starts 2 to 4 d after acquisition access.

Serological blocking of tungro-complex transmission. When the source is infected with RTBV and RTSV, GLH generally transmit both to susceptible varieties. Furthermore, GLH can transmit RTSV independently while RTBV depends on RTSV for transmission. GLH nymphs lose infectivity after molting. During acquisition feeding, RTBV and RTSV particles are adsorbed only to the mouth surface and can be neutralized by allowing



1. Weekly light trap collection of RTV vectors and BPH, and percentage of infective insects. IRRI, 1984.

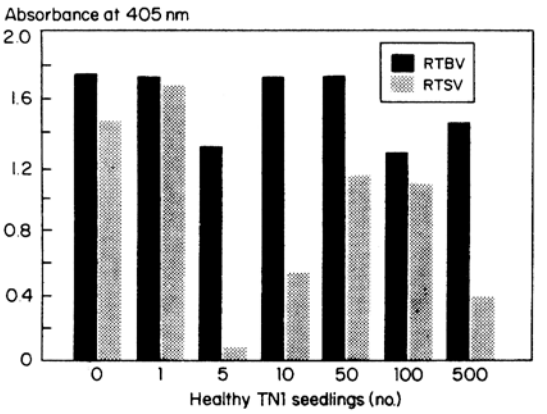
Table 3. Detection by ELISA of RTBV and RTSV in rice seedlings infected with RTBV+RTSV complex at various days after inoculation. IRRI, 1984.

Days after inoculation	Plants (no.) that reacted to IgG against			Plants (no.) with no reaction
	RTBV	RTSV	RTBV + RTSV	
Control	0	0	0	60
2	13	1	9	37
4	30	1	11	10
6	24	2	27	6
8	8	3	47	1

viruliferous GLH to feed on antiserum to either virus.

Twenty-five adult GLH, previously fed on TN1 plants infected with both RTSV and RTBV, were confined and fed on 0.5 ml of 0.01 M phosphate buffer (pH 7.4) containing 2% sucrose and different concentrations of IgG through a stretched parafilm membrane. After 8 or 16 h confinement, the insects were transferred to healthy TN1 seedlings in test tubes (1 insect/seedling) for 24 h inoculation access. One month after inoculation, RTSV or RTBV or both were detected in test plants serologically by latex test.

When viruliferous GLH were fed for 16 h on anti-RTBV IgG diluted 25 times, RTBV was neutralized and only RTSV was transmitted (Table 4). When viruliferous GLH were fed on anti-RTSV IgG diluted 10 to 50 times for 16 h, RTSV infectivity was greatly reduced. However, when RTBV was blocked, RTSV transmission was much lower than that in the control. Similarly, when RTSV was blocked, RTBV transmission was lower. Therefore blocking either virus reduces transmission of the unblocked virus. It suggests RTSV and RTBV have specific affinity once adsorbed in the GLH mouth. In contrast, viruliferous GLH that fed on normal IgG transmitted both viruses at a high rate. The study also showed that serological

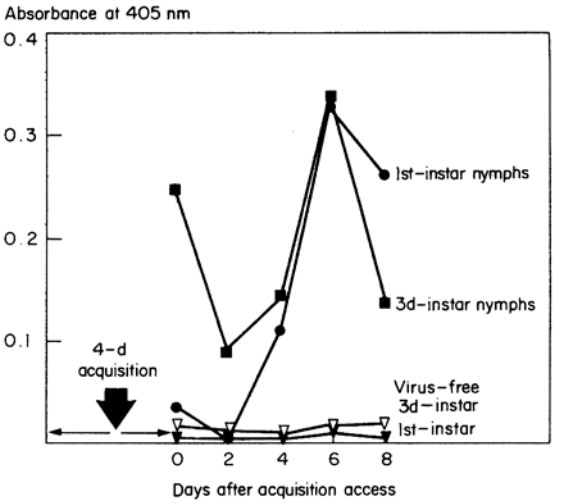


2. Detection by ELISA of RTBV and RTSV from mixed batches of one RTV-infected TN1 seedling with various numbers of healthy seedlings. IRRI, 1984.

blocking of RTBV + RTSV transmission by GLH through membrane feeding was an effective method for selectively transmitting either virus. This is significant for testing rice varieties for resistance to RTBV alone.

Another test examined whether neutralization of RTSV infectivity changes RTBV transmission. Adult GLH, previously fed on RTSV-infected TN1 plants for 3 d, were allowed to feed on anti-RTSV IgG. After 16 h feeding, half were used immediately to inoculate 7-d-old TN1 seedlings in test tubes. The other GLH were given 8-h acquisition access to RTBV-infected plants. When RTSV-carrying GLH were fed on anti-RTSV IgG for 16 h and then transferred to RTBV-infected TN1 plants for 8 h, RTBV was transmitted and infected plants contained RTBV alone. In contrast, GLH fed on normal IgG transmitted both viruses (Table 5). This feeding method seemed to be more effective in obtaining RTBV-carrying GLH. This experiment further showed that RTSV need not be infective to transmit RTBV, and RTSV itself may not be the helper component for RTBV transmission.

Etiology. *Etiology of orange leaf.* Rice plants showing orange leaf symtoms were collected at six



3. Relative amount of RSV antigen at various days after 4-d acquisition access. IRRI, 1984.

Table 4. Transmission of RTSV and RTBV by *N. virescens* that fed on different dilutions of RTSV and RTBV antiserum (IgG) at different durations. IRRI, 1984.

IgG	IgG dilution[a]	Feeding duration (h)	Leafhoppers (no.) that transmitted[b]				Leafhoppers tested (no.)
			RTBV	RTSV	RTSV + RTBV	None	
RTSV	10X	16	13	0	2	59	74
	25X	16	97	0	6	55	158
	50X	16	71	0	3	63	137
RTBV	25X	8	1	10	1	59	71
	50X	8	1	6	0	13	20
	25X	16	0	53	0	140	193
	50X	16	1	29	1	66	97
Normal IgG[c] (check)	10X	16	23	8	34	31	96
	25X	8	27	0	21	15	63
	25X	16	26	1	62	13	102
	50X	16	48	3	39	35	125

[a]Partially purified IgG diluted with 2% sucrose solution prepared in 0.01 M phosphate buffer (pH 7.4). [b]Detected by latex 1 mo after inoculation. [c]IgG partially purified from blood serum of healthy rabbit.

Table 5. Transmission of RTSV and RTBV by *N. virescens* given sequential feeding on RTSV-infected TN1 plant, RTSV antiserum (SIgG), or normal serum (NIgG), and RTBV-infected TN1 plant. IRRI, 1984.

IgG dilution[a]	Feeding sequence				Leafhoppers (no.) that transmitted[c]				Leafhoppers tested (no.)
	1st (3 d)	2d (16 h)	3d[b] (8 h)	Inoculation (24 h)	RTBV	RTSV	RTSV + RTBV	None	
25X	RTSV	SIgG	RTBV	TN1	18	0	0	2	20
50X	RTSV	SIgG	RTBV	TN1	11	6	0	3	20
25X	RTSV	SIgG	–	TN1	0	2	0	18	20
50X	RTSV	SIgG	–	TN1	0	5	0	15	20
10X	RTSV	NIgG[d]	RTBV	TN1	8	1	30	1	40
25X	RTSV	NIgG	RTBV	TN1	2	0	13	5	20
50X	RTSV	NIgG	RTBV	TN1	4	1	15	0	20

[a]Partially purified IgG diluted with 2% sucrose solution prepared in 0.01 M phosphate buffer (pH 7.4). [b]– = insects were transferred directly to TN1 for 24-h inoculation access. [c]Detected by latex 1 mo after inoculation. [d]Check: IgG partially purified from blood serum of healthy rabbit.

Table 6. Transmission of orange leaf by *Recilia dorsalis* from source plants collected at various Philippine locations, 1984.

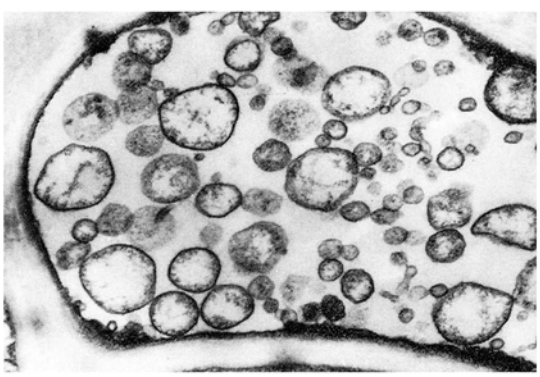
Location	Variety	Insects (no.)		Incubation period (d)		Retention in insects (d)
		Tested	Infective	Insect	Plant	
Los Baños, Laguna (IRRI field)	IR36	60	12	19-33	10-27	28-41
Calauan, Laguna	C-4	36	3	16-20	10-24	26-34
Santa Maria, Laguna	Unknown	80	15	15-25	18-24	25-34
Biñan, Laguna	Unknown	40	3	22-27	16-28	30-42
Santa Rosa, Laguna	Unknown	80	6	17-28	15-21	21-36
Guimba, Nueva Ecija	IR42	160	26	15-25	15-28	18-43

Philippine locations and tested for transmission by vectors and presence of disease agent.

Recilia dorsalis nymphs were given 2- and 4-d acquisition feeding on plants. Thirteen percent of the insects transmitted the disease agent with incubation of 15-33 d. The pathogen persisted in the vector. About 10% of the infective insects transmitted the disease continuously until death. Insects retained the disease from 18 to 43 d (Table 6).

The incubation period was 10-28 d. In addition to orange leaf symptoms, inoculated seedlings also had ragged and twisted leaves. Infected seedlings died 3-4 wk from symptom appearance.

Ultrathin sections of leaf tissue from infected plants were examined under the electron microscope. Mycoplasma-like organisms (MLO) were observed in sieve tubes. The MLO were bounded with a unit membrane and pleomorphic, 50-1100 nm in diameter (Fig. 4). This indicates that MLO causes orange leaf in the Philippines.



4. Mycoplasma-like organisms in sieve tube of orange leaf-infected rice leaf cell. 27,000X.

Physiology and biochemistry. *RNA segments of ragged stunt virus.* Studies were conducted in cooperation with the Institute for Plant Virus Research, Japan. RSV-infected rice plants were homogenized with phosphate buffer (pH 7.0) containing $MgCl_2$. RSV was purified from the homogenate by clarification with CCl_4, treatment with polyethylene glycol and Triton X-100, high speed

centrifugation, and sucrose gradient centrifugation with histidine buffer (pH 7.0) containing $MgCl_2$ used in the final step.

The purified virus particles were about 55 nm in diameter and highly infectious to rice seedlings inoculated by vector BPH. Ten double-stranded RNA segments with approximately equimolar amounts were found in purified RSV. Total molecular weight of RSV-RNA was estimated as 22.91 $\times 10^6$ with segments of 3.64, 3.55, 3.40, 3.38, 2.38, 1.76, 1.55, 1.52, 0.88, 0.85 $\times 10^6$ based on standards developed by Glinski et al (1982).

Distribution of rice ragged stunt virus in infected TN1 plants. The relative amount of RSV in various plant parts was determined by ELISA. Roots, leaf sheaths, and leaf blades of 30-d-old TN1 plants infected with RSV at seedling stage were separately homogenized in 4 volumes (wt/vol) phosphate buffered saline solution (pH 7.4). In another set of samples, the leaves and sheaths were numbered according to tiller number and leaf position from older to younger and were homogenized separately. The virus amount was indicated as absorbance at 405 nm in the micro-ELISA reader.

Virus antigen was detected more in sheaths than in roots and leaves (Table 7). Regardless of tiller number, the second and third sheaths exhibited higher mean absorbance value than other parts (Table 8). RSV was also detected in the youngest leaf and sheath which did not show symptoms. However, none was detected in the oldest leaves of some samples.

Purification and serology of rice tungro spherical virus. RTSV was purified following the procedure for rice waika virus (RWV) (Fig. 5). The purified virus had maximum absorbance at 259-260 nm and minimum at 239-240 nm, typical of nucleoprotein. The ratio of UV absorption at 260 nm and 280 nm (A 260/280) for the purified virus ranged from 1.52 to 1.74. Electron microscope examination of purified virus fraction negatively stained with 2% phosphotungstic acid showed isometric particles about 30 nm in diameter very similar to RWV (Fig. 6).

Rabbits were immunized with purified RTSV and antiserum obtained had titer 1:640 in ring interphase test and 1:160 in precipitin double gel-diffusion test. Antiserum to RTSV was compared to antiserum to RWV from Japan using the double gel-diffusion test. A single band was formed between RTSV and antiserum to RTSV and RWV. The reaction bands fused (Fig. 7). Hence, RTSV is not only morphologically similar but also serologically identical to RWV.

FUNGAL DISEASES

Cultivar mixtures for blast control. *On-farm trials.* Increasing genetic diversity within a crop stand is one approach to disease management. In a blast (Bl)-prone upland rice region in Zamboanga del Sur, upland varieties C22, UPLRi 3, and UPLRi 5 were evaluated in pure and mixed stands. The 5- $\times$ 5-m plots were sown to either a pure stand of 1 variety or an equal proportion of the 3 varieties randomly mixed before seeding. Two experiments were replicated across farmers' fields, one replication per field. In both experiments, leaf Bl was mild and panicle Bl more severe (Table 9). Leaf Bl in the mixed stand was less in the pure stands of C22, the most susceptible component, and equal to that in UPLRi 3 and UPLRi 5. Yield in experiment 1 did not differ significantly between treatments. In experiment 2, however, the yield of C22 was less than that of UPLRi 3 and UPLRi 5 (Table 9) and yields of mixed stands equaled those of best pure stands.

Table 7. Relative amount of RSV in root, sheath, and leaf blade of TN1 plants at 1 mo after inoculation, revealed as absorbance at 405 nm in ELISA.[a] IRRI, 1984.

Sample	Trial	Absorbance		
		Root	Sheath	Leaf
Infected	I[b]	0.395 ± 0.13[c]	0.485 ± 0.14	0.45 ± 0.07
	II[d]	0.645 ± 0.26	0.727 ± 0.6	0.45 ± 0.07
Healthy		0.075 ± 0.025	0.015 ± 0.005	0.026 ± 0.009

[a]Extract at 1/5 dilution was tested directly in ELISA. [b]Mean absorbance value from 4 infected plants. [c]Standard deviation at 5% level. [d]Mean absorbance value from 9 infected plants.

Table 8. Distribution of RSV in infected TN1 plants 1 mo after inoculation, revealed as absorbance at 405 nm in ELISA.[a] IRRI, 1984.

Sample	Samples (no.)	Absorbance	
		Range	Mean[b]
First tiller			
Root	9	0.35-1.29	0.65 ± 0.27
Sheath 1	9	0.13-1.30	0.65 ± 0.34
Sheath 2	9	0.12-1.19	0.76 ± 0.36
Sheath 3	8	0.52-1.10	0.78 ± 0.24
Sheath 4	7	0.50-1.05	0.73 ± 0.18
Sheath 5	3	0.30-0.91	0.62 ± 0.25
Leaf 1	8	0.08-0.52	0.32 ± 0.16
Leaf 2	8	0.15-0.97	0.41 ± 0.25
Leaf 3	8	0.31-1.14	0.56 ± 0.29
Leaf 4	6	0.17-0.88	0.51 ± 0.21
Leaf 5	3	0.38-0.72	0.59 ± 0.15
Youngest leaf and sheath	3	0.35-1.42	0.71 ± 0.50
Second tiller			
Sheath 1	7	0.40-0.88	0.63 ± 0.19
Sheath 2	7	0.34-1.47	0.63 ± 0.43
Sheath 3	5	0.32-0.91	0.62 ± 0.21
Sheath 4	3	0.39-0.50	0.43 ± 0.05
Leaf 1	7	0.06-0.75	0.37 ± 0.23
Leaf 2	7	0.14-0.48	0.34 ± 0.11
Leaf 3	5	0.32-0.83	0.52 ± 0.16
Leaf 4	3	0.33-0.45	0.40 ± 0.05

[a]Extract at 1/5 dilution was tested directly in ELISA. [b]Standard deviation at 5% level. Mean absorbance of healthy plant: root = 0.075 ± 0.25, sheath = 0.015 ± .005, leaf = 0.026 ± .009.

Mixture response across a drought-stress gradient. Bl disease development across a gradient of drought stress was studied in pure and mixed stands of C22, UPLRi 3, and IR10011-16-3. Four weeks after sowing, plants at the center of each 2- × 2-m subplot were inoculated and symptoms allowed to develop. Line source sprinkler irrigation was then applied thrice in 11 d. A gradient of leaf Bl developed in the susceptible variety C22 and in the mixture (Fig. 8). UPLRi 3 and IR10011-16-3 showed little disease. The disease gradient was not as pronounced for panicle Bl severity (Fig. 9), probably because it was read about 50 d after differential irrigation ended. The relatively low panicle Bl severity at the far end of the gradient was presumably related to low panicle density due to damage from drought and Bl.

Ecology of *Pyricularia oryzae*. Overseasoning by the Bl fungus in the tropics can be a critical part of its disease cycle, especially in rainfed rice. Alternative host species may permit survival of *P. oryzae*. In a host range study, two previously unreported hosts were found: *Brachiaria distachya* and *Rottboellia exaltata*. *Echinochloa colona*, *Leptochloa chinensis*, and *Leersia hexandra* were also susceptible to some *P. oryzae* isolates. Several other wild grass species were susceptible, but only to isolates originally taken from the same species.

Bacterization of rice plants for sheath blight control. Sclerotia are the primary source of inoculum for sheath blight (ShB) development. Bacteria reduced the viability of sclerotia collected from irrigated rice fields (Annual report for 1983). Two groups of bacteria — the fluorescent *Pseudomonas* and the nonfluorescent type — were isolated from *Rhizoctonia solani* sclerotia, ricefield floodwater, diseased and healthy rice plants, and rhizosphere of healthy and infected plants (Table 10). Many isolates inhibited mycelial growth of the pathogen. The inhibition zones formed ranged from 2 to 31 mm. At different concentrations — 103, 105, and 107 colony-forming units (CFU) — sclerotial viability was altered. At 105 CFU of nonfluorescent isolate In-b-17, sclerotia germination was reduced to 8.6% after 14 d.

A greenhouse study evaluated the effect of

Diseased leaves
Homogenized in 0.01 M EDTA (pH 8.0)
Filtered thru muslin cloth
Heated at 40°C, 60 min.
10,000 rpm, 15 min.

Supernatant
Add 7% PEG 6000 (W/V), 0.2 M NaCl,
1% Triton X-100. Stir 30 min.
10,000 rpm, 15 min.

Pellet
Suspended in 0.01 M EDTA (pH 8.0)
Add 20% CCl_4 (V/V), blended for 15 min.
10,000 rpm, 15 min.

Aqueous layer
Add 7% PEG 6000 (W/V), 0.2 NaCl
10,000 rpm, 15 min.

Pellet
Suspended in 0.01 M EDTA (pH 8.0)
10,000 rpm, 15 min.

Supernatant
40,000 rpm, 40 min.

Pellet
Suspended in 0.01 M EDTA (pH 8.0)
10,000 rpm, 15 min.

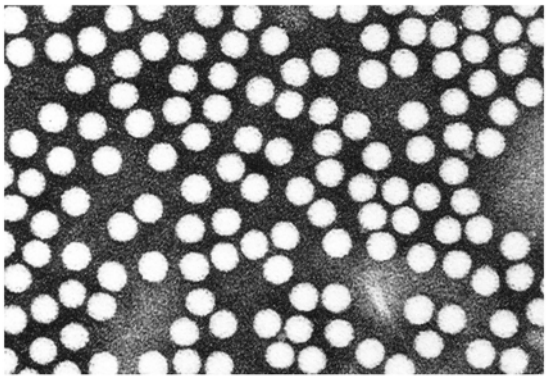
Supernatant
Layered in 10-50% sucrose density gradient
25,000 rpm, 180 min.

Virus zone
Diluted with 0.01 M EDTA (pH 8.0)
40,000 rpm, 40 min.

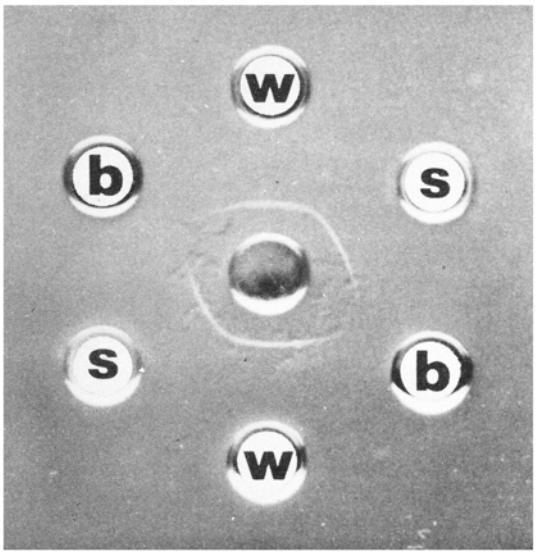
Pellet
Suspended in 1 ml 0.01 M phosphate buffer
(pH 7.4), 10,000 rpm, 10 min.

Virus suspension

5. Purification procedure for RTSV. IRRI, 1984.



6. Electron micrograph of purified RTSV negatively stained with 2% phosphotungstic acid (200,000X). IRRI, 1984.



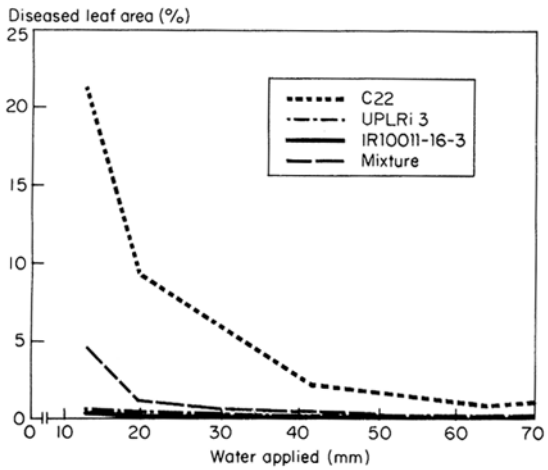
7. Agar gel diffusion test showing serological relation between RTSV and RWV: the center well contains purified RTSV and the outer wells contain antiserum to RWV (W), antiserum to RTSV (S), and phosphate buffer (b). IRRI, 1984.

Table 9. BI severity and yield of pure and mixed stands of 3 upland rice cultivars grown in farmers' fields in Zamboanga del Sur, Philippines,[a] 1984.

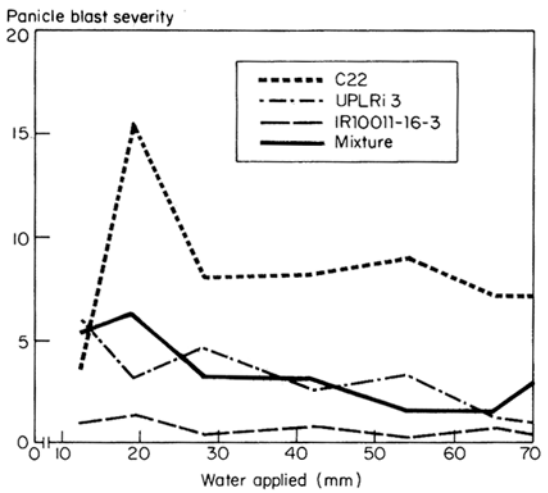
	Experiment 1			Experiment 2		
	Leaf BI[b]	Panicle BI[c]	Yield (t/ha)	Leaf BI	Panicle BI	Yield (t/ha)
C22	0.9	27.6 b	3.0 a	0.3	14.7 b	3.7 b
UPLRi 3	0	1.0 a	3.5 a	0.1	2.4 a	4.8 a
UPLRi 5	0	3.7 a	3.3 a	0	2.4 a	4.8 a
Mixture	0.2	8.0 a	3.9 a	0.1	2.6 a	4.3 ab

[a] One replication per field. Five replications for experiment 1 and 11 for experiment 2. [b] Mean percent diseased leaf area visually scored on the youngest 4 leaves of 20 plants per plot, 8 wk after seeding. [c] Ratings scaled 0-100 based on incidence and severity of infection on panicle base and branches of at least 100 panicles per plot. All tissues showing symptoms were incubated in a moist chamber to confirm *Pyricularia oryzae*.

bacterization on ShB development and on plant growth at two consecutive plantings. Bacteria-treated IR36 seeds were sown in *Rhizoctonia*-infested soil for the first crop, while untreated seeds were sown in the same soil at second planting. The bacteria reduced disease incidence and severity at two consecutive plantings (Fig. 10, Table 11) and promoted IR36 growth. The population of bacteria



8. Leaf Bl severity 64 d after sowing (DAS) in pure and mixed upland rice stands as affected by water applied from 41 to 55 DAS. IRRI, 1984.



9. Relative panicle Bl severity in pure and mixed upland rice stands as affected by water applied from 41 to 55 d after sowing, IRRI, 1984.

after each crop was higher in soil sown with bacteria-treated seeds (Table 11).

In other experiments, seed treated with bacteria were sown in pathogen-free soil to evaluate the effect on germination. Treated and untreated seeds did not differ in viability. Furthermore, bacteria growth on plant prints on agar media indicates they can establish on rice plants after seed treatment. The bacteria appear capable of moving from seeds to upper parts of plants, enhancing their efficiency as biocontrol agent.

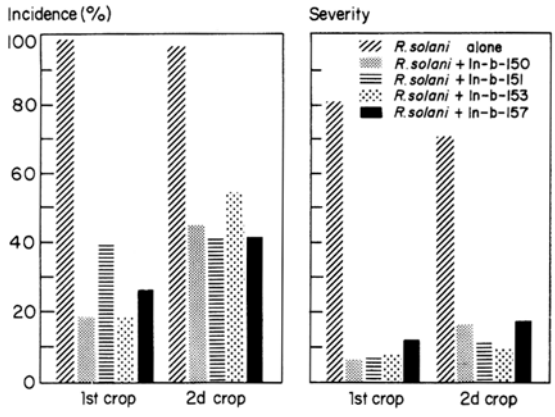
BACTERIAL DISEASES

Seed transmission of bacterial blight pathogen. Several methods of detecting *Xanthomonas campestris* pv. *oryzae* in rice seeds were evaluated. Two sets of IR36 plants were artificially infested with bacterial strain PXO 79 by injection at flowering stage. At maturity, the seeds were examined for the pathogen by three methods: direct isolation, phage-plaque count test, and growing-on method. Direct isolation involved seed washing, using water suspension of ground rice hulls and brown rice. Bacteria were also isolated from rice seeds on blotting paper. Phage-plaque count test involved adding a species-specific phage to crushed rice hulls or seed washing. A significant increase of phages expressed by plaque count indicates bacteria in the sample. In the growing-on test, disinfested rice seeds were sown either in sterile soil, moist blotting paper in petri dish, or nitrogen-enriched solution in beakers. Typical symptoms of BB were observed for 21 d and seedlings apparently infected were further examined by direct isolation and pathogenicity test.

X. c. pv. *oryzae* could not be detected from rice grain and parts of IR36 by injection method following the three detection methods (Table 12, 13). Instead, bacteria with yellow colonies were

Table 10. Source of bacteria isolated from rice plants, paddy water, and rhizosphere soil, inhibitory to the mycelium growth of *Rhizoctonia solani*, the rice sheath blight pathogen. IRRI, 1984.

Origin	Isolates		
	Total no.	No. with antagonistic activity	% of total
Rhizosphere			
Infected rice plant	93	29	31
Healthy rice plant	96	41	43
Sclerotia from			
Dryland rice field	97	30	31
Irrigated rice field	97	54	56
Rice plants			
Sheath blight-infected	103	47	46
Healthy	103	49	48
Paddy water	114	48	42



10. ShB incidence and severity in IR36 where seeds were treated prior to sowing in *Rhizoctonia solani*-infested soil. IRRI, 1984.

isolated from rice grain and seedlings of IR36 (Table 13). Two major groups were identified based on colony morphology from several seed lots. Group A colonies were similar to *X. c.* pv. *oryzae*, group B colonies were distinctly different. Frequency of isolation of group A ranged from 22.0 to 40.0%; that of group B ranged from 32.0 to 65.0% in all seed lots. Results on bacteriological tests, phage sensitivity, and pathogenicity tests indicated some yellow colonies were not *X. c.* pv. *oryzae* but were comparable to *Erwinia herbicola* (Table 14). The yellow colonies will be further characterized.

We tried detecting the bacteria from different parts of the rice panicle to trace them from the visibly infected portion to healthy tissues (Table 15). Further tests of bacteria with yellow colonies

Table 11. Influence of saprophytic bacteria applied to seeds of IR36 on incidence and severity of ShB, on plant growth, and the bacterial count at 2 consecutive plantings[a] in ShB-infested soil. IRRI, 1984.

Bacterial isolate	Incidence (%)		Lesion length (cm)		Plant height (cm)		Bacteria[b] (CFU/g oven-dry soil)	
	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop
Fluorescent								
In-b-4	81	56	5	5	30	30	4×10^9	2×10^7
In-b-22	86	42	3	2	45	43	4×10^9	5×10^7
In-b-23	89	38	4	3	39	38	4×10^9	6×10^8
Nonfluorescent								
In-b-17	60	28	2	1	40	45	5×10^9	5×10^8
In-b-9	81	56	4	2	44	42	4×10^9	4×10^7
In-b-3	86	56	4	3	48	49	5×10^9	5×10^4
Without bacteria	96	96	10	9	28	28	6×10^7	1×10^6

[a]Seeds of second planting not treated with bacteria. [b]Bacterial count on protein-sucrose agar medium.

Table 12. Detection of bacteria from rice grains of IR36 infected by injection method at the uppermost internode during panicle exsertion. IRRI, 1984.

Seed lot	Grains observed (no.)	Rice grain and parts	Bacteria with yellow colonies		Pathogenicity test
			Direct isolation	Phage test[a]	
1	200	Hull	+	–	–
2	500	Whole grain-washing	+	–	–
3	67	Whole grain - bacterial ooze[b]	+	–	–
4	31	Whole grain - bacterial ooze[c]	+	–	–
5	2,800	Hull	+	–	–
		Brown rice	+	–	–
6	8,200	Hull	+	–	–
		Brown rice	+	–	–

[a]Phage test was specific to *X. campestris* pv. *oryzae*. [b]1,500 seeds observed. [c]2,250 seeds observed.

Table 13. Detection by growing-on test of bacteria obtained by injection method from IR36 grains. IRRI, 1984.

Treatment	Seedlings sown (no.)	Abnormal seedlings (no.)	Direct isolation	Pathogenicity test
100 ppm N	2,500	23	+	–
Blotting paper in plates	4,644	117	+	–
Sterile soil	10,200	22	+	–

Table 14. Characterization of bacteria with yellow colonies from rice grains and panicle branches.[a] IRRI, 1984.

Source of bacteria	Grain reaction	Flagella (no.)	Phage sensitivity		Pathogenicity	
			P_{BB}	P_{BLS}	BB	BLS
Yellow colonies[b] from rice seeds						
Group A	–	1	–	–	–	–
Group B	–	3-4	–	–	–	–
Yellow colonies from panicle branches	–	1	+	–	+	–
X. campestris pv. *oryzae* (check)	–	1	+	–	+	–
X. campestris pv. *oryzicola* (check)	–	1	–	+	–	+
Erwinia herbicola (check)	–	3-5	–	–	–	–

[a] BB = bacterial blight, BLS = bacterial leaf streak. [b] Group A - colonies similar to *X. c.* pv. *oryzae*. Group B - colonies distinctly different from *X. c.* pv. *oryzae*.

Table 15. Detection of *X. campestris* pv. *oryzae* from different parts of the panicle of IR36 plants infected by injection method. IRRI, 1984.

Part of panicle	Direct isolation	Phage test[a]	Pathogenicity to rice
	Trial 1		
Panicle axis	+	NT	+
Primary branch	+	NT	+
Secondary branch	–	NT	–
Pedicel	–	NT	–
Grain	–	NT	–
	Trial 2		
Panicle branches	+	+	+
Grain	–	–	–

[a] NT = not tested.

isolated from panicle branches reveal they were *X. c.* pv. *oryzae* (Table 14).

Bacteriocin of bacterial leaf streak. Bacteriocins are highly specific proteinaceous antibacterial substances produced by many bacterial species. They differ principally from bacteriophage in that they cannot reproduce in host bacterial cells. A good criterion for specific bacteriocin production is whether the producing bacterium is insensitive to generally effective concentrations of its own bacteriocins. The producer is rarely sensitive to its own bacteriocin, but strains of the same species are.

X. c. pv. *oryzicola*, the causal organism of bacterial leaf streak (BLS) of rice, produced a bacteriocin in both solid and liquid media. Thirty-nine of the 126 isolates tested produced bacteriocin as evidenced by inhibition zones formed on double-layered agar plates. Only two typings were identified. The optimum temperature for bacteriocin production was 20-24° C. The bacteriocin was thermolabile. Trypsin and protease destroyed the

Table 16. Influence of bacteriocins on bacterial leaf streak (caused by *X. c.* pv. *oryzicola*) development. IRRI, 1984.

Dilution of bacteriocin[a]	Disease scale[b]		Control level (%)	
	IR50	IR20	IR50	IR20
1:5	0.309**	0.400**	88.68	86.20
1:10	0.404**	0.397**	85.20	86.31
1:20	1.223*	1.613*	55.20	44.37
Control	2.730	2.900	–	–

[a] Purified 1:5 bacteriocins:buffer. [b] Mean of 3 replications. Observation obtained by fixing 50 leaves for each replication.

bacteriocin activity, but both DNase and RNase had no effect, suggesting its protein nature. No correlation was found between bacteriocin production and virulence to rice plants.

A bacteriocin technique was developed to test biological activity of the whole cells. It was more sensitive in detecting cells of *X. c.* pv. *oryzicola* in leaf tissue than in paddy or seeds. The purified bacteriocin is more effective in reducing BLS development, but it is more efficient to use whole cells of weakly virulent bacteriocin-producing strains (Table 16).

Control and management of rice pests

Insects

Entomology Department

ECOLOGY AND BIOLOGY **190**
- Leaffolder food web **190**
- Green leafhopper feeding on tungro-infected rice **190**

DAMAGE ASSESSMENT **190**
- Sequential sampling **190**
- New predator-pest sampler **190**
- Yield loss by rice whorl maggot, stem borer, rice tungro virus, and black bug **192**

INTEGRATED PEST MANAGEMENT **194**
- Training farmers **194**
- Farmer's surveillance methods **195**

CULTURAL CONTROL **195**
- Effect of a weedy fallow on hoppers **195**
- Arthropod abundance by crop establishment method and flooding duration **197**

BIOLOGICAL CONTROL **198**
- Parasites **198**
  - Yellow stem borer **198**
  - Leaffolders **199**
  - Black bug **199**
- Predators **200**
- Fungal pathogens **200**

BOTANICAL CONTROL **202**
- Neem oil **202**
  - GLH feeding on neem-oil treated plants **202**
  - Neem oil odor as green leafhopper deterrent **203**
  - Neem oil effect on brown planthopper survival and grassy stunt-ragged stunt transmission **203**
  - Neem oil disruption of brown planthopper mating **204**
  - Effect of neem cake-treated soil on tungro virus in seedlings **204**
- Chinaberry seed oil against common insect pests **205**
- Karanja oil against common insect pests **205**

CHEMICAL CONTROL **206**
- Laboratory evaluation **206**
  - Contact toxicity **206**
  - Foliar spray **206**
  - Insecticide-calcium peroxide seed treatment **207**
- Field evaluation **207**
  - Foliar spray **207**
  - Granules **208**
  - Seed treatment **208**
  - Black bug in Palawan **209**
  - Pipe duster **210**
  - Control of vegetative stage insects **210**
- Insectistatics **211**
- Carbofuran effectiveness at different pH values **211**
- Susceptibility of brown planthopper, green leafhopper, and rice bug to insecticides **212**
  - LD_{50} values by topical application **212**
  - Foliar spray and contact toxicity **212**
- Granule effect on natural enemies **214**
- Rice tungro virus prevention on susceptible rice cultivars **214**
  - Foliar spray **214**
  - Broadcast **214**
  - Soil incorporation of granules and foliar spray **214**
  - Broadcast and foliar spray **214**
  - Seedling root dip and foliar spray **216**
  - Seedbox treatment and foliar spray **216**

ECOLOGY AND BIOLOGY

Leaffolder food web. Four species of leaffolders (LF) — *Marasmia exigua* (Butler), *M. patnalis* (Bradley), *M. ruralis* (Walker), and *Cnaphalocrocis medinalis* (Guenée) — damage rice in the Philippines. Their food web of 152 species comprises parasites or predators, pathogens, and hyperparasites (Fig. 1). Species of predators (77) outnumber parasites (51) and secondary natural enemies (24). The dominant predators are beetles (21 species), ants and predatory wasps (16 each), spiders (12), true bugs (10), odonotans (9), and salientians (3).

The gryllids *Metioche* and *Anaxipha* preyed on eggs and the trichogrammatids *Trichogramma* and *Trichogrammatoidea* parasitized eggs. The braconid and ichneumonid wasps were dominant larval parasites. Very few tachinids were reared from larvae.

The pyemotid mite *Pyemotes ventricosus* is an egg predator. Several pathogens attack larvae.

Of 24 species of hyperparasites — mostly spiders — 12 species belong to Ichneumonidae, Scelionidae, Psammocharidae, and Sarcophagidae; 6 of Hymenoptera belong to Pteromalidae, Braconidae, Ceraphronidae, and Chalcididae; and 2 species each are from Orthoptera, Diptera, and Coleoptera.

Green leafhopper feeding on tungro-infected rice. In a choice test, tungro (RTV)-infected TN1 rice plants attracted significantly more green leafhoppers (GLH) *Nephotettix virescens* than did healthy plants, but after 24 h, more GLH settled on healthy plants (Table 1). Insect feeding on diseased plants was disrupted (Fig. 2) and the quantity of food ingested and assimilated was significantly less than on healthy plants (Table 2). Although as many nymphs became adults on infected as on healthy plants, GLH matured slower on diseased plants. A significant reduction in adult longevity, fecundity, egg hatchability, and population growth was observed on RTV-infected plants; however, oviposition was not affected (Table 3, 4). RTV-infected plants had significantly more free sugar but less soluble protein than did healthy plants. When given a choice, insects ingested more of the weaker sucrose (0.001, 0.01, and 0.1 M) and glucose solutions (0.01 and 0.1 M) than higher concentrations or than water (Table 5). Fructose was more or less inert at all concentrations tested. Thus, harmful effect of RTV-infected plants on GLH could be attributed to poor food quality.

DAMAGE ASSESSMENT

Sequential sampling. Sequential sampling quickly classifies populations into categories producing light, medium, or heavy infestations. It simplifies pest management because farmers can make quicker, more reliable estimate of pest populations. By using the sequential table, the farmer can decide to treat, avoid treatment, or to continue sampling. Table 6 shows sequential sampling for planthoppers.

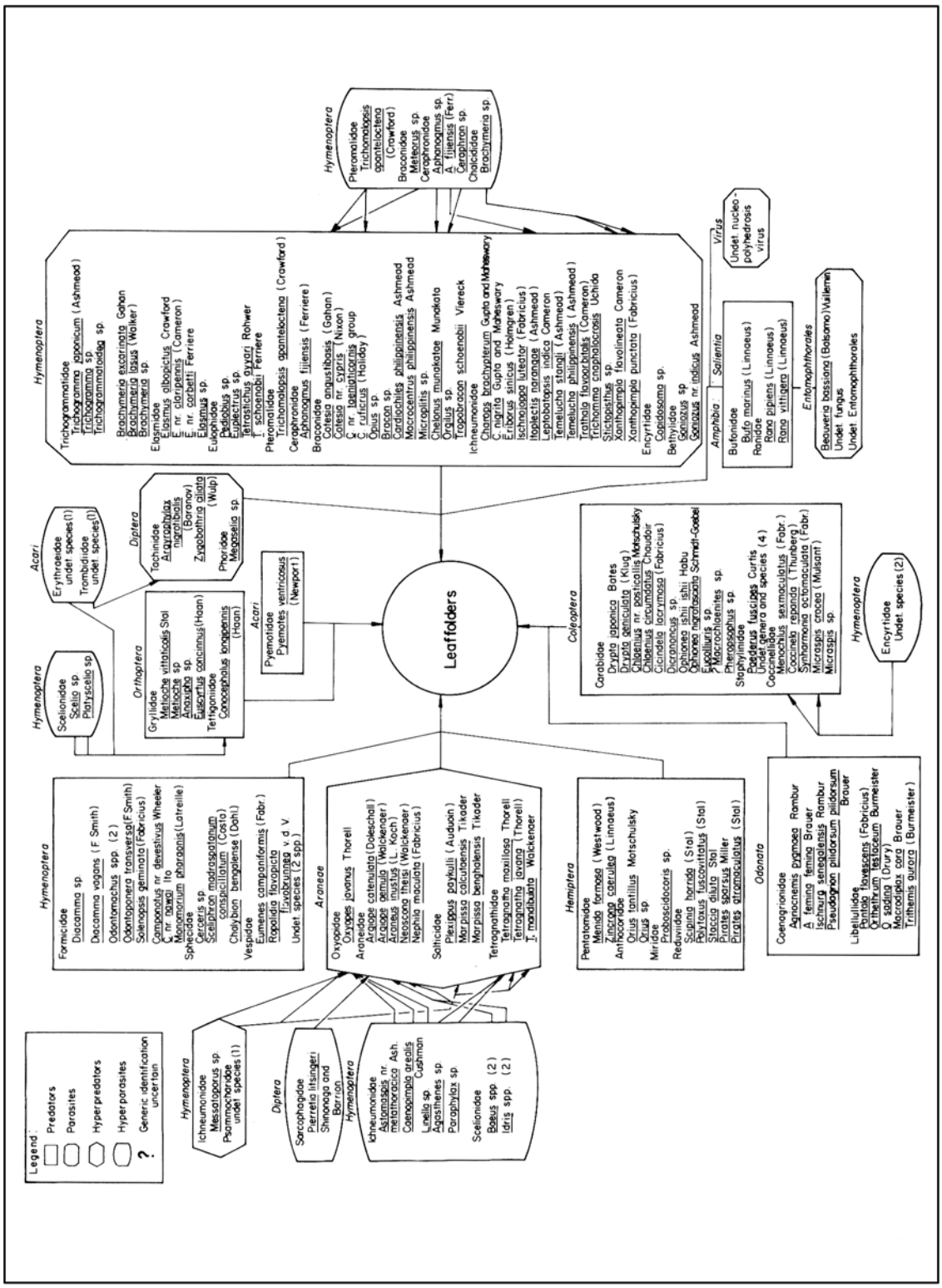
Sequential sampling is based on 1) the economic threshold of the pest, 2) the level of risk in making a wrong decision, and 3) the mathematical distribution of the insect.

An experiment in Victoria, Laguna, during 1985 wet season (WS) (July-August) compares sequential sampling with intensive sampling in direct seeded and transplanted rice. Each plot was 80 m^2 with 4 replications. Intensive sampling involved using 10 hills/plot, then deciding whether to treat based on the economic threshhold of 20 hoppers/hill or 1 hopper/tiller.

The hopper population was low and the "don't treat" decision predominated throughout the season. Sequential sampling used fewer samples, saving 60% in time. Intensive and sequential methods agreed 93% of the time. In nonagreement, the sequential method advocated that sampling be continued, while the intensive method suggested a treatment.

New predator-pest sampler. A device was developed to sample pests and predators in flooded rice. An aluminum cone is placed over a hill and carbon dioxide is introduced to anesthetize the arthropods or other predators. To determine its efficiency, the device (CO_2NE) was compared with FARMCOP, a suction sampler.

Sampling was conducted at 44 and 60 d after transplanting (DT) in a 2,500-m^2 field planted to IR22. Three hundred samples were taken per sampling occasion. Statistically, the two samplers did not vary significantly in sampling planthoppers and the predatory mirid bug *Cyrtorhinus lividipennis*. However, more *Nephotettix* spp. and



1. Food web of *Cnaphalocrocis medinalis* and *Marasmia* spp. rice leaffolders in the Philippines.

Table 1. Settling response of GLH on healthy and RTV-infected rice plants 1, 8, 24, and 48 h after infestation. IRRI, 1983-84.

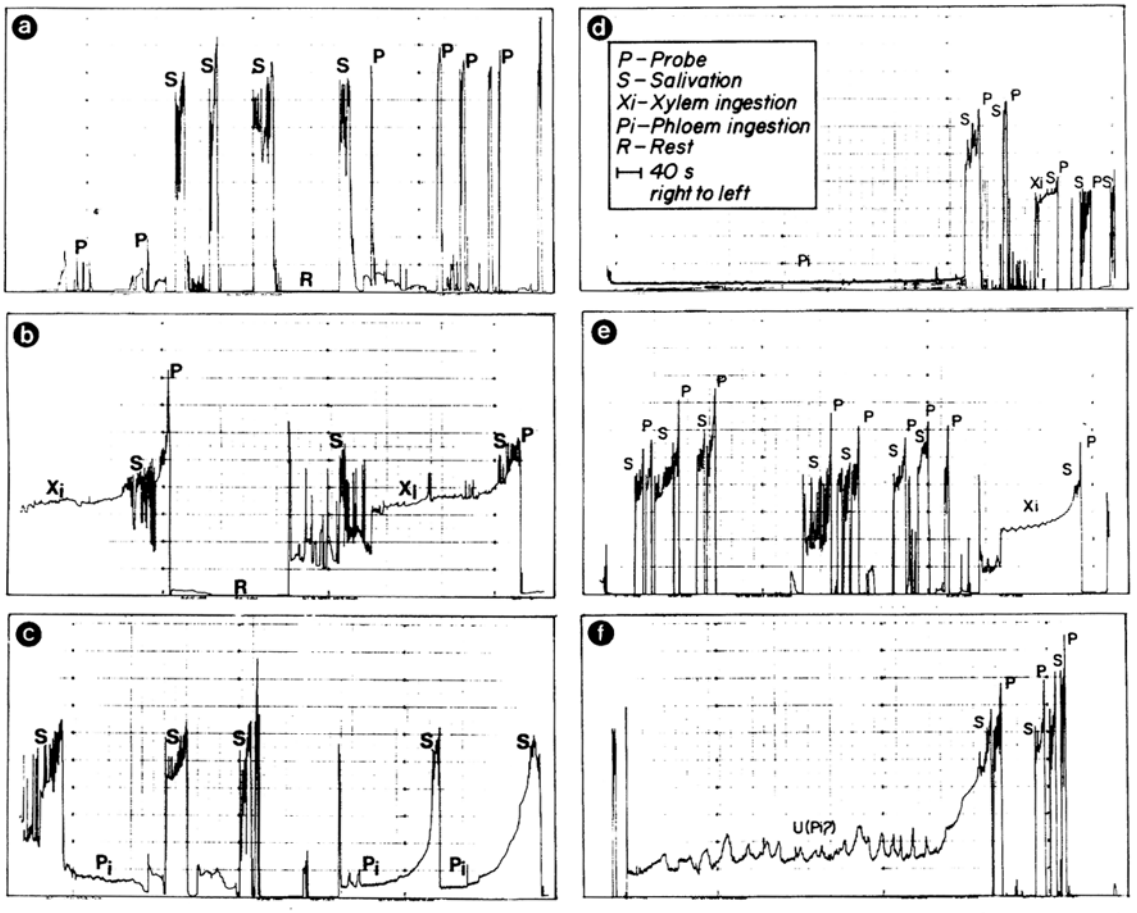
Plants	Females (%) that settled on plants[a]			
	1	8	24	48
Healthy	35.5	46.7	57.5	58.9
RTV-infected	59.0	46.0	38.1	34.0
Difference	−23.5**	0.7ns	19.4**	24.9**

[a]Av of 8 replications, each with 10 healthy and 10 diseased plants, and 100 newly emerged females.

Table 2. Quantity of food ingested and assimilated by GLH females on healthy and RTV-infected rice plants in 24 h.[a] IRRI, 1983-84.

Plants	Food ingested (mg)/female per 24 h	Food assimilated (mg)/female per 24 h
Healthy	8.27	0.68
RTV-infected	5.69	0.46
Difference	2.58**	0.22**

[a]Av of 15 replications, each with 5 newly emerged females caged individually in parafilm sachets.



2. Waveform sequences during feeding by *N. virescens* females on healthy (a-d) and RTV-infected (e-f) plants: a) initial P and S; b) Xi; c) short-duration Pi, and d) normal and sustained feeding on healthy plants; e) normal Xi; and f) unidentified voltage reversals during phloem feeding [U (Pi?)] on RTV-infected plants. IRRI, 1984.

Microvelia douglasi atrolineata were collected with the FARMCOP. The CO_2NE sampler yielded more spiders. Coefficients of variability (CV) for the two devices were similar except for *Nephotettix* spp., for which the CV was higher with the CO_2NE than with the FARMCOP. However, using the CO_2NE sampler was quicker. This method would be appropriate for estimating insect and spider populations in flooded rice.

Yield loss by rice whorl maggot, stem borer, rice tungro virus, and black bug. Percent leaves damaged by rice whorl maggot (RWM), deadhearts

Table 3. Longevity and fecundity of GLH adults on healthy and RTV-infected rice plants.[a] IRRI, 1983-84.

Plants	Adult longevity (d)		Fecundity (no. of eggs laid by 10 females)
	Male	Female	
Healthy	13.5	15.2	857
RTV-infected	11.4	11.3	572
Difference	2.1**	3.9**	285**

[a]Av of 15 replications, each with 10 newly emerged males and females.

Table 4. Population increase of GLH on healthy and RTV-infected rice plants 30 and 60 d after infestation.[a] IRRI, 1983-84.

Plants	Insects recovered (no.)	
	30 d	60 d
Healthy	247	1652
RTV-infected	192	732
Difference	55**	920**

[a]Av of 15 replications, in each of which 3 gravid females were released.

Table 5. Phagostimulatory response of GLH to different concentrations of fructose, glucose, and sucrose solutions. IRRI, 1984.

Concentration *M*	Phagostimulation[a] for solutions of		
	Fructose	Glucose	Sucrose
0.001	0.80 ab	1.39 b	11.94 b**
0.01	0.75 ab	2.70 a**	26.64 a**
0.1	1.60 a	3.24 a**	11.08 b**
1.0	0.28 b	0.38 c	0.67 c

[a]Phagostimulation = amount of test solution ingested/amount of water ingested. Means followed by double asterisks are significantly different from phagostimulation for water (value = 1) at 0.01 level of probability by least significant difference.

caused by stem borer (SB), and percent rice hills showing RTV symptoms were correlated to yield losses, using 10 rice cultivars. The correlation coefficients (r) were +0.57 (n = 10) (+0.18 excluding IR36 and IR42 because of high RTV infections) between percent leaves damaged by RWM and yield loss; +0.02 (n = 10) between percent deadhearts and yield loss, and +0.98 (n = 10) between percent hills with RTV symptoms and yield loss.

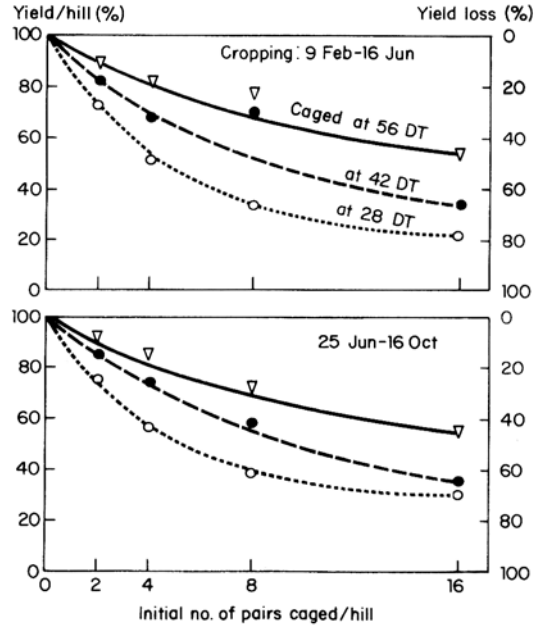
Black bug feeding on IR36 was measured in Palawan fields twice — 9 Feb-16 Jun and 25 Jun-16 Oct — by caging 0, 2, 4, 8 and 16 adult pairs/hill at

Table 6. Sequential sampling for planthoppers. IRRI, 1984.

Sample no.	Hoppers (no.)	Cumulative no. of hoppers	Lower limit	Upper limit
1				
2				
3				
4			< 57	100>
5			< 77	120>
6			< 97	140>
7			<116	160>
8			<136	179>
9			<156	199>
10			<176	219>
11			<195	239>
12			<215	258>
13			<235	278>

Don't treat — Continue sampling — Treatment required

28, 42, and 56 DT. Results show that the earlier the infestation and the higher the population density, the heavier the intensity of damage. Figure 3 shows the relationships among black bug populations, starting time of infestation, and IR36 yield loss in two seasons. When 16 pairs were released on each hill at 28 DT, yield loss was 68-79%; at 56 DT, yield loss was 44-45%.



3. Relationships among number of *S. coarctata* pair/hill, time of caging, and IR36 yield loss. Maasin, Brookes Point, Palawan, Philippines, 1984.

Black bugs were light trapped in Palawan, Philippines. Although black bug catches were high at least one week in every month of the year, January-June averaged higher catches, with catches highest in February, 2,876,000 during 13-19 Feb and 3,268,000 for all of February.

INTEGRATED PEST MANAGEMENT

Training farmers. Two projects in Nueva Ecija, one in Talavera by the Ministry of Agriculture (MA) (1979-81) and the other in Jaen and Zaragosa by IRRI (1979-83), taught integrated pest management (IPM) to farmers. Both projects were located in the Upper Pampanga River gravity system irrigating WS and dry season (DS) crops. When projects started, farmers applied insecticides 4-6 times after transplanting and 1-2 times in the seedbed. Both sites had histories of RTV/GLH and BPH outbreaks. Modern varieties (MVs) have been grown since the mid-1960s.

In 1984, 34 randomly chosen farmers in each project site were interviewed; half had IPM training. IPM-trained farmers averaged 59 h of instruction in Jaen and 87 in Talavera. Non-IPM farmers in adjacent villages had no formal IPM training.

IPM farmers named more total and major insect pests than non-IPM farmers (Table 7), and this correlated positively with instruction hours. Most trained farmers named LF, SB, and caseworm (CW), but few knew RWM, green semilooper (GSL), and *Rivula* hairy caterpillar — all major pests. Few could distinguish whitebacked planthopper (WBPH) from brown planthopper (BPH). Many trained farmers still used general terms like "worm" and "hopper." Local languages lack names for many rice pests. Farmers recognize insect damage such as defoliation more than insects responsible for it.

Nueva Ecija farmers should be able to recognize 10 insects in immature and adult forms, plus their damage symptoms. For example, the distinction between BPH and WBPH is vital as most MVs resist BPH but not WBPH.

All farmers interviewed grew MVs with insect resistance, yet less than half, trained or untrained, could name one pest controlled by resistant varieties. Twenty-five percent said "hoppers" were controlled by resistant varieties. Only 19% named GLH and 9% RTV, but 18% gave incorrect answers for LF, 13% for "worms," and 16% for "all pests." However, 29% cited resistant varieties as the reason for no recent pest outbreaks. Farmers correctly stated the following pests overcame pest-resistant varieties: RTV (39%), planthoppers (25%), and GLH (18%). Trained and untrained farmers gave similar answers for mechanisms of resistance — 81% said because of "hard stems" and 48% said "hard leaves." Less than 10% mentioned bad taste and bad odor. However, IPM classes did not stress mechanisms of resistance.

Farmers, however, knew rice varieties. Farmers knew about seed (55%) and procured seed from neighbors (77%). Most (65%) planted more than one variety each season, mainly to avoid risk (35%) or as a trial (14%). They chose varieties based on high yield (77%) or pest resistance (69%). Most farmers changed varieties frequently, many (29%) each season. Reasons for changing were weakened resistance (20%), to rest the soil (19%), as a trial (13%), uneven growth (12%), and yield decline (11%). The disadvantages of pest-resistant varieties cited by farmers were lodging (29%) and susceptibility to other pests (15%). More trained (46%) than untrained (12%) farmers stated newer varieties needed fewer sprays.

Table 7. Effect of training on farmers learning IPM technology.[a] Jaen and Talavera, Nueva Ecija, Philippines, 1984.

Knowledge test items	Correct answers (per farmer)		*r* for h of training (no./farmer)
	Trained (n = 35)	Untrained (n = 34)	
Total insect pests (no.)	3.1	1.7	0.57**
Major pests named (no.)	2.3	1.0	0.65**
Pests controlled by varietal resistance (%)	45	35	0.13 ns
Resistant varieties named (%)	83	86	-0.19 ns
Insecticide applications (no.)	3.5	5.7	-0.27*
Recommended insecticide (%)	85	70	0.19 ns
Mode of insecticide action (no.)	1.9	1.2	0.34**
Safety precautions (no.)	2.8	2.2	0.20 ns
Natural enemies named (no.)	2.9	1.4	0.52**

More IPM trained farmers (85%) used economic thresholds in deciding to apply insecticide, compared to 6% of untrained farmers. Only 12% of untrained farmers sprayed without looking for damage. Untrained farmers sprayed because a neighbor sprayed (76%) (insecticide applied to a crop is said to drive the pests to unsprayed fields) and 89% sprayed saying that fertilizers made stems soft and susceptible to insect damage.

IPM farmers sprayed fewer times than untrained farmers. Half of untrained farmers, but only 11% of trained ones said they used more insecticide now than 5 yr ago. Farmers used sprayable insecticides and most (80%) determined dose by reading the label. The most common insecticides in 1983 were monocrotophos, chlorpyrifos + BPMC, and BPMC. Trained and untrained farmers used a recommended insecticide on more than 70% of occasions.

Training did not improve safety practices. Farmers commonly used protective clothing including a bandanna over the nose and mouth, and sprayed downwind. Some farmers believed eating candy while spraying prevented toxicity. Only 5% said they washed themselves after spraying.

Trained farmers named twice as many natural enemies of rice insects (2.9) as did untrained farmers (1.4) (Table 7). More trained (96%) than untrained (59%) farmers knew insecticides killed natural enemies.

Farmer's surveillance methods. Sixty farmers equally divided into three groups (IPM group members, IPM leaders, and non-IPMs) in Zaragosa and Jaen were asked every 2-3 wk during the 1984 WS why they sprayed.

Because they used modern monitoring methods, IPM participants averaged four insecticide applications compared to seven for nontrained farmers. Trained farmers based their application more on insect counts.

All farmer groups based insecticide applications equally on damage symptoms and on presence of pests. The most frequently used damage symptoms were yellow or white foliage or cut leaves or deadhearts. Farmers noted location of damage — in high or low parcels or near a dike — as well as its distribution — uniform, uneven.

IPM farmer leaders used more quantitative units of measurement. Farmers noted insect damage in patches and counted them per parcel or per field. Some counted by hill or plant.

Farmers rarely went to fields just to monitor pests. They observed pests while weeding, cleaning dikes, checking paddy water level, etc. They also watched neighbors' fields.

When monitoring, farmers first selected lowest lying parcels and went to their wettest parts or downwind edges. Their strategy is good. Most lowland rice pests are aquatic; CW larvae float and would be blown downwind. Most farmers inspected from dikes, noting moths and tapping or submerging hills near the bund to note hoppers or leafworms. The most industrious farmers entered the field and walked either 1) straight to the other side, 2) in a zigzag, or 3) in a circular pattern, flushing moths, tapping and inspecting plants along the way.

CULTURAL CONTROL

Effect of a weedy fallow on hoppers. Before an irrigation system was installed, the 500 ha of Batitang, Zaragosa, Nueva Ecija, were first-class rainfed ricelands. Batitang is now at the tail end of the system; canals have blocked the natural drainageways, creating flooding in WS; water seldom arrives in DS. Only one-sixth of the area is now planted to rice, and farmers who plant use pumps. Thus ricefields are asynchronously planted with no rice-free period. The other five-sixths is not cropped and is mainly a weedy fallow dominated by *Echinochloa glabrescens* and *Leersia hexandra* (52 and 38% of total biomass dry wt per area). Batitang is a rat haven, fields are zinc deficient, and RTV is endemic. Yields, once highest in the area, are now the lowest (Table 8).

Kerosene light trap catches along a transect of six locations from the head of the system to Batitang revealed increasing GLH and RTV (Table 8). A large proportion (up to 47%) of GLH are *Nephotettix malayanus*, an uncommon species in the Philippines. IRRI greenhouse studies show *N. malayanus* intermediate in transmission of RTV, between *N. virescens* and *N. nigropictus*.

GLH numbers exponentially increased with greater asynchrony of planting. RTV was positively correlated ($R^2 = 0.66$*) with more GLH of all three species over the 1981 WS and 1982 DS.

Table 8. GLH abundance and RTV incidence along a transect of 6 locations of increasing asynchrony from the head to tail end of Lateral A of the Upper Pampanga River Integrated Irrigation System, Nueva Ecija, Philippines, 1981 WS and 1982 DS.

Location	Distance along canal (km)	Asynchrony[a] of planting (SD days)	Total[b] *Nephotettix* sp. (thousands)	Composition by species (%)			Tungro[c] (% hills)	Yield[d] (t/ha)
				N. virescens	*N. nigropictus*	*N. malayanus*		
Ibabaw bana	0	7.0	0.6	80	10	10	0	5.0
Rajal Centro	9	9.5	6.6	72	15	13	0.4	3.3
Marawa	15	14.7	3.1	62	18	20	4.5	3.5
Santa Rita E.	16	15.5	7.2	56	16	28	8.0	3.8
Manaol	17	17.7	5.1	49	11	40	4.0	4.0
Batitang	19	20.7	24.2	38	15	47	10.5	2.9

[a]Measured within a radius of 1.4 km from the center of each pair of light traps. Planting dates courtesy of National Irrigation Administration (NIA). [b]Total from daily catches from a pair of kerosene-powered light traps at each location. [c]5 fields per location sampled in the reproductive or ripening stages, 125 hills/field. RTV incidence was confirmed by iodine starch test from 2 leaves/hill. [d]1981 WS. Source: NIA, based on water tenders' reports within rotational areas served by UPRIIS.

Rajal Centro had high GLH numbers (particularly *N. virescens*) and low RTV despite being a synchronous area. However, it is located 2 km from a highly synchronous area which may have produced the high *N. virescens* populations. Manaol had lower RTV in 1981 WS than the GLH population would indicate; farmers reported the area was highly synchronous the preceding DS. Biweekly FARMCOP suction sampling of ricefields in Batitang May-Sep 1982 failed to capture *N. malayanus* nymphs, but did sample equal proportions of *N. virescens* (n = 1,191) and *N. nigropictus* (n = 1,166) nymphs.

Sweep net sampling of ricefields in Batitang and Santa Rita every 10 d from Jan to May 1982 produced only 1-3% *N. malayanus* nymphs from the total GLH collected. Most *N. malayanus* came from weedy lowland fallow in Batitang. *N. virescens*, monophagous on rice, was not recovered in the weedy fallow. *N. nigropictus* was half as abundant as *N. malayanus* (Table 9).

N. malayanus breeds in lowland weedy fallows but seldom contracts RTV in nature because rice is not a natural host. *N. malayanus* is more dispersive than *N. nigropictus* and *N. virescens*, and will be collected in light traps set in ricefields, several

Table 9. Hopper sweep net abundance in weedy fallow, and in ricefields near and away from weedy fallow.[a]Batitang and Santa Rita, Nueva Ecija, Philippines. Jan-May 1982.

Hopper	Batitang				Santa Rita ricefields (away)	
	Nonrice weedy[b] fallow		Ricefields (near)			
	Thousands	%/complex	Thousands	%/complex	Thousands	%/complex
GLH complex						
N. virescens	0.3	8	7.4	75	4.8	86
N. nigropictus	1.4	34	2.6	25	0.6	11
N. malayanus	2.3	58	0.04	0	0.2	3
WBPH complex						
Sogatella furcifera	0.07	1	1.6	35	0.8	50
S. panicicola	4.7	70	1.5	33	0.6	37
Sogatodes pusanus	1.7	26	0.5	10	0.1	8
S. kolophon	0.2	3	1.0	22	0.08	5
BPH complex						
Nilaparvata lugens	0.05	66	0.20	76	0.05	83
N. bakeri	0.03	34	0.05	24	0.01	17
ZLH[c]						
Recilia dorsalis	0.09	–	0.06	–	0.01	–

[a]Sampled every 10 d from 5 fields in each habitat. [b]*Echinochloa glabrescens* and *Leersia hexandra*. [c]Zigzag leafhopper.

kilometres from its breeding grounds. *N. malayanus* no doubt evolved to be highly dispersive. *N. virescens* breeds only on rice so has not acquired long distance dispersal behavior and flight capability.

Similar results were evident among the conspecifics of WBPH and BPH (Table 9). *S. furcifera* and *N. lugens* were most abundant in ricefields while their conspecifics *S. panicicola*, *S. kolophon*, *Sogatodes pusanus*, and *N. bakeri* were most prevalent in weedy fallow.

Light trap collections do not provide data on host preference. We were unable to rear *N. malayanus* on rice, but did succeed with *E. glabrescens* and *L. hexandra*. *N. malayanus* would only play a role in RTV epidemiology if those weeds could host RTV. Ricefields are the preferred hosts of *N. virescens*, *S. furcifera*, and *N. lugens*.

Arthropod abundance by crop establishment method and flooding duration. A field trial measured insect pest and predator numbers on ratoon and seedbed second crops. Transplanted rice (TPR) and wet seeded rice (WSR) main crops were ratooned and compared to a second crop of TPR or WSR. The second crops were maintained under continuous standing water (flooded 3 times/wk) or intermittent flooding (flooded 1/wk — water remained only 1-2 d) in a randomized complete block design. IR1917 (insect susceptible but RTV resistant) rice was planted without insecticide.

Ratoon was less attractive to RWM — fewer eggs and damaged leaves were recorded than on a seeded second crop (Table 10). Few RWM developed because a ratoon crop has a short vegetative period. RWM is usually attracted to flooded fields, but infestation in continuously and intermittently flooded fields did not differ. WSR plots, with more rapid plant cover, had fewer eggs and damaged leaves than TPR.

Although LF populations were small, more developed on ratoon than on seeded second crop (Table 10). The ratoon infestation was not a carryover from the main crop. As LF prefers to oviposit more on a ratoon than a vegetative stage seeded crop, it perhaps prefers reproductive stage to vegetative stage. Neither water management nor seeding method affected LF, again indicating that it is a pest of older rice.

Ratoon sustained more SB than did the seeded second crop (Table 10). Striped SB (SSB) and dark-headed SB (DHSB) were equally prevalent on main crop, but after harvest SSB was most abundant. SB numbers declined markedly during ripening stage of main crop. Young larvae left in stubble after harvest predominated on young ratoon. The seeded second crop had no older larvae or pupae, indicating late infestation. SB population on ratoon declined progressively.

The TPR second crop had more SB than the WSR second crop. The WSR main crop had more

Table 10. Effect of crop establishment method and flooding regime of the second crop on insect pests and their predators[a], IRRI, Aug 1983-Feb 1984.

Arthropod	Crop establishment method[b]			Seeding method[c]			Flooding regime[d]		
	Ratoon	Seeded	Δ	TPR	WSR	Δ	Intermittent	Continuous	Δ
RWM[e] (no. eggs/m^2)	0.6	1.4	**	1.4	2.8	**	2.0	2.2	ns
RWM[f] 30 DT (% damaged leaves)	0.8	2.4	**	11.3	14.8	**	2.9	2.9	ns
LF[g] (% damaged leaves)	0.6	0	**	0.3	0.4	ns	0.4	0.3	ns
GLH[h] (no./m^2)	0.6	1.4	**	1.1	1.9	**	1.7	2.2	**
BPH[h] (no./m^2)	0.9	0.7	ns	0.8	0.7	ns	0.6	0.9	ns
WBPH[h] (no./m^2)	1.1	1.8	**	0.9	0.9	ns	0.9	1.0	ns
Spiders[h] (no./m^2)	9.5	3.9	**	7.2	6.2	ns	4.1	9.3	**
Ripple bug[h] (no./m^2)	15.4	11.9	ns	11.3	14.4	ns	7.9	9.4	**
Mirid bug[h] (no./m^2)	0.3	1.1	**	0.4	0.9	**	0.6	0.8	ns
SB[i] (% infested tillers)	0.4	0.1	**	0.3	0.1	**	0.1	0.2	ns

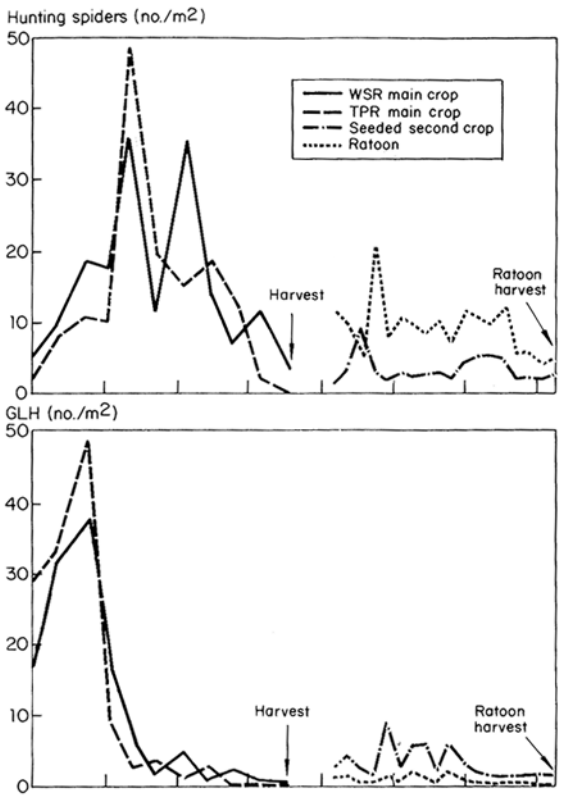
[a]Av of 3 replications. [b]Averaged over seeding methods and flooding regimes. [c]Averaged over crop establishment methods and flooding regimes. [d]Averaged over crop establishment and seeding methods. [e]20-m^2 sampled weekly 1-4 week after transplanting (WT). [f]20-m^2 sampled 30 DT. [g]20-m^2 sampled 40 DT. [h]20-m^2 sampled twice a week (18 times) with FARMCOP suction sampler. [i]1-m^2 sample unit in 3 locations per date over 7 sampling dates 1-7 WT.

SB than did TPR main crop, but differences were insignificant.

GLH was equally abundant in TPR and WSR main crops, but all hopper populations dramatically declined toward harvest, probably from natural predators. Although Figure 4 only shows this decline for GLH, all pest populations declined similarly and all were low in ratoon and second crop, with predator populations similar to that shown for hunting spider.

Ratoon had significantly fewer GLH than did seeded second crop (Table 10) but numbers were low. Significantly more GLH occurred in WSR than TPR, and in continuous rather than intermittent flooding.

TPR main crop developed more BPH than did WSR. Main crop populations, however, markedly declined with age for both seeding methods. BPH was almost absent from ratoon or seeded second crop.



4. Abundance of predator (hunting spider *Lycosa pseudoannulata*) and insect pest (GLH *Nephotettix virescens*) on wet-seeded and TPR main crops and their ratoons compared to a second seeded crop. IRRI, Aug 1983-Feb 1984.

The TPR main crop sustained higher WBPH numbers than WSR. WBPH were fewer on ratoon than on seeded crop.

Spiders were equally abundant on WSR and TPR main crops (Fig. 4). The decline of spiders reflected the decline of hopper prey toward crop maturity. Hunting spiders were twice as abundant in the main crop as space-web spiders and five times more prevalent than orb-web spiders. More spiders were in ratoon than in seeded second crop. Ratoon is a spider refuge. Spiders probably foraged from ratoon plots to second seeded plots.

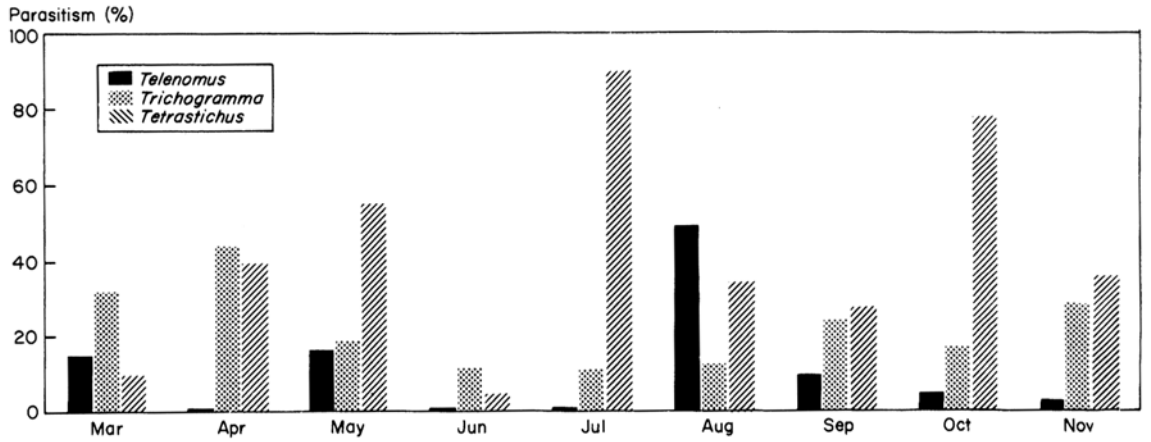
The hunting spiders were dominated by *Lycosa pseudoannulata* throughout the ratoon crop. *Callitrichia formosana* space-web spider declined slightly as ratoon matured. *C. formosana* webs at tiller base; therefore it and mobile hunting spiders may remain unaffected during ratoon harvest and growth. Orb-web spiders such as *Tetragnatha* spp. and *Dyschiriognatha* sp. spin webs in tall foliage. Normally abundant during later growth, even they declined at main crop harvest when hoppers had dispersed to colonize younger crops.

Microvelia ripple bug and *Cyrtorhinus* mirid bug declined with crop age on the main crop but can rapidly colonize newly planted fields. *Microvelia* was abundant in all crops. *Cyrtorhinus*, however, did not rebuild its population after its eggs were removed in straw of the main crop. *Cyrtorhinus* moreover became significantly more abundant in seeded second crop than on ratoon.

More spiders on ratoon undoubtedly significantly reduced GLH and WBPH. Ripple bug being equally abundant on both second crops probably explains similar BPH numbers in both second crops. Among all predators *Cyrtorhinus* became more abundant in the direct seeded second crop, perhaps in response to GLH numbers. *Microvelia* and spiders were more abundant in the continuously flooded field.

BIOLOGICAL CONTROL

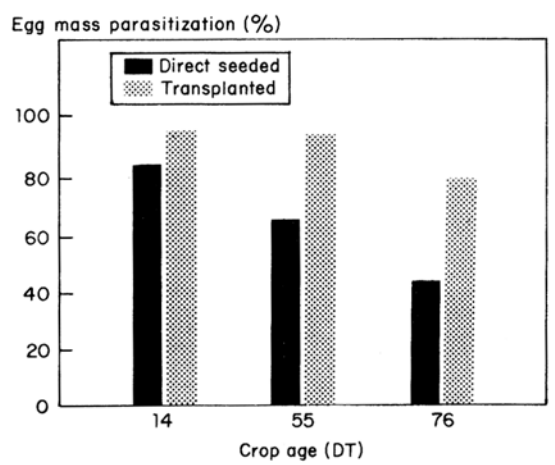
Parasites. *Yellow stem borer.* Untreated fields at IRRI were planted monthly to rice, direct-seeded and TPR, to compare pest and beneficial insect populations. Yellow stem borer (YSB) *Scirpophaga incertulas* egg masses were placed in these fields from March through November to determine the seasonal abundance of YSB egg parasites. After



5. Percent parasitism of YSB egg masses 14 DT. IRRI farm, 1984.

several days, eggs were returned to the laboratory and held until YSB larvae hatched or parasites emerged. The three major genera of parasites attacking the egg masses were *Telenomus*, *Tetrastichus*, and *Trichogramma*. *Tetrastichus* were almost always most abundant in direct seeded and in TPR. The seasonal abundance of these parasites in transplanted fields is illustrated in Figure 5. Parasitism was usually higher in TPR especially during WS (July-November), reaching almost 90% in July.

Figure 6 shows parasitism by all species in TPR and direct-seeded fields at 14, 55, and 76 d. Parasitization of YSB egg masses declined only slightly with age of TPR, but declined substantially in direct-seeded rice. Parasites may have more difficulty locating egg masses in the denser canopy of direct-seeded rice.



6. Percent parasitization of YSB egg masses at 14, 55, and 76 d after seeding in direct-seeded and transplanted rice. IRRI farm, 1984.

Clearly, egg parasites kill significant numbers of YSB. Conservation of beneficial insects through wise use of pesticides will help ensure natural control of YSB.

Leaffolders. Collections of leaffolders (*Marasmia patnalis*, *M. ruralis*, and *Cnaphalocrocis medinalis*) throughout the growing season revealed that more than 30% of larvae in farmers' fields were parasitized. Twelve species of parasites have been identified.

Black bug. A biological control program directed toward the black bug *Scotinophara coarctata* uses egg parasites and insect pathogens.

Scotinophara latiuscula, a related species of black bug on Luzon, is not an economic pest. Perhaps its population is controlled by egg parasites *Telenomus cyrus* and *Psix lacunatus*, which also readily attack the economically important *S. coarctata*. *T. cyrus* has not been found on Palawan where *S. coarctata* is a pest. *T. cyrus* and *P. lacunatus* are being reared and released on Palawan to try to establish them there.

Biological information is being gathered for rearing the species more efficiently and assessing the potential for control.

To determine parasitization of black bug eggs on Palawan, more than 200 egg masses were collected August-December in farmers' fields and brought to the laboratory. Over 50% of the masses but <25%

of eggs were parasitized by *Telenomus triptus*. After egg laying, female black bugs guard the egg masses until eggs hatch. Thus, parasitization is limited to the edge of the mass, reaching 80% near the periphery.

Predators. Arthropod predators limit populations of most rice insect pests. Sampling for predators is more reliable than sampling for parasites; predators are normally larger and easier to see. Glasshouse, laboratory, and field experiments evaluated the effectiveness of major predators.

To study predation on YSB egg masses by naturally occurring arthropods in the field, egg masses were placed in direct-seeded rice and in TPR. Predators consumed more eggs in TPR than in direct-seeded rice. Also, more predation occurred in untreated fields at IRRI than in farmers' fields which received insecticide treatments.

Figure 7 shows numbers of WBPH nymphs killed by the lycosid spider *Lycosa pseudoannulata* in cages in the glasshouse. The figure shows a saturation level of 150 to 200 WBPH nymphs killed; any increase in WBPH killed thereafter depended on time available for predation.

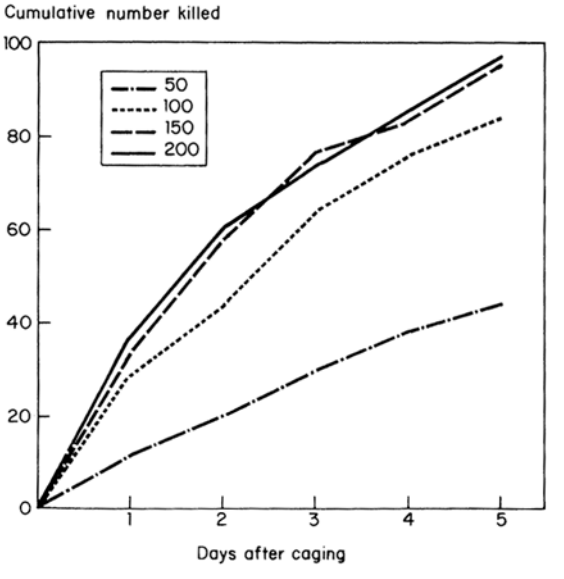
Larvae of the lady beetle *Synharmonia octomaculata* consumed fewer hoppers than did lycosid spiders. Lady beetle larvae were more effective against BPH nymphs than adults. Approximately equal numbers of nymphs were consumed up to 6 d irrespective of 6, 8, or 10 nymphs/cage. Each *S. octomaculata* larva consumed about 3-5 BPH nymphs/d.

The predatory bug *Cyrtorhinus lividipennis* feeds on BPH eggs and nymphs. Either 3, 5, or 7 gravid BPH females were caged with rice plants, and after allowing 4-5 d for oviposition, *C. lividipennis* were added. The predators killed significant numbers of emerging BPH nymphs.

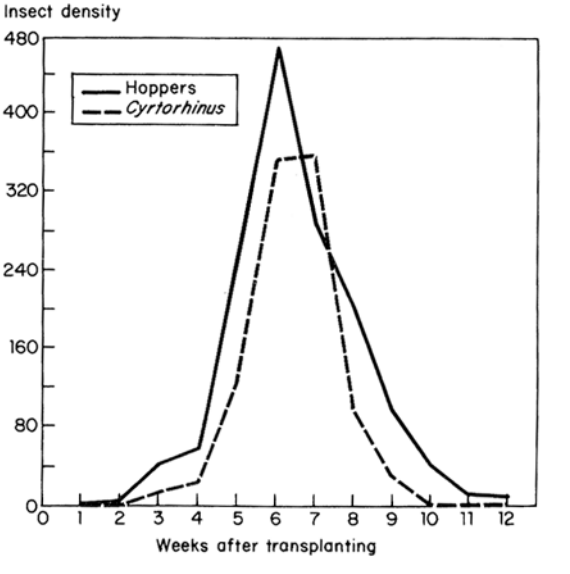
In ricefields in South Cotabato, Mindanao, numbers of hoppers (BPH, WBPH, ZLH, and GLH) mirrored those of the mirid *C. lividipennis* (Fig. 8). Although correlation does not prove a causal relationship, the concomitant growth and decline in populations suggest these predators are probably major regulators of hopper populations.

Fungal pathogens. Several surveys in the Philippines and other Southeast Asian countries yielded new strains of entomogenous fungi and viruses of rice insect pests. Corollary to its collection of entomogenous fungi, IRRI has begun to collect rice insect pest viruses as a base for an international depository for biological control of rice pests around the world.

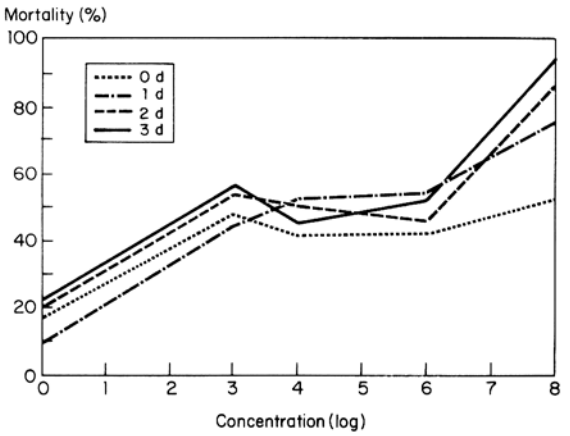
A bioassay system for testing entomogenous



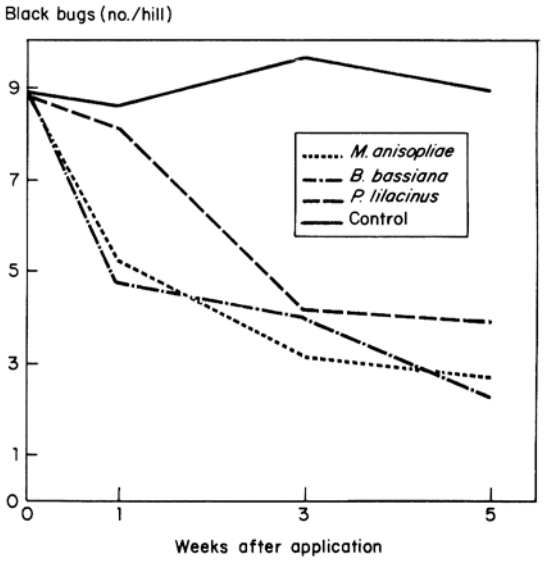
7. Cumulative numbers of WBPH nymphs killed by *L. pseudoannulata* spiders in cages in the glasshouse during a 5-d period. IRRI, 1984.



8. Numerical response of *C. lividipennis* to populations of hoppers (BPH, GLH, ZLH, and WBPH). Visual counts of hoppers per 100 hills. South Cotabato, Philippines, 1984.



9. Effect on BPH mortality of increase in dosage of conidia and period of high relative humidity at beginning of incubation period. IRRI, 1984.



10. Mortality of adult black bugs *S. coarctata* in the field after treatment with a suspension of conidia of 3 species of insect fungi. IRRI, 1984.

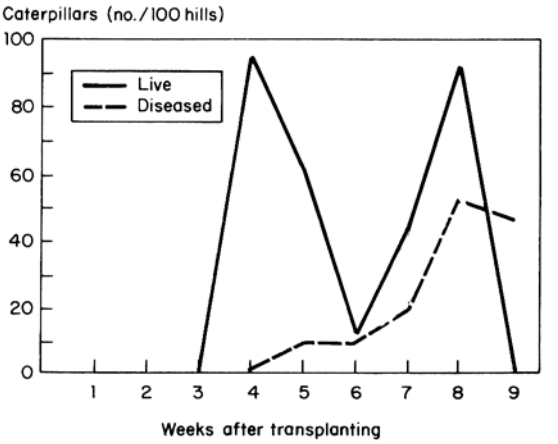
fungi on BPH has been developed, and tested on strains of *Beauveria bassiana*, *Metarhizium anisopliae*, *M. flavoviride*, and *Hirsutella citriformis*. No striking differences in virulence between fungal species and strains have been detected. However, BPH mortality gradually increased because of treatment with increasing dosages of fungal conidia. Prolonged high relative humidity at the beginning of the incubation period enhanced infection of the insects (Fig. 9).

Fungal pathogens of the black bug have been collected throughout Southeast Asia and field tested. Black bugs can be infected readily in the laboratory by *B. bassiana*, *M. anisopliae*, and *Paecilomyces lilacinus*. Although *P. lilacinus* has not been found to infect the black bug in the Philippines, it commonly does so in Malaysia. Introduced into Philippine fields, the fungus killed substantial numbers of black bugs 1 wk after introduction, and populations remained low for 2 mo (Fig. 10).

Fungal species showed no significant differences in virulence as indicated by mortality rates at different doses of fungal conidia in field cage tests (Fig. 10). Temperature and humidity play a crucial role in infection and in overall black bug mortality.

Ricefields in South Cotabato, Mindanao, were monitored to evaluate natural enemies which regulate insect pests. Weekly samples of 100 hills were examined throughout the growing (wet) season. In these fields, insect populations never reached damaging levels. Figure 11 presents an example of possible control by a fungus. A naturally occurring fungus, *Nomuraea rileyi*, wiped out the population of the second generation of green hairy caterpillars, perhaps preventing the pest from reaching damaging levels.

Pesticides in the field can limit epidemics of fungal pathogens which keep insect pests under control. Tests were designed to determine how



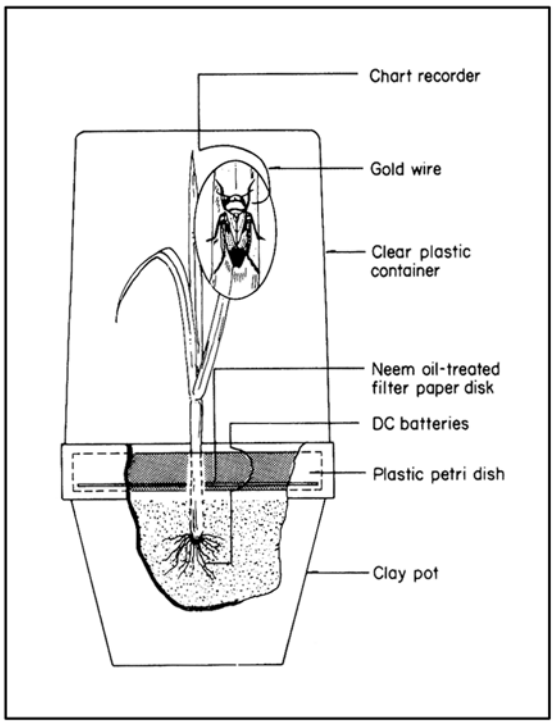
11. An epizootic of the fungus *N. rileyi* in a field population of hairy caterpillars. South Cotabato, Philippines, 1984.

agro-chemicals limit fungal germination, growth, and sporulation. Not surprisingly, fungicides retarded development of the three species of insect fungi. However, several other pesticides, including an insecticide (carbaryl) and a herbicide (edifenphos) strongly inhibited them.

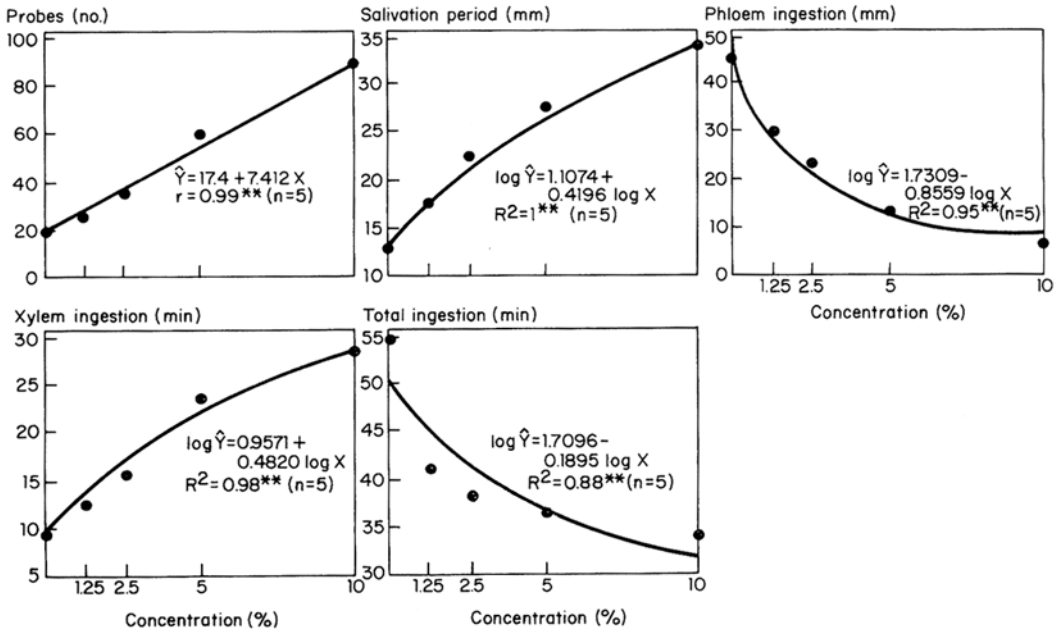
Several laboratory studies of the isolation, growth, and mass-production of hyphomycetous insect fungi were undertaken. Most fungi considered can be isolated and grown in a relatively simple medium. A small mass-production unit at IRRI can produce weekly 50 litres of wet mycelial material of various fungi. This can greatly aid programs involving large-scale field testing of beneficial fungi.

BOTANICAL CONTROL

Neem oil. *GLH feeding on neem oil-treated plants.* Using an electronic device, we monitored feeding behavior of *N. virescens* on TN1 rice plants sprayed with neem oil. Neem oil disrupted the insect's normal feeding. Phloem feeding by GLH on plants sprayed with neem oil at 1.25, 2.5, 5, or 10% concentration was significantly less than on control plants sprayed with acetone (Fig. 12). Phloem



13. Schematic diagram of assembly for electronic recording of *N. virescens* feeding on rice plants with background odor of neem oil. IRRI, 1984.



12. Effects of different neem oil concentrations on feeding activity of *N. virescens*. IRRI, 1984.

Table 11. Feeding behavior of GLH in presence of different concentrations of neem oil.[a] IRRI, 1984.

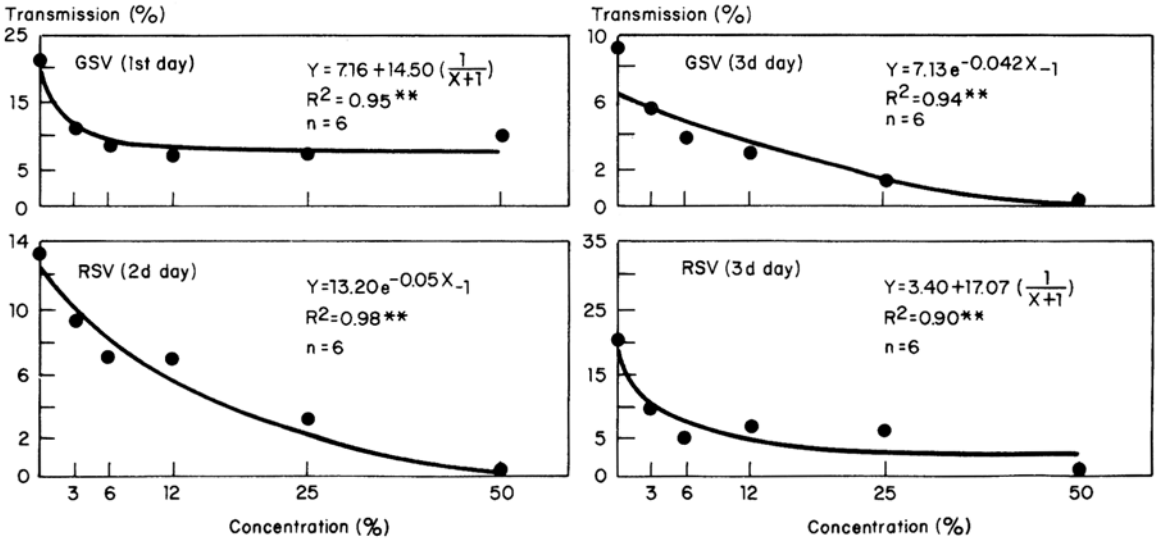
Oil concn[b] (%)	Probes (no.)	Salivation (min)	Phloem feeding (min)	Xylem drinking (min)	Total ingestion (min)
25	125 a	30.9 a	2.7 e	31.3 a	33.9 c
12	116 a	28.1 a	8.7 d	22.2 b	30.9 c
6	77 b	23.0 b	18.7 c	19.2 b	37.9 c
3	47 c	15.4 c	40.4 b	10.9 c	51.3 b
0 (1.66% Teepol)	43 c	14.5 c	51.8 a	9.4 c	61.3 a
0 (paraffin oil)	41 c	13.5 c	47.5 ab	9.1 c	56.6 ab

[a] Av of 10 replications, each replication using a new plant and a new insect. Feeding activity was monitored for 180 min.
[b] All neem oil concentrations prepared in aqueous 1.66% Teepol solution.

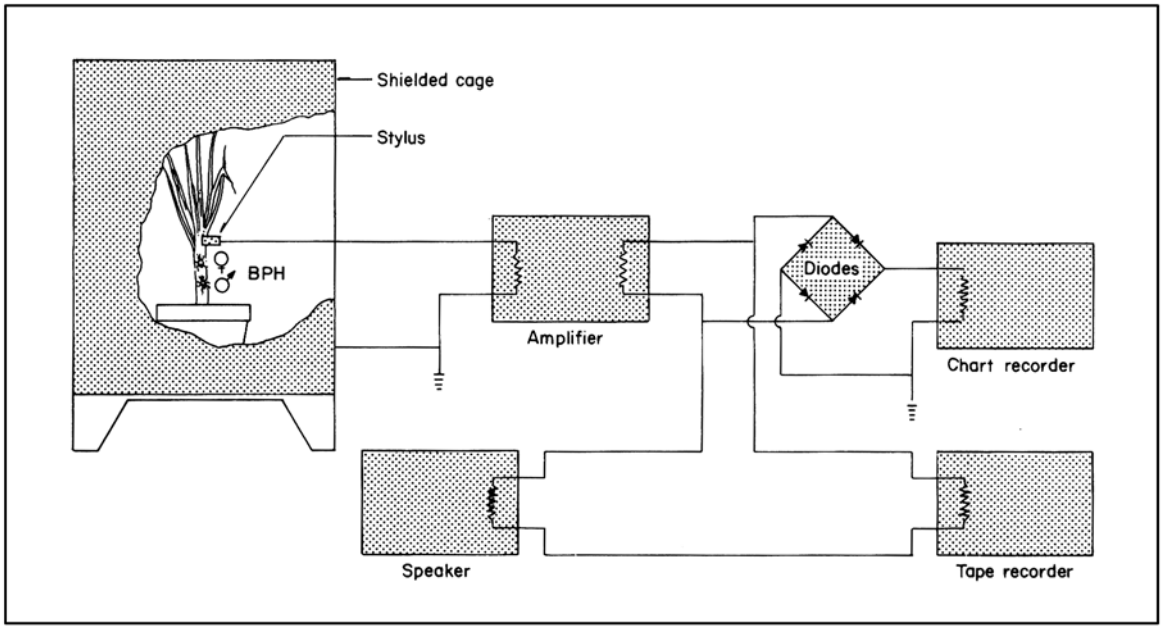
feeding was erratic on plants sprayed with 5 and 10% neem oil, but decreased progressively with increased concentration of neem oil. Reduced intake from phloem feeding on neem-oil treated plants was associated with significantly more probing and longer salivation and xylem feeding. The total feeding time on neem oil-treated plants was significantly less than on control plants. On plants sprayed with 10% neem oil, the insects became restless, probed repeatedly, salivated profusely, and fed mainly on the xylem. Disruption of phloem feeding and associated aberrations in the feeding behavior may explain lower GLH survival on neem oil-treated plants and a corresponding decrease in RTV transmission.

Neem oil odor as green leafhopper deterrent. Neem oil has a strong garlicky odor perceptible from a distance. With an electronic device (Fig. 13), we investigated how neem oil odor affected GLH feeding behavior. In an arena permeated with neem oil odor, GLH probed more often, salivated longer, and fed more on xylem (Table 11). These aberrations in insect feeding caused by neem oil odor may explain the proportionate absence of phloem-specific RTV in untreated ricefields surrounded by neem oil-sprayed rice.

Neem oil effect on brown planthopper survival and grassy stunt-ragged stunt transmission. Neem seed oil was highly effective in reducing BPH survival and in suppressing transmission of grassy stunt (GSV) and ragged stunt (RSV) diseases of rice (Fig. 14). Generally, insect survival and disease



14. Effect of concentrations of neem oil on GSV 2-RSV transmission in neem oil-treated rice seedlings. IRRI, 1984.

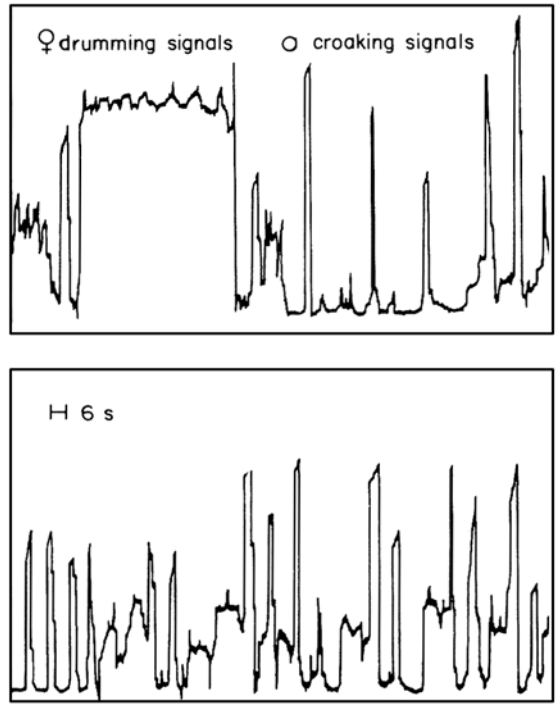


15. Schematic diagram of equipment and circuitry for recording *N. lugens* mating signals. IRRI, 1984.

transmission decreased with increasing neem oil concentrations. After 3 d exposure, the insects failed to transmit the viruses to TN1 plants sprayed with 50% neem oil, but transmission was successful on control TN1 plants.

Neem oil disruption of brown planthopper mating. We recorded BPH mating signals on rice plants and examined whether application of neem oil to either sex would change the characteristics of mating signals. Mating behavior was observed after a 5-d-old male and a 3- to 5-d-old BPH female were placed on a potted 30-d-old TN1 rice plant. Male "croaking" signals and female "drumming" or "calling" signals were recorded as shown in Figure 15. Topical application of neem oil at a rate of 5 μg/female altered female calling signals and disrupted mating (Fig. 16).

Effect of neem cake-treated soil on tungro virus in seedlings. We investigated the effect of applying different rates of neem cake to soil used to grow TN1 rice plants. Transmission and multiplication of both tungro bacilliform (RTBV) and spherical (RTSV) virus particles, detected by enzyme-linked immunosorbent assay, were significantly reduced in rice seedlings grown in soil treated with ≥150 kg neem cake/ha. The percent infection of RTBV, RTSV, or RTBV + RTSV in seedlings grown in



16. "Drumming" and "croaking" acoustic signals emitted prior to mating by a sexually mature BPH female and a male on a rice plant (*top*). Frequency and duration of calling signals are changed and mating is disrupted if the female is topically treated with neem oil (*bottom*). IRRI, 1984.

Table 12. Growth, longevity, and fecundity of BPH, WBPH, and GLH on TN1 rice plants sprayed with *M. azedarach* oil. IRRI, 1984.[a]

Insect	Oil concn (%)	Nymphs[b] becoming adults (%)	Growth[c] index	Longevity[d] (d)		Fecundity[d] (no. of viable eggs/♀)
				Male	Female	
BPH	0	96 d	5.59 b	14 c	14 b	149 d
	3	37 c	2.14 a	14 c	13 b	68 c
	6	24 bc	1.95 a	8 b	10 b	18 b
	12	18 b	1.26 a	9 b	11 b	13 ab
	25	2 a	1.05 a	2 a	2 a	0 a
WBPH	0	77 d	4.75 c	17 c	16 c	187 c
	3	46 c	2.72 b	12 bc	13 bc	148 c
	6	25 b	1.63 b	6 a	9 ab	46 b
	12	20 ab	1.80 b	9 ab	8 a	23 ab
	25	3 a	0.60 a	15 c	8 a	0 a
GLH	0	94 d	4.95 d	21 c	23 c	115 d
	3	63 c	3.43 c	18 bc	18 b	44 c
	6	56 c	3.08 c	17 bc	19 b	46 c
	12	34 b	1.88 b	15 ab	16 b	21 b
	25	7 a	0.77 a	11 a	14 a	0 a

[a]In a column for each insect, means are separated by Duncan's multiple range test at the 5% level. [b]Av of 10 replications, 10 first-instar insects per replication. [c]Calculated as percent nymphs becoming adults to development period. [d]Av of 20 replications, 2 insects per replication.

soil treated with 150-250 kg neem cake/ha was comparable to that in seedlings treated with furadan at 0.75 kg ai/ha.

Chinaberry seed oil against common insect pests. Chinaberry *Melia azedarach* L. trees are widespread in southern and southwestern China. Like those of neem, chinaberry seeds are rich in "bitter" principals apparently undesirable to insect pests. We evaluated the potential of chinaberry seed oil against BPH, WBPH, and GLH.

The more chinaberry seed oil sprayed on TN1 plants, the fewer the insects surviving to adulthood and the poorer the growth. Adults died sooner and females laid fewer viable eggs on chinaberry oil-treated rice (Table 12).

Karanja oil against common insect pests. Karanja *Pongamia glabra* Vent., a tall leguminous tree widespread in India, is a source of nonedible oil. Rural people use karanja seed oil extensively for pest control and medicinal purposes. We evaluated karanja oil against BPH, WBPH, and GLH. Fewer BPH females settled on TN1 plants sprayed with karanja oil than on control plants (Table 13). The more oil, the better the repellancy. Similarly, BPH females on karanja oil-treated rice plants ate less. Karanja oil was toxic to BPH and WBPH at ≥20 μg/female (Table 14), but not to GLH.

Table 13. Settling and food ingestion of brachypterous biotype 1 BPH females on TN1 rice plants sprayed with karanja oil in a free-choice test. IRRI, 1984.

Concn (%)	Females (%) that settled on plants at indicated h after infestation[a]			Food ingested (mg/female) in 24 h[a]
	1 h	6 h	24 h	
0 (1.66% Teepol)	35 b	43 c	42 c	30.3 c
3	17 ab	18 ab	21 bc	26.6 c
6	21 ab	23 bc	23 bc	25.6 c
12	9 a	7 a	10 ab	16.5 b
25	18 ab	9 ab	4 a	8.9 a

[a]Av of 5 replications, 25 females per replication.

Table 14. Mortality of newly emerged BPH (biotype 1), WBPH, GLH females following topical application of karanja oil. IRRI, 1984.

Dose (μg/female)	Mortality at 24 h after application[a] (%)		
	BPH	WBPH	GLH
1	11 c	8 d	0 c
5	8 c	10 d	4 c
10	10 c	27 c	6 b
20	81 b	73 b	14 ab
50	98 a	96 a	40 a

[a]Mortality corrected using Abbott's formula; av of 5 replications, 10 insects per replication.

CHEMICAL CONTROL

Laboratory evaluation. Coded and commercial insecticides were evaluated in the laboratory against BPH, WBPH, and armyworm (AW).

Contact toxicity. Insecticide effectiveness as contact spray was evaluated using Potter's spray tower. Test insecticides were sprayed on BPH, GLH, and WBPH at 0.15% active ingredient, except for MK 936 and DCH at 0.01%. Of 15 chemicals and 5 mixtures, 14 were effective on BPH, 16 on GLH, and 15 on WBPH (Table 15).

Eggs and larvae of AW were evaluated by dipping them in insecticide solutions for 30 s. Of 11 insecticides, 10 (azinphos ethyl, carbofuran, carbosulfan, chlorpyrifos + BPMC, cypermethrin, diazinon, methomyl, triazophos, carbaryl, and monocrotophos) were effective on 1-d-old eggs. Three insecticides were evaluated against first- to sixth-instar larvae by dipping. All (triazophos, monocrotophos, and carbaryl) killed more than 80% of 1st- to 5th-instar larvae, but only triazophos was consistently effective on the 6th instar.

Seventeen insecticides and two mixtures were evaluated by dipping sixth-instar AW larvae. All but acephate and bendiocarb were effective, showing more than 80% mortality 48 HT (Table 16). However, 100% mortality in 24 HT came only with triazophos, monocrotophos, azinphos ethyl, chlorpyrifos + BPMC, diazinon, isazophos, and PP 321.

Foliar spray. TN1 plants were sprayed with insecticides and infested with untreated insects 1 d after spraying. Rates were usually 0.75 kg ai/ha and spray volume 500 litres/ha.

Of 15 insecticides and 5 mixtures, 6 insecticides were effective on BPH, 16 on GLH, and 8 on

Table 15. Laboratory evaluation of 15 insecticides and 5 mixtures by contact toxicity against BPH, GLH, and WBPH. IRRI insectary, 1984.

Insecticide[a]	Mortality 48 HT[b]		
	BPH	GLH	WBPH
Test 1			
Carbofuran 12 F	●	○	●
WL 108477 25 WP	●	○	●
Cypermethrin + profenofos 2.5 and 40EC	●	○	○
Cypermethrin + profenofos 4 and 40EC	●	○	○
Cypermethrin + profenofos Q 2.5 and 40EC	●	○	○
Cypermethrin + diazinon 5 and 55EC	●	○	●
Monocrotophos 30 EC	○	●	○
Furathiocarb 40 EC	○	●	○
BAS 263 31 I 48 EC	●	●	○
DCH 20 EC		●	
Thiodicarb 34 F			
MK 936 1.8 EC	●	●	●
Test 2			
PP321 2.5 EC		●	
PP563 10 EC		●	
Isazophos 50 EC	○	○	○
Carbofuran 12 F	○	●	○
FMC 4428 5 F	●		●
Bendiocarb 20 WP		●	●
Fenitrothion + fenvalerate 40 and 1 EC	●	●	○
FMC 67878 10 EC	●		○
NK 8116 10 EC			

[a] Applied at 0.15% ai except for MK 936 and DCH at 0.01%, carbofuran at 0.05% ai, PP563 and PP321 at 0.0083, and NK8116 at 0.33% ai. Spray volume was 2 ml/replication. [b] Av of 4 replications, 20 insects/replication. ● = ⩾ 80% mortality, ○ = 100% mortality.

Table 16. Laboratory evaluation of 17 insecticides and 2 mixtures as dip against 6th-instar larvae of AW. IRRI insectary, 1984.

Insecticide[a]	Accumulated mortality[b]	
	24 HT	48 HT
Test 1		
Triazophos 40 EC	○	○
Monocrotophos 30 EC	○	○
Azinphos ethyl 40 EC	○	○
Chlorpyrifos + BPMC 21 and 10.5 EC	○	○
Diazinon 20 EC	○	○
Carbosulfan 20 EC	●	○
Methomyl 18 EC	●	○
Carbaryl 85 WP	●	●
Carbofuran 12 F	●	●
Cypermethrin 5 EC	●	○
Acephate 75 WP		
Test 2		
Isazophos 50 EC	○	○
PP 321 2.5 EC	○	○
LAB 137 385 I 50 EC	●	○
OK 385 30 EC	●	○
OK 135 30 EC	●	●
Fenitrothion + fenvalerate 40 and 1 EC	●	●
PP563 10 EC		○
Bendiocarb 20 WP		

[a] Solution contained 0.15% ai except for carbofuran at 0.10%, cypermethrin 0.01% ai (vol/vol), PP321 and PP563 0.005% ai (vol/vol). [b] Sixth-instar larvae were dipped into each solution for 30 s. ● = ⩾ 80% mortality, ○ = 100% mortality.

Table 17. Laboratory evaluation of 15 insecticides and 5 mixtures as foliar spray against BPH, GLH, and WBPH. IRRI insectary, 1984.

Insecticide[a]	Mortality at indicated DAT[b]								
	BPH			GLH			WBPH		
	1 d	5 d	10 d	1 d	5 d	10 d	1 d	5 d	10 d
				Test 1					
Carbofuran 12 F	●			○	○		●	○	
FMC 67878 10 EC	●			○			●		
Bendiocarb 20 WP	●			●			●		
FMC 4428 5 EC	●			●			●		
Isazophos 50 EC				●			●		
PP321 2.5 EC				●	●				
Fenitrothion + fenvalerate 40 and 1 EC				●			●		
PP 563 10 EC				●	●				
NK8116 10 EC									
				Test 2					
WL 108477 25 WP									
BAS 263 31 I 48 EC									
MK 936 1.8 EC	●						●		
DCH 20 EC				●					
Furathiocarb 40 EC				●					
Thiodicarb 34 F				●					
Cypermethrin + profenophos 4 and 40 EC				●					
Cypermethrin + profenophos 2.5 and 40 EC				●					
Cypermethrin + profenophos Q 2.5 and 40 EC				●					
Cypermethrin + diazinon 5 and 55 EC				●					
Carbofuran 12 F									
Monocrotophos 30 EC	●			○			●	●	

[a] Applied at 0.75 kg ai/ha except for PP563 and PP321 at 0.025, NK8116 at 0.10, MK 936 and DCH at 0.05, and carbofuran at 0.25 kg ai/ha (vol/vol). Spray volume was 500 litres/ha (3.125 ml/potted plants). [b] Av of 4 replications. ● = ⩾ 80% mortality, ○ = 100% mortality. DAT = d after treatment.

WBPH (Table 17). But residue effect was less than 5 d except for carbofuran, PP 321, and PP 563 against GLH, and carbofuran and monocrotophos against WBPH.

Eleven insecticides were evaluated for AW mortality, leaf damage, and yield loss (Table 18). Triazophos, monocrotophos, and azinphos ethyl caused high mortality (93-98%), low leaf damages, and low yield loss; methomyl, acephate, carbosulfan, and carbofuran caused moderate mortalities, moderate leaf damage, but low yield loss. Cypermethrin caused a low mortality (58%), low leaf damage, and low yield loss and may have a repellent effect. Chlorpyrifos + BPMC caused the highest yield loss despite a high mortality (93%).

Of 9 other insecticides, LAB 137 385 I, PP 321, OK 135, and OK 385 caused high mortalities and low leaf damage, whereas isazophos caused high mortality (90%) but high leaf damage (Table 19).

Thus, high mortalities do not always show low leaf damages and low yield losses. For example, triazophos showed 90-100% mortality up to 14 DAT and the lowest leaf damage of 1%, whereas cypermethrin showed 5-32% mortality but the 2d lowest leaf damage of 9% 14 DAT (Table 20).

Insecticide-calcium peroxide seed treatment. Of 7 insecticides, acephate, carbofuran, chlorpyrifos, fenthion, and prothiofos were not effective and only isofenphos and carbosulfan showed high BPH mortalities up to 25 to 30 DAT but lower GLH mortality. Thus, the two insecticides were tested further with and without calcium-peroxide (cal-per) seed coating against BPH (Table 21) and GLH (Table 22). Each insecticide performed similarly with and without cal-per coating.

Field evaluation. *Foliar spray.* Eleven insecticides were sprayed on IR29. Last-instar larvae of AW were allowed to feed on the sprayed plants. Triazophos, monocrotophos, carbofuran, azinphos ethyl, BPMC + chlorpyrifos, and carbosulfan are

Table 18. Laboratory evaluation of 11 commercial insecticides as foliar spray against AW.[a] IRRI insectary, 1984.

Insecticide[b]	Mortality[c]	Leaf damage[d] (%)	Grain loss[e] (%)
Triazophos 40 EC	●	8 a	1.3 a
Chlorpyrifos + BPMC 21 and 10.5 EC	●	31 b	15.8 c
Monocrotophos 30 EC	●	6 a	3.3 a
Azinphos ethyl 40 EC	●	5 a	6.7 ab
Methomyl 18 EC		19 b	4.9 a
Acephate 75 WP		31 b	3.3 a
Carbosulfan 20 EC		28 b	3.4 a
Carbofuran 12 F		28 b	4.1 a
Cypermethrin 5 EC		5 a	4.2 a
Carbaryl 85 SP		51 c	13.8 bc
Diazinon 20 EC		84 d	10.1 abc
Check		96 e	96.0 d

[a]IR36 with the panicles fully emerged was sprayed and infested with 10 6th-instar larvae/potted plant. [b]Applied at 0.75 kg ai/ha except for carbofuran at 0.40 and cypermethrin at 0.05 kg ai/ha (vol/vol). Spray volume was 3.125 ml/potted plant (=500 litres/ha). [c]Untreated 6th-instar larvae were caged on sprayed plants 1 DAT and mortality was recorded 2 d after releasing larvae. ● = ⩾ 80% mortality. [d]Based on 10 tillers/pot. 0 = no leaf damage, 100 = all leaves eaten. [e]Grain detached from 10 panicles/pot. Av of 4 replications.

Table 19. Laboratory evaluation of 4 commercial and 5 coded insecticides as foliar spray against AW.[a] IRRI insectary, 1984.

Insecticide[b]	Mortality[c]	Leaf damage[d] (%) at 2 DAT
Triazophos 40 EC	○	6 c
LAB 137 385 I 50 EC	○	9 de
OK 135 30 EC	●	9 de
Isazophos 50 EC	●	21 efg
PP 321 2.5 EC	●	3 a
OK 385 30 EC	●	4 b
Fenitrothion + fenvalerate 40 and 1 EC	●	13 def
PP 563 10 EC		8 d
Bendiocarb 20 WP		33 fg
Check		95 g

[a]Av of 4 replications. [b]IR36 with the panicles fully emerged was sprayed and infested with 10 6th-instar larvae/potted plant. Applied at 0.75 kg ai/ha except for PP 321 and PP 563 at 0.025 kg ai/ha (vol/vol). Spray volume was 3.125 ml/potted plant (= 500 litres/ha). [c]Untreated 6th-instar larvae were caged on sprayed TN1 potted plants 1 DAT and mortality was recorded 2 d after releasing larvae. ● = ⩾ 80% mortality, ○ = 100% mortality. [d]Based on 10 tillers/pot: 0 = no leaf damage, 100 = all leaves eaten.

promising in causing mortality. In mortality and defoliation, triazophos is the best followed by carbosulfan (Table 23).

These 11 insecticides were also tested against RWM, but none was effective.

Granules. Seven granular insecticides were broadcast into paddy water at 1, 20, 35, 50, and 65 DT. Against BPH and WBPH, no insecticide (isazophos, cartap + MIPC, diazinon, propaphos, propoxur, profenofos, and carbofuran) showed any promising results.

Seed treatment. Eleven insecticides (bendiocarb 50 WP, carbofuran 35 ST, carbosulfan 5 G, diazinon 5 G, disulfoton 5 G, disulfoton + PHC 3+2 G, formetanate 50 WP, furathiocarb 40 SD, isazophos 3 G, propaphos 5 G, and thiodicarb 75 WP) were applied as pregermination seed dressing at 0.75 kg ai/ 100 kg dry seeds per ha. Mortalities of BPH, GLH, and WBPH adults 48 HAI at 12, 17, 22, 27, and 32 d after seeding (DAS) were 0 to 70% on direct seeded IR22 in 1984 WS. However, results are inconclusive because populations of these

Table 20. Laboratory evaluation of 11 commercial insecticides as foliar sprays against AW. IRRI insectary, 1984.

Insecticide[a]	Mortality 48 HAI at indicated DAT[b]			Leaf damage (%) at indicated DAT[c]		
	1	7	14	1	7	14
Triazophos 40 EC	●	●	○	5 a	4 a	1 a
Monocrotophos 30 EC	●	●		7 b	12 ab	42 ab
Chlorpyrifos + BPMC 21 and 10.5 EC	●			21 def	41 c	94 c
Azinphos ethyl 40 EC	●			13 cd	24 bc	41 ab
Methomyl 18 EC				8 c	40 c	86 b
Carbosulfan 20 EC				18 cde	49 c	87 b
Cypermethrin 5 EC				5 a	10 a	9 a
Acephate 75 WP	●			40 ef	89 e	96 d
Carbaryl 85 SP				20 cdef	42 c	100 d
Carbofuran 12 F				39 ef	81 d	100 d
Diazinon 20 EC				86 f	92 ef	100 d
Check				92 f	99 f	100 d

[a]Applied at 0.75 kg ai/ha except for carbofuran at 0.40 and for cypermethrin at 0.05 kg ai/ha (vol/vol). Spray volume was 3.125 ml/potted plant (= 500 litres/ha). [b]Mortality of 6th-instar larvae was checked 48 h after inoculation (HAI). ● = ⩾80% mortality, ○ = 100% mortality. [c]0 = no damage, 100 = all leaves eaten.

Table 21. Laboratory evaluation of 2 insecticides as seed coating with and without calcium peroxide (cal-per) against BPH. IRRI insectary, 1984.

Insecticide[a]	Adult mortality[b] (%) at indicated DAT					
	13	18	23	28	33	38
Flooded with 5-cm water						
Isofenphos 40 DS + cal-per	●	○	●	●	●	
Isofenphos 40 DS		○	●	●	○	●
Carbosulfan 25 ST + cal-per	●					
Carbosulfan 25 ST	●	●				
Cal-per						
Saturated soil						
Isofenphos 40 DS + cal-per	○	○	●	●	●	
Isofenphos 40 DS	○	●	●	●	●	
Carbosulfan 25 ST + cal-per	●					
Carbosulfan 25 ST	○					
Cal-per						

[a]Each insecticide at 0.5 kg ai was applied to 50 kg seeds before coating seeds with cal-per. Cal-per and seed ratio was 1:1 (wt/wt). Infestation was started after seedlings emerged from water surface. [b]Av of 4 replications. ● = ⩾ 80% mortality, ○ = 100% mortality.

Table 22. Laboratory evaluation of 2 insecticides as seed coating with and without cal-per against GLH. IRRI insectary, 1984.

Insecticide[a]	Adult mortality[b] (%) at indicated DAT					
	13	18	23	28	33	38
Flooded with 5 cm water						
Isofenphos 40 DS + cal-per						
Isofenphos 40 DS		●	●	●		
Carbosulfan 25 ST + cal-per						
Carbosulfan 25 ST	●					
Cal-per						
Saturated soil						
Isofenphos 40 DS + cal-per	●	●		●	●	
Isofenphos 40 DS	●	●				
Carbosulfan 25 ST + cal-per						
Carbosulfan 25 ST	●					
Cal-per						

[a]Each insecticide at 0.5 kg ai was applied to 50 kg seeds before coating seeds with cal-per. Cal-per and seed ratio was 1:1 (wt/wt). Infestation was started after seedlings emerged from water surface. [b]Av of 4 replications. ● = ⩾ 80% mortality.

insects in untreated plots were very low. These chemicals were not effective on RWM and LF but were very effective in preventing deadhearts caused by SB 40 DAS.

Black bug in Palawan. In DS, of 16 conventional insecticides and 3 synthetic pyrethroids, 5 (monocrotophos, deltamethrin, fenthion, carbosulfan, and acephate) showed promising results as foliar spray.

In WS, the five and five other chemicals which showed promising results in 1983 were tested at different rates. Deltamethrin (0.025 kg ai/ha), permethrin (0.100), carbosulfan (0.750), and monocrotophos (0.75) showed good results, but endosulfan (0.75) and fenthion (0.75) were inferior to

Table 23. Field evaluation of 11 conventional insecticides as foliar spray against last-instar larvae of AW on IR29. IRRI, 1984.

Insecticide[a]	Mortality[b] (%) 48 h after infestation						Defoliation[e] (%)											
	1st application[c] 26 DT			2d application 77 DT[d]			1st application 26 DT[c]						2d application 77 DT[d]					
	1 DAI	3 DAI	7 DAI	1 DAI	3 DAI	7 DAI	1 DAI		3 DAI		7 DAI		1 DAI		3 DAI		7 DAI	
Triazophos 40 EC	○	○		●	●		7.5	c	10.0	a	22.5	a	3.8	a	7.3	b	18.1	a
BPMC + chlorpyrifos 31.5 EC	●			●			11.3	cde	35.0	de	36.3	b	12.0	b	17.0	def	35.0	cd
Azinphos ethyl 40 EC	●	●		●			5.0	b	15.0	a	48.8	c	8.9	b	20.8	efg	31.3	bcd
Monocrotophos 30 EC	○	●		○	●		5.0	b	22.5	bc	35.0	b	6.0	a	5.4	a	28.8	bcd
Diazinon 20 EC							33.8	ef	73.8	f	47.5	c	36.3	c	28.8	fg	24.4	b
Carbofuran 12 F	○	●		●			2.5	a	13.8	a	22.5	a	4.6	a	7.6	c	29.4	bcd
Carbosulfan 21.6 EC	●			●			5.0	b	46.3	def	41.3	bc	8.3	a	15.6	def	32.5	cd
Methomyl 20 EC	●				●		10.0	cd	20.0	b	41.3	bc	8.9	b	7.4	b	24.4	b
Acephate 75 WP	●						13.8	cdef	52.5	ef	42.5	bc	14.1	b	14.6	cde	28.1	bc
Carbaryl 85 SP							16.3	def	30.0	cd	35.0	b	19.0	bc	15.8	def	35.6	de
Cypermethrin 5 EC	●	●					8.8	c	11.3	a	36.3	b	18.5	bc	12.8	cd	28.1	bc
Check							85.0	f	83.8	f	63.8	d	41.9	c	38.1	g	44.4	e

[a] Applied at 0.75 kg ai/ha except cypermethrin at 0.05 kg ai/ha. [b] ● = ⩾ 80% mortality, ○ = 100% mortality. DAI = d after infestation. [c] Ten larvae/2 hills per plot; insects placed on undamaged plants at 1, 3, 7 DAI. [d] Twenty larvae/2 hills per plot; insects placed on undamaged plants at 1, 3, 7 DAI. [e] Av of 2 hills/plot. Rating: 0-9. Ten sample hills/plot. 0 = no damage, 9 = 100% leaves damaged.

deltamethrin, permethrin, carbosulfan, and monocrotophos.

Of six insecticides in another evaluation, three (dicrotophos, profenofos + cypermethrin, and metamidophos) showed promise as foliar spray. Profenofos + cypermethrin was especially effective even at 0.22 kg ai/ha.

Of 4 granular insecticides, only carbofuran showed promising results 7 to 12 DAT.

Pipe duster. MIPC 2% dust formulation was applied in 2 maximum yield trial plots (0.5 ha each) at IRRI at 0600-0630 29 Mar, using knapsack-type power applicator (Maruyama NP150) with a 25-m plastic pipe. In one plot, 8 kg dust/0.5 ha was applied in 4 min by 2 operators. In the other plot, 14 kg dust/0.5 ha was applied in 8 min by 1 operator. The MIPC 2% dust effectively suppressed GLH populations in staggered rice cropping in both plots. In the first plot, dusting reduced GLH from an average of 15 adults/10 sweeps (range 4.2-29.4) to 4 adults/10 sweeps (range 1.0-9.8). In the second plot, GLH were reduced from 23.5 (6.2-41.9) to 5.1 (1.0-11.7).

Control of vegetative stage insects. RWM is the key pest of lowland rice in the Philippines. In over 50 trials in 1976-83 in 5 provinces, 47% of decisions to use insecticide based on economic thresholds involved RWM. In yield loss trials using the insecticide-check method, 50-70% of an average yield reduction of 1 t/ha at Nueva Ecija and Pangasinan was attributed to RWM and associated leaf-feeding insects (Table 24).

Although soil incorporation of carbofuran G before transplanting is often recommended, farmers hesitate to apply an extensive input without first seeing an immediate need.

Previous trials eliminated diazinon G broadcast into paddy water as feasible because of lack of water control in most irrigated fields. Diazinon G being non-systemic requires continuous standing water for efficacy. We compared synthetic pyrethroids with monocrotophos as foliar sprays in DS. Earlier work recommended at least two foliar sprays, especially during 1-2 wk after transplanting. Monocrotophos and triazophos, the best foliar insecticides for RWM, do not work well in the rainy season. Monocrotophos, less expensive than triazophos, served as check alongside carbofuran. Cypermethrin was applied by knapsack and by electrostatic Electrodyn sprayers. Applications were

Table 24. Yield losses from insect pests at 3 crop growth stages in 2 Philippine locations with high pest pressure, 1984.

Year	Season	Yield loss (t/ha)			
		Total	Vegetative stage	Reproductive stage	Ripening stage
			Irrigated transplanted rice — Nueva Ecija		
1979	Dry	0.5	0.5	0	0
	Wet	2.4	1.1	0.8	0.5
1980	Dry	0.4	0.2	0.2	0
1982	Wet	0.9	0.2	0.1	0.6
1983	Dry	0.9	0.5	0.2	0.2
	$\bar{X}$	1.0	0.5	0.3	0.2
			Rainfed transplanted rice — Pangasinan		
1976	Wet	0.9	0.9	0	0
1977	Wet	0.8	0.8	0	0
1978	Wet	1.6	0.9	0.7	0
1979	Wet	1.3	0.4	0.4	0.5
1980	Wet	0.4	0.4	0	0
	$\bar{X}$	1.0	0.7	0.2	0.1

at 2, 9, 15 DT, but that at 15 DT did not improve control.

Carbofuran was ovicidal and gave more than 80% control of RWM damage. Carbofuran G-treated plots received fewer eggs. Roots take up carbofuran, which moves to the leaves and passes out the hydathodes into the air. Therefore a fumigant may have repelled ovipositing RWM and killed eggs. No other insecticide reduced oviposition, but others (cypermethrin, deltamethrin, and monocrotophos) were ovicidal. Cypermethrin was ovicidal applied with a knapsack but not by Electrodyn.

Deltamethrin gave outstanding LF control. Only carbofuran G failed to control LF.

All insecticides effectively controlled green semilooper and green hairy caterpillar. We continue to search for better control of RWM. Carbofuran works well as a prophylactic, but we seek technology more responsive to RWM populations on a field to field basis.

Insectistatics. Buprofezin 50 WP (molting inhibitor) was sprayed on TN1 at 5 different rates to control BPH in the laboratory. The results suggest 12.5 g ai/ha is sufficient for effective control.

Combinations of buprofezin and a synthetic pyrethroid (cypermethrin) were evaluated for BPH and GLH female adult mortality and BPH progeny population. These results may suggest that combinations of buprofezin + cypermethrin (WP or EC) 25 + 12.5 or 50 + 25 g ai/ha are acceptable, despite low mortalities (50-70% to adults).

Seven insectistatics (a molting inhibitor, growth regulators, and a combination) were evaluated on AW and SSB by dipping. All chemicals (DU 415 146, DU 415 155, SIR 8514, LAB 141 305 I, LAB 149 525 I, HOE 522, and a combination of buprofezin and cypermethrin) were effective on the larvae of these two lepidopteran pests.

Five insectistatics were evaluated for contact toxicity and as foliar spray against BPH, GLH, and WBPH nymphs. Against BPH, buprofezin was excellent as both contact and foliar treatment, buprofezin + cypermethrin was excellent as contact treatment but less so as foliar spray. Against GLH and WBPH, buprofezin and buprofezin + cypermethrin belonged to the best group. As foliar spray, DU 415 155 was effective against GLH and WBPH. Other sprays (DU 415 146, LAB 141 305 I, and LAB 149 525 I) were not effective.

Practical application of buprofezin to suppress BPH populations was tested on IR8 in a maximum yield trial at IRRI in 1984 DS and WS. One application during one peak period suppressed BPH.

A coded neurotoxin, WL 108477, and BPMC were foliar sprayed every 10 or 14 d depending on the experiments. At 0.250-0.500 kg ai/ha, either was effective on BPH, but neither was promising on GLH, LF, RWM, SB, or RTV.

Carbofuran effectiveness at different pH values. The effect against BPH and GLH of carbofuran 3 G incorporated into the soil at different soil and floodwater pH levels was examined. Carbofuran

Table 25. Effect of different levels of soil and floodwater pH values on efficacy of carbofuran 3G against BPH and GLH.[a] IRRI insectary, 1984.

pH[b] value ± 0.5		Adult female mortality (%) at indicated DAT							
		BPH				GLH			
Soil	Water	1	5	10	15	1	5	10	15
6	7	100 a	100 a	100 a	54 a	100 a	100 a	100 a	60 ab
7	8	100 a	100 a	100 a	59 a	100 a	99 a	100 a	80 a
8	9	100 a	99 ab	100 a	61 a	100 a	100 a	100 a	58 ab
9[c]	9	95 a	84 b	74 b	50 a	83 b	98 a	95 b	44 b
10[d]	10	98 a	96 ab	–	–	91 ab	90 a	–	–
6[e]	7	5 b	9 c	15 c	4 b	1 c	5 b	6 a	4 c

[a]Av of 4 replications. Carbofuran 3G incorporated into the soil at 1.0 kg ai/ha. Plants were infested with 20 insects per replication. [b]pH was adjusted by mixing sodium peroxide into the soil. [c]Plants started wilting at 10 DAT. [d]Plants started wilting at 1 DAT and were dead at 10 DAT. [e]No insecticide treatment.

controlled BPH and GLH well at all pH levels; however, it performed significantly poorer at pH 9-10 than at pH 6-8 because plants wilted or died (Table 25).

Susceptibility of brown planthopper, green leafhopper, and rice bug to insecticides. *LD_{50} values by topical application.* LD_{50} values were obtained for BPH brachypterous adult females at 4 different temperatures. The values are different for BPMC but not for carbofuran (Table 26).

LD_{50} values of monocrotophos for five instars and adult females of rice bug (RB) are presented. The lowest value was for adult females and the highest for the 4th instar (Table 27).

LD_{50} values of 3 carbamates for BPH, GLH, and RB are given in Table 28. BPH and GLH are most susceptible to carbofuran.

Insecticide susceptibility of BPH at IRRI farm in 1984 was monitored. Resistance ratio of BPH was the highest of 1.3-10.0 for monocrotophos and the lowest of 1.6-1.8 for MIPC. The range for carbofuran was 1.3-2.4 (Table 29).

Table 26. LD_{50} values for BPH brachypterous adult females at 4 different temperatures. IRRI phytotron, Oct 1984.

Temperature (°C)	LD_{50}[a] (μg/g, 24 h)	
	BPMC	Carbofuran
18	1.46 bc	0.05 a
24	0.72 b	0.02 a
27	0.57 a	0.02 a
33	0.50 a	0.01 a

[a]Av of 3 replications, 20 females per replication.

At 40 locations including IRRI farm (Fig. 17), BPH were collected. LD_{50} values for 5 popular insecticides were compared, using adult females (Fig. 18). The values fluctuated considerably among locations. For example, LD_{50} of monocrotophos was lowest (0.544 μg/g) at location 36 and highest (24.877 μg/g) at location 40.

Foliar spray and contact toxicity. BPH 5th-instar

Table 27. LD_{50} values of monocrotophos for different stages of RB. IRRI Insectary, 1984.

Stage	LD_{50}	
	μg/g	μg/insect
First instar	0.52 c	0.70 a
Second instar	0.62 c	1.70 b
Third instar	0.56 c	4.85 c
Fourth instar	0.89 d	16.24 e
Fifth instar	0.37 b	39.11 f
Adult (♀)	0.06 a	9.73 d

Table 28. LD_{50} values of 3 carbamates for 3 insect pests of rice. IRRI insectary, 1984.

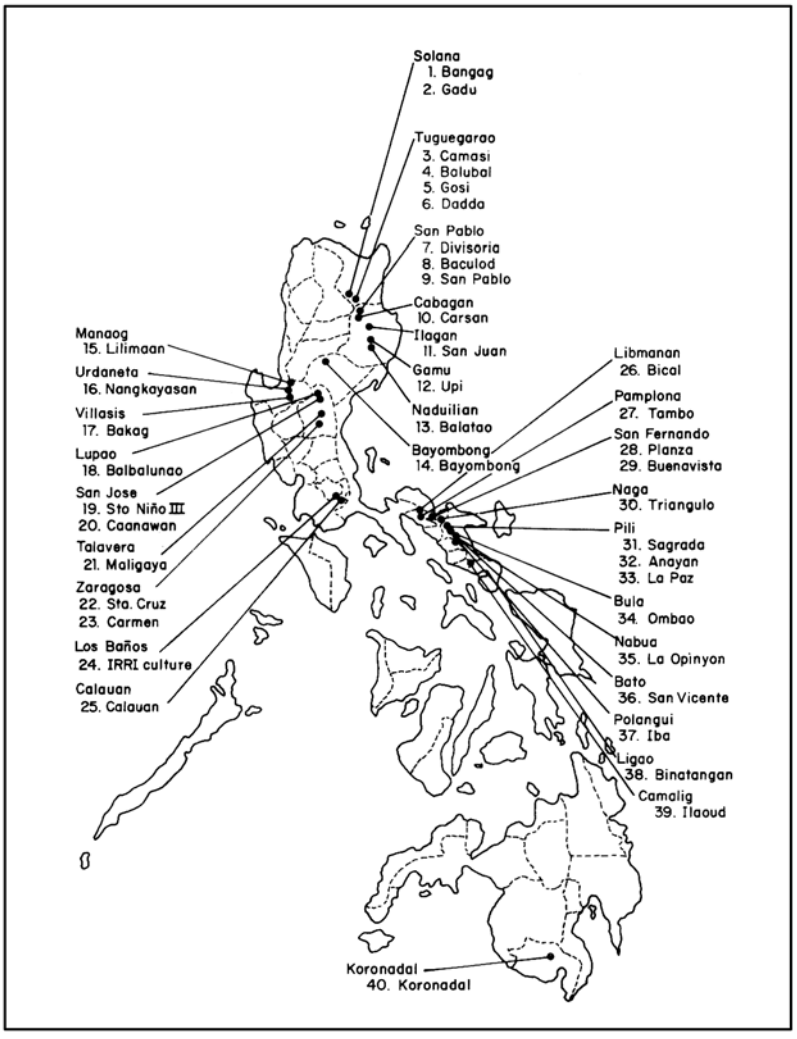
Insect	Insecticide	LD_{50} (μg/g)
BPH[a]	BPMC	1.38
	Carbofuran	0.44
	Mexacarbate	2.77
GLH	BPMC	2.80
	Carbofuran	1.08
	Mexacarbate	4.21
RB	BPMC	0.14
	Carbofuran	0.12
	Mexacarbate	0.24

[a]Brachypterous.

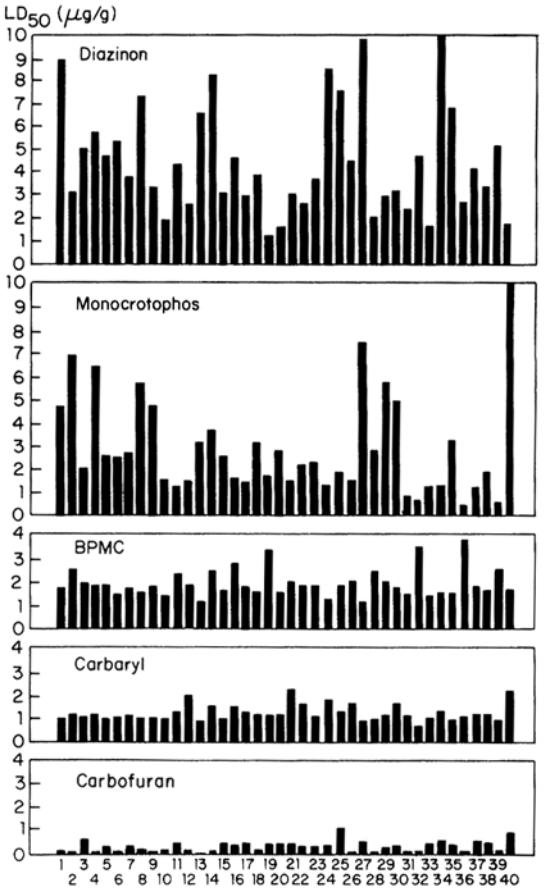
Table 29. Insecticide susceptibility levels of BPH macropterous adult females at IRRI farm, 1984.

Insecticide	LD_{50} (μg/g, 24 h)					
	2d generation from field-collected population[b]		Insecticide-free greenhouse population[c]		Resistance ratio[a]	
	Feb (Apr)[d]	Mar (Jun)[e]	Feb (Apr)	Mar (Jun)	Feb (Apr)	Mar (Jun)
BPMC	2.20	–	0.57	–	3.86	–
Carbaryl	7.80	7.96	2.75	3.24	2.84	2.46
Carbofuran	1.82	0.97	0.77	0.73	2.36	1.33
Diazinon	37.40	–	11.75	–	3.18	–
Endosulfan	13.10	–	4.79	–	2.73	–
MIPC	14.70	5.23	9.43	2.98	1.56	1.75
Monocrotophos	8.04	11.46	6.15	1.13	1.30	10.14
MTMC	4.38	13.00	2.64	2.99	1.66	4.35

[a] RR = LD_{50s} for second generation from field population/LD_{50s} for greenhouse population. [b] Macropterous adult females in 2d generation. [c] Brachypterous adult females. [d] Field population collected in February and macropterous adult females of 2d generation tested in April. [e] Field population collected in March; those tested in June.



17. Collection sites of BPH material for LD_{50} assessment in 1983.



18. LD_{50} of 5 popular insecticides to BPH macropterous adult females within 2 generations from the field populations collected at 40 locations. Brachypterous ones from location 24 (IRRI greenhouse culture) were used as the standard. IRRI, 1983.

nymphs collected at IRRI in February 1984 and a greenhouse insecticide-free population maintained since about 1975 were compared for susceptibility to foliar sprays and contact insecticides. All nine insecticides with both treatments killed fewer field BPH than greenhouse insecticide-free insects (Fig. 19).

Granule effect on natural enemies. Seven granular insecticides were broadcast in paddy water where IR22 was transplanted. Spider populations were not reduced except by isazophos at 36 and 43 DT and cartap + MIPC at 36 DT (Table 30).

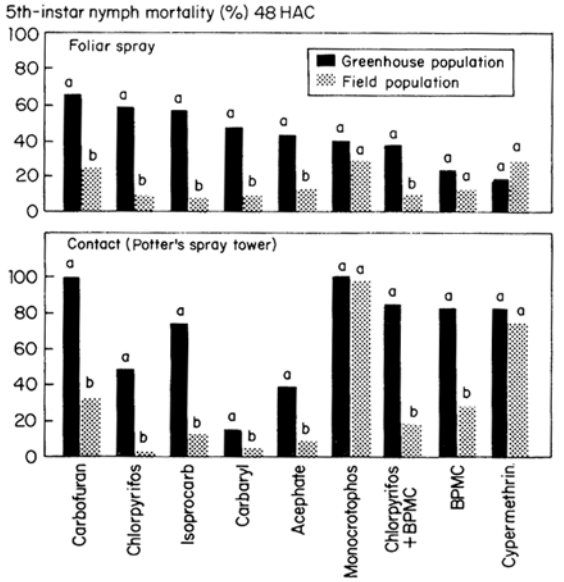
Rice tungro virus prevention on susceptible rice cultivars. To prevent RTV by killing the vector GLH with insecticides, six field trials were conducted at IRRI. Rice seedlings were covered with nylon mesh in the seedbed.

Foliar spray. Four insecticides were applied as foliar spray 8 times weekly starting 1 DT. With cypermethrin, 8% of hills showed RTV symptoms on IR22 and 10% on TN1 at 60 DT; with MTI 500, RTV showed on 8% of IR22 and 22% of TN1. Untreated plots showed 30% and 82% (Table 31).

Broadcast. Of seven broadcast granules (isazophos, cartap + MIPC, diazinon, propaphos, propoxur, profenfos, and carbofuran), isazophos showed 12% RTV-infected hills at 60 DT compared to 49% in untreated plots, and the best value in GLH nymph and adult population suppression effect.

Soil incorporation of granules and foliar spray. Combinations of soil incorporated carbofuran 3 G and foliar spray of deltamethrin 2.5 EC and buprofezin 50 WP were applied at different rates. All treated plots were significantly lower (38-48%) in RTV-infected hills than untreated control plots (82%).

Broadcast and foliar spray. Four commercial and two coded insecticides were applied twice



19. Susceptibility of the IRRI greenhouse insecticide-free BPH and of field BPH collected at IRRI in February 1984. Test insects were caged 1 DAT. Bars with the same letter for 2 populations for each insecticide were not significantly different at the 5% level. HAC = h after caging.

Table 30. Effect on spiders (*Lycosa*) of 7 granular insecticides broadcast. IRRI, 1984 WS.

Insecticide[a] (1 kg ai/ha)	*Lycosa* (no.) caught by FARMCOP/10 hills							
	10 DT	17 DT	22 DT	29 DT	36 DT	43 DT	50 DT	57 DT
Isazophos 3 G	2 a	4 a	4 ab	10 a	6 b	8 c	12 a	44 a
Cartap + MIPC 4 and 5 G	1 a	6 a	6 a	11 a	7 b	18 ab	18 a	22 a
Diazinon 5 G	2 a	5 a	6 a	17 a	13 ab	13 bc	16 a	34 a
Propaphos 5 G	1 a	5 a	6 a	15 a	17 a	23 a	16 a	28 a
Propoxur 4 G	2 a	4 a	6 a	11 a	16 ab	18 ab	10 a	23 a
Profenofos 3 G	1 a	6 a	6 a	14 a	16 ab	20 ab	18 a	24 a
Carbofuran 3 G	2 a	6 a	4 ab	16 a	18 a	14 abc	17 a	25 a
Control	1 a	6 a	2 b	14 a	16 a	19 ab	22 a	28 a

[a]Applied at 1, 20, 35, 50, and 65 DT.

Table 31. Field evaluation of 4 insecticides to prevent RTV on IR22 and TN1 by foliar spray after transplanting. IRRI, 1984 WS.

Insecticide[a]	Rate (kg ai/ha)	Hills (%) showing RTV symptoms			
		IR22		TN1	
		40 DT	60 DT	40 DT	60 DT
MTI 500 20 EC	0.100	3.99 ab	7.75 a	11.15 c	21.73 abc
Cypermethrin 5 EC	0.050	3.34 a	7.80 a	4.93 ab	9.55 a
Alphamethrin 10 EC	0.0125	3.63 a	11.54 ab	8.67 bc	21.29 abc
Deltamethrin 2.5 EC	0.0125	5.41 abc	14.38 abc	8.98 bc	29.65 bc
Control	—	9.48 c	30.34 c	22.19 d	81.86 d

[a]Applied at 1, 8, 15, 22, 29, 36, 43, and 50 DT in Oct 1984 to Jan 1985.

Table 32. Field evaluation of 8 granular insecticides to prevent RTV on IR22 by seedbox treatment followed by foliar spray. IRRI, 1984 WS.

Insecticide[a]	RWM rating		GLH adult mortality[b] (%)		GLH adults (no./10 sweeps)				RTV-infected hills (%)
	25 DT	35 DT	5 DAT	10 DAT	1 WAT	2 WAT	3 WAT	4 WAT	60 DT
Disulfoton 5 G + FS	3.30 c	4.43 d	●	○	0.25 a	6.25 ab	3.75 ab	0.50 c	1.25 b
Carbosulfan 5 G + FS	3.75 c	4.93 cd	●	●	0.50 a	5.25 ab	4.25 ab	0.00 c	0.47 b
Carbofuran 3 G + FS	3.43 c	5.03 cd	●	●	0.50 a	12.25 a	3.50 ab	1.00 c	0.47 b
Cartap 4 G + FS	3.68 c	5.80 bc	○		0.25 a	3.50 ab	1.75 b	0.50 c	0.47 b
Disulfoton 5 G	6.08 b	6.03 abc	○	●	0.25 a	4.00 ab	3.75 ab	5.50 b	2.34 b
Carbosulfan 5 G	7.30 ab	6.15 abc	●		0.25 a	8.25 ab	2.50 ab	7.25 b	4.38 b
Carbofuran 3 G	7.01 ab	6.38 ab			0.50 a	7.50 ab	3.00 ab	9.00 b	1.72 b
Cartap 4 G	6.83 ab	6.48 ab			0.25 a	2.25 b	2.75 ab	11.50 ab	2.50 b
Control	7.65 a	7.23 a			0.75 a	7.25 ab	6.50 a	36.50 a	29.22 a

[a]Granules applied on seedlings grown in seedboxes 1 DBT. Foliar sprays (FS) of deltamethrin, monocrotophos, and MIPC alternatively and weekly starting 2 WT up to 65 DT. [b]● = ⩾ 80% mortality, ○ = 100% mortality.

except for carbofuran 3 G, applied once. Plots sprayed with deltamethrin (12.5 g ai/ha) and S423 (at 1,000 g ai/ha) showed significantly less (34-45%) RTV-infected hills at 50 DT than the untreated plots (66%). After the first application at 10 DT, GLH mortalities were 61% in S423 (1,000 g ai/ha), 59% in MIPC, and 41% in deltamethrin (12.5 g ai/ha).

Seedling root dip and foliar spray. Two insecticides, deltamethrin and S534, were applied as seedling-root dip and spray and compared to BPMC as the standard check under very high pressure of RTV. The plots sprayed by S534 three times showed less RTV infection (44%) than those by deltamethrin (80%) at 81 DT. The BPMC control showed 70% infection.

Seedbox treatment and foliar spray. Combinations of four granular insecticides and foliar sprays of three insecticides were evaluated, using a seedbox treatment. Granules were applied to the seedbox 1 d before transplanting (DBT) and foliar application was from 2 wk after transplanting to 65 DT (3 times with both deltamethrin and monocrotophos, and twice with MIPC). Untreated plots showed 29% RTV-infected hills, but the 6 treated plots showed 0.5-4.4% at 60 DT (Table 32).

Control and management of rice pests

Weeds

Agronomy Department

HERBICIDE SCREENING **218**
- Irrigated transplanted rice **218**
  - Preliminary screening **218**
  - Secondary screening **218**
  - Advanced trials, IRRI and BPI **218**
  - Time of herbicide application **218**
- Irrigated wet-seeded rice **219**
  - Preliminary screening **219**
  - Secondary screening **219**
  - Advanced trials, IRRI and BPI **219**
  - Time of herbicide application **220**
- Rainfed transplanted rice **222**
  - Preliminary screening **222**
- Rainfed wet seeded rice **222**
  - Secondary screening **222**
- Dry seeded rice **222**
  - Preliminary screening **222**
  - Advanced evaluation **222**
- Upland rice **224**
- Deep water rice **224**

PERENNIAL WEEDS AND THEIR CONTROL **224**
- Transplanted rice **224**
- Direct seeded flooded rice **225**
- Management and control of *Scirpus maritimus* **226**

2,4-D LOW-VOLUME APPLICATION TECHNIQUES **226**
- Performance of controlled drop applicators **226**
  - Effect on weeds **228**
  - Dose or droplet number **228**
  - Concentration and dose **229**
  - Droplet size and dose **229**
  - Formulation and droplet size **230**
  - Formulation and dose **230**

HERBICIDE SCREENING

Research to identify herbicides for weed control in rice continued at IRRI, at the Maligaya, Bicol, and Visayas research stations of the Philippine Bureau of Plant Industry (BPI), and in a farmer's field in Batangas Province.

Echinochloa crus-galli ssp. *hispidula*, *Echinochloa glabrescens*, *Monochoria vaginalis*, and *Cyperus difformis* were common at all lowland sites. *Echinochloa colona*, *Eleusine indica*, *Digitaria ciliaris*, *Commelina diffusa*, and *Cyperus iria* were dominant in the upland fields.

Irrigated transplanted rice. *Preliminary screening.* No significant differences between treatments were observed because of low weed population. However, BAS 514 herbicide was safe to transplanted rice (TPR) but SC 0254 caused leaf yellowing and crop stunting (Table 1).

Secondary screening. No granular herbicide controlled the predominant *Scirpus maritimus*, and rice yields were similar to that of the untreated check (Table 2).

Advanced trials, IRRI and BPI. All herbicides at IRRI and Bicol gave significantly higher yields than the untreated check in dry season (DS) (Table 3). At Maligaya, yields did not differ significantly among treatments; weed infestation was low. At IRRI, the hand-weeded (HW) check and all herbicides except pendimethalin gave comparable yields. At Bicol all herbicide treatments yielded significantly less than the HW check.

In wet season (WS), all plots with herbicide treatments and HW and untreated checks gave similar yields at IRRI and Bicol, and except for the oxyfluorfen-treated plot at Maligaya (Table 4). At Visayas, all herbicide treatments yielded significantly more than the untreated check, but only the DPX 5384 treatment gave yield comparable to that of the HW check. Yields at IRRI, Maligaya, and Bicol were low because the crop lodged badly.

Time of herbicide application. When averaged across herbicide treatments, weed weights did not significantly differ among application times (3 d before transplanting and 0, 6, and 9 d after transplanting [DT]). Weed weights at 50 DT in plots treated with butachlor — 2,4-D, DPX 5384, and pretilachlor — safener were not significantly different from those of the HW check. Weed

Table 2. Effect of promising granular herbicides applied before weed emergence (2 DAT) on weed control and IR36 yield.[a] IRRI, 1984 DS.

Treatment	Rate (kg ai/ha)	Weed wt[b] (g/m^2)	Yield (t/ha)
HW check[c]	—	3 a	4.8 a
Butachlor check	1.0	87 b	1.8 b
X-52 B	1.0	182 c	1.7 b
A-6754A	0.8	88 b	1.5 b
A-6754A	0.4	88 b	1.4 b
MY 93E	2.0	172 bc	1.1 b
BAS 514	0.3	210 c	1.0 b
MY 93E	1.0	195 bc	0.9 b
X-52 B	0.5	181 c	0.8 b
Untreated check	—	149 bc	0.8 b

[a] Av of 4 replications. [b] Predominantly *Scirpus maritimus*. [c] HW at 14 and 36 DT.

Table 1. Effects of herbicides on weed control, crop tolerance, and yield of irrigated transplanted IR58. IRRI, 1984 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2)			Visual rating[c] of toxicity to rice	Rice yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Broadleaf weeds	Grasses	Sedges		
BAS 514 WP	0.3	4	1 a	42 a	6 a	0	4.4 a
MO-butachlor EC	1.0	3	4 ab	12 a	0 a	4	4.4 a
SC 0254 DF	2.0	4	0 a	9 a	0 a	4	4.3 a
Thiobencarb — 2,4-D check	1.5	3	2 ab	38 a	6 a	0	4.3 a
Naproanilide — butachlor	1.0	3	1 ab	34 a	10 a	3	4.3 a
HW[d] check	Twice	15 + 30	16 ab	4 a	0 a	0	4.2 a
SC 0254 G	2.0	3	0 a	11 a	0 a	4	4.2 a
MO-butachlor G	2.0	3	1 a	35 a	13 a	4	4.2 a
BAS 514 G	0.3	3	28 b	10 a	0 a	0	3.9 a
Untreated check	—	—	18 ab	27 a	0 a	0	3.7 a

[a] A spaced dash (—) means 2 herbicides were applied as a proprietary mixture. [b] Av of 3 replications. [c] Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity, 10 = complete kill. [d] Hand weeded.

Table 3. Effect of granular herbicides applied before weed emergence (4 DT) on IR36 yield at 3 locations in the Philippines, 1984 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Bicol
HW check[c]	–	5.7 a	4.6 a	5.1 a
DPX 5384	0.05	5.1 ab	4.9 a	4.5 b
Naproanilide – thiobencarb	1.0 - 0.7	5.7 a	4.1 a	4.6 b
Butachlor	1.0	5.9 a	4.0 a	4.3 bc
Molinate – simetryn – MCPB	0.83 - 0.05 - 0.05	5.3 ab	4.5 a	4.1 c
Piperophos – 2,4-D	0.3 - 0.2	4.6 ab	3.6 a	4.6 b
2,4-D	0.8	4.3 ab	4.6 a	3.6 d
Pendimethalin	0.75	3.7 b	3.8 a	4.4 bc
Oxyfluorfen	0.14	4.5 ab	3.5 a	3.7 d
Untreated check	–	1.6 c	3.5 a	2.8 e
CV (%)		23.2	20.9	5.1

[a]A spaced dash (–) means that 2 or more herbicides were applied as a proprietary mixture. [b]Av of 4 replications/site. [c]HW at 15 and 35 DT.

Table 4. Effect of granular herbicides applied before weed emergence (4 DT) on IR36 yield at 4 locations in the Philippines, 1984 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
HW check[c]	–	3.3 a	3.2 a	2.8 ab	5.2 a
DPX 5384	0.05	3.3 a	3.1 a	2.6 ab	5.0 ab
2,4-D	0.8	3.9 a	2.5 a	3.1 a	4.3 de
Pendimethalin	0.75	3.6 a	3.1 a	2.4 ab	4.6 cd
Butachlor	1.0	4.1 a	2.4 ab	2.7 ab	4.4 cd
Naproanilide – thiobencarb	1.0 - 0.7	3.3 a	2.9 a	2.6 ab	4.7 bc
Piperophos – 2,4-D	0.3 - 0.2	3.1 a	2.4 ab	2.7 ab	4.7 bc
Molinate – simetryn – MCPB	0.83 - 0.05 - 0.05	3.9 a	2.5 a	2.1 b	4.4 cd
Oxyfluorfen	0.14	3.8 a	1.6 b	2.0 b	4.4 cd
Untreated check	–	3.0 a	2.9 a	2.3 ab	4.0 e
CV (%)		20.5	20.0	22.9	5.2

[a]A spaced dash (–) means that 2 or more herbicides were applied as a proprietary mixture. [b]Av of 4 replications/site. [c]HW at 15 and 35 DT.

control was poor (weed weights were not significantly different from the unweeded check) with thiobencarb, 2,4-D, piperophos – 2,4-D, and pendimethalin.

Irrigated wet seeded rice. *Preliminary screening.* Except for pyridate alone, all herbicides gave direct seeded rice yields significantly higher than the untreated checks (Table 5). The BAS 514 compounds controlled weeds effectively, caused slight crop toxicity, and the granule gave significantly higher yield than the thiobencarb – 2,4-D check and other herbicides. Naproanilide – butachlor, SC O254, and the pyridate compounds were highly toxic to irrigated direct seeded rice.

Secondary screening. Only BAS 514 at 0.5 kg ai/ha gave significantly lower weed weight and more yield than the untreated check. Other herbicide treatments (A-6754A, X-52B, MY93E, BAS 514 at 0.3 kg ai/ha) did not differ significantly in weed weight and grain yield from the untreated check.

Advanced trials, IRRI and BPI. In DS at IRRI, direct seeded rice with DPX 5384, naproanilide – thiobencarb, oxyfluorfen, and thiobencarb – 2,4-D yielded significantly more than the untreated check (Table 6). The molinate – simetryn – MCPB combination was severely toxic to rice and gave significantly less yield than other chemicals. All

Table 5. Effect of herbicides on weed control, crop tolerance, and yield of irrigated, direct seeded IR58. IRRI, 1984 WS.

Treatment[a]	Application		Weed wt[c] (g/m^2)			Visual toxicity rating[d]	Yield[c] (t/ha)
	Rate (kg ai/ha)	Time (DAS)[b]	Broadleaf weeds	Grasses	Sedges		
BAS 514 G	0.3	6	0 a	0 a	2 a	2	4.3 a
BAS 514 WP	0.3	6	0 a	0 a	1 a	3	3.6 ab
Thiobencarb – 2,4-D check	1.5	6	0 a	6 ab	54 b	3	3.3 bc
MO-butachlor EC	1.0	6	34 bc	13 ab	10 ab	4	3.1 bc
Naproanilide – butachlor G	2.0	6	5 ab	27 bc	52 b	6	2.6 bc
SC 0254 G	2.0	6	38 c	6 ab	12 ab	6	2.6 bc
SC 0254 DF	2.0	6	39 c	2 ab	32 b	6	2.4 c
MO-butachlor G	2.0	6	18 abc	98 cd	8 a	3	2.4 c
Pyridate – MCPA WP	2.0	29	0 a	134 d	0 a	5	1.3 d
Pyridate EC	1.0	29	0 a	94 cd	0 a	6	0.6 de
Untreated check	–	–	43 c	69 cd	57 ab	0	0 e

[a]A spaced dash (–) means 2 herbicides were applied as a proprietary mixture. [b]Days after seeding. [c]Av of 3 replications. [d]Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity, 10 = complete kill.

Table 6. Effect of early postemergence (6-8 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at 3 locations in the Philippines, 1984 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Bicol
DPX 5384	0.05	5.4 a	4.2 ab	5.0 ab
Naproanilide – thiobencarb	1.0 - 0.7	3.9 abc	4.8 a	5.2 a
Oxyfluorfen	0.14	4.4 ab	3.3 bc	5.1 a
Piperophos – 2,4-D	0.3 - 0.2	3.6 abcd	4.5 a	4.6 b
Butachlor + 2,4-D	0.75 - 0.5	3.4 bcd	4.7 a	4.6 b
Thiobencarb – 2,4-D	1.0 - 0.5	4.1 abc	4.0 ab	3.9 c
Butachlor	1.0	2.4 cd	4.7 a	3.7 c
Pendimethalin	0.75	2.4 cd	2.0 d	5.0 ab
Molinate – simetryn – MCPB	0.83 - 0.05 - 0.05	0.3 e	2.9 c	4.8 ab
Untreated check	–	1.9 de	1.8 d	3.1 d

[a]A spaced dash (–) means that 2 or more herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately at about the same time. [b]Av of 4 replications/site.

herbicides at Bicol and Maligaya, except the pendimethalin treatment, gave significantly higher yields than the untreated check.

In WS at IRRI, all herbicide-treated plots, except pendimethalin, butachlor, and molinate – simetryn – MCPB plots, gave significantly higher yields than the untreated plot (Table 7). Yields of all herbicide-treated plots at Maligaya (except the butachlor + 2,4-D plots), at Bicol, and at Visayas (except the DPX 5384 plots) were comparable with the yields of untreated plots. At Maligaya, butachlor + 2,4-D treatment gave markedly lower yield than the untreated check. At Visayas, the DPX 5384-treated plot yielded significantly higher than the untreated. Yields at Maligaya were extremely low because the crop lodged severely.

Time of herbicide application. Crop stand was greatly affected by the herbicide applied and the application time (Table 8). All herbicides except DPX 5384 applied at 0.05 kg ai/ha reduced crop stand at some application time. The greatest stand reductions were caused by thiobencarb applied 6 d after seeding (DAS) and butachlor applied at 0, 3, and 6 DAS. All herbicides reduced stands compared to the HW check except DPX 5384 at 0.05 kg ai/ha at all application times, thiobencarb – 2,4-D applied at 3 d before seeding (DBS), pretilachlor – safener at 3 DBS, and DPX 5384 at 0.075 kg ai/ha at 6 DAS.

Butachlor applied at 6 DAS gave the poorest weed control. Treatments which controlled weeds as well as the HW check were DPX 5384 applied at

Table 7. Effect of early postemergence (6-8 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at 4 locations in the Philippines, 1984 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
DPX 5384	0.05	3.9 a	1.9 a	2.3 ab	4.0 a
Naproanilide – thiobencarb	1.0 - 0.7	3.6 ab	1.3 abc	2.5 ab	3.7 ab
Piperophos – 2,4-D	0.3 -0.2	2.9 ab	1.7 ab	2.6 a	3.7 ab
Thiobencarb – 2,4-D	1.0 - 0.5	3.2 ab	1.6 ab	2.3 ab	3.7 ab
Oxyfluorfen	0.14	3.0 ab	1.1 bc	2.6 a	3.5 abc
Butachlor + 2,4-D	0.75 - 0.5	3.6 ab	0.8 c	2.4 ab	3.1 c
Pendimethalin	0.75	2.1 bc	1.1 bc	2.2 ab	3.7 ab
Butachlor	1.0	2.5 abc	1.0 bc	2.1 ab	3.3 bc
Molinate – simetryn – MCPB	0.83 - 0.05 - 0.05	2.3 abc	1.3 abc	1.7 b	3.3 bc
Untreated check	–	1.3 c	1.6 ab	1.8 ab	3.3 bc

[a]A spaced dash (–) means that 2 or more herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately at about the same time. [b]Av of 4 replications/site.

Table 8. Effect of time of application of different herbicides on stand count, weed weight, and yield of wet-seeded rice. IRRI, 1984.

Treatment[a]	Application		Rice stand count (no./m^2)	Weed wt (g/m^2)	Yield (t/ha)
	Rate (kg ai/ha)	Time			
Butachlor	0.75	3 DBS	110 de	47 bcdef	2.4 a
		0 DAS	42 fgh	53 bcdef	0.5 b
		3 DAS	34 gh	64 cdef	0.1 b
		6 DAS	33 gh	366 g	0.0 b
Butachlor	1.0	3 DBS	80 ef	52 bcdef	2.3 a
		6 DAS	23 h	135 efg	0.0 b
Thiobencarb	1.5	3 DBS	76 ef	51 bcdef	1.6 a
		6 DAS	19 h	40 bcdef	0.3 b
2,4-D	0.8	3 DBS	158 bcd	60 cdef	2.1 a
		6 DAS	113 de	50 bcdef	1.8 a
Butachlor – 2,4-D	0.75	3 DBS	152 bcd	110 def	2.1 a
		6 DAS	79 ef	35 bcd	2.6 a
Thiobencarb – 2,4-D	1.0	3 DBS	190 abc	62 bcdef	2.0 a
		6 DAS	59 fg	19 ab	2.5 a
Pretilachlor – safener	0.5	3 DBS	157 bcd	15 abc	2.7 a
		0 DAS	111 de	34 bcdef	2.3 a
		3 DAS	201 ab	41 abcd	2.6 a
		6 DAS	158 bcd	46 bcdef	2.8 a
DPX 5384	0.05	3 DBS	208 ab	95 def	1.9 a
		0 DAS	184 abc	62 bcdef	1.9 a
		3 DAS	172 abcd	33 bcde	2.8 a
		6 DAS	178 abc	46 bcdef	2.6 a
DPX 5384	0.075	3 DBS	138 bcd	58 cdef	1.9 a
		0 DAS	152 bcd	40 bcdef	2.5 a
		3 DAS	127 cde	27 abc	2.5 a
		6 DAS	195 ab	18 abc	2.5 a
HW		21 + 45 DAS	234 a	5 a	2.7 a
Untreated check		–	157 bcd	180 fg	0.4 b

[a]A dash (–) means herbicides were applied as a proprietary mixture.

0.075 kg ai/ha at 3 and 6 DAS, pretilachlor – safener applied at 3 DBS and 3 DAS, and thiobencarb – 2,4-D applied at 6 DAS.

Yields were low because of tungro. However, yields from all the plots except those treated with butachlor and thiobencarb after seeding were not

significantly different from the untreated check. When weed control was good, the crop compensated for stand reductions as high as 75%, as with thiobencarb – 2,4-D applied 6 DAS, by producing more tillers per plant.

In a greenhouse trial, herbicides were applied at different times to determine rice seedling mortality and growth when plants were flooded to a depth of 5 cm immediately after seeding. IR60 was the test cultivar and herbicides were applied before sowing (3 and 6 d), at sowing (0 d), and after sowing (2, 4, 6, and 8 d). Trays were drained 6 DAS to promote better root anchorage, and reflooded to 5 cm 3 d later.

Butachlor, thiobencarb, and thiobencarb – 2,4-D were toxic to seedlings regardless of application time, and they reduced stands from 32 to 100% at 14 DAS. When herbicides were applied from 0 to 4 DAS, no seedlings survived by 21 DAS. In other treatments, surviving seedlings were shorter and smaller.

Rainfed transplanted rice. *Preliminary screening.* The weed population in rainfed TPR was low; however, BAS 514 compounds reduced grassy weeds by about 70% and had 16% more yield than thiobencarb – 2,4-D and 30% more than the untreated checks. SC 0254 and pyridate herbicides stunted plants (Table 9).

Rainfed wet seeded rice. Except for BAS 514, other herbicides were slightly to severely toxic to rice. Toxicity significantly reduced grain yields in the pyridate treatments (Table 10).

Secondary screening. The dominant weed was the annual sedge *Fimbristylis littoralis*. DPX 5384 was relatively safe and gave yields significantly higher than the untreated and butachlor checks (Table 11). X-52B also performed significantly better than did butachlor. DPX 5384 + butachlor severely reduced the initial stand and appeared more toxic to rice than each applied singly.

Dry seeded rice. *Preliminary screening.* In dry-seeded rice (DSR), the major weeds in order of decreasing predominance were *E. colona*, *C. iria*, *C. diffusa*, *D. ciliaris*, and *Eriochloa procera*. All herbicide-treated plots had significantly lower weed weights than the unweeded check (Table 12), but no herbicide controlled weeds as well as did the HW check.

Yields were low because of rice bug infestation. All herbicide treatments except oxadiazon + DPX 5384 gave significantly higher yields than the untreated check. Treatments with grain yields comparable to the HW check were DPX 5384 + pendimethalin, oxadiazon + thiobencarb, and butachlor applied sequentially.

Advanced evaluation. Major weeds in order of decreasing predominance were *E. colona*, *C. iria*, *D. ciliaris*, *E. indica*, and *Eclipta alba*. Bromoxynil – MCPA caused stunting and yellowing and, like fluazifop-butyl – 2,4-D, failed to control grasses. Pendimethalin + fluazifop-butyl controlled grasses but failed to control broadleaf weeds and sedges. Propanil – MCPA – oxyfluorfen also failed to control grasses adequately (Table 13).

Table 9. Effect of herbicides on weed control, crop tolerance, and yield of rainfed TPR IR58. IRRI, 1984 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2)		Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Grasses	Sedges		
BAS 514 G	0.3	5	31 cdef	10 abcd	0	3.0 a
BAS 514 WP	0.2	4	38 bcde	12 abcd	1	3.0 a
HW check	Twice	15 & 30	3 a	0 a	0	2.9 a
SC 0254 DF	2.0	4	7 ab	19 abcd	4	2.9 a
Naproanilide – butachlor G	2.0	5	57 def	23 bcd	3	2.8 a
SC 0254 G	3.0	5	10 abc	1 ab	5	2.7 a
MO-butachlor EC	1.0	4	44 cdef	33 d	3	2.7 a
Pyridate – MCPA WP	2.0	29	75 cdef	4 abc	5	2.7 a
MO-butachlor EC	2.0	5	28 bcd	28 abcd	3	2.5 a
Thiobencarb – 2,4-D check	1.5	5	13 abcd	30 cd	0	2.5 a
Pyridate WP	1.0	29	86 ef	2 abc	5	2.2 a
Untreated check	–	–	113 f	16 abcd	0	2.1 a

[a] A spaced dash (–) means 2 herbicides were applied as a proprietary mixture. [b] Av of 4 replications. [c] Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity, 10 = complete kill.

Table 10. Effect of herbicides on weed control, crop tolerance, and yield of rainfed wet-seeded IR58. IRRI, 1984 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2)		Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Broadleaf weeds	Grasses		
Untreated check	–	–	2 ab	10 a	0	3.5 a
SC 0254	2.0	7	0 a	2 a	6	3.4 a
BAS 514 WP	0.3	11	13 ab	11 a	2	3.2 a
Thiobencarb – 2,4-D check	1.5	7	13 ab	9 a	3	3.2 a
BAS 514 WP	0.2	11	6 ab	3 a	0	3.2 a
Naproanilide – butachlor G	2.0	7	56 b	7 a	7	3.0 a
MO-butachlor EC	1.0	11	19 ab	8 a	3	3.0 a
Pyridate EC	2.0	11	19 ab	2 a	7	2.2 b
Pyridate – MCPA WP	1.0	11	10 ab	1 a	6	2.0 b

[a] A spaced dash (–) means 2 herbicides were applied as a proprietary mixture. [b] Av of 4 replications. [c] Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity, 10 = complete kill.

Table 11. Effect of herbicides on weed control, stand count, crop tolerance, and yield of rainfed wet-seeded IR58. IRRI, 1984 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2)		Stand count at 30 DAS[b] ($no./m^2$)	Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Grasses	Sedges			
DPX 5384 G	0.075	6	2 a	14 a	280 a	1	3.8 a
X-52B G	0.75	6	0 a	30 a	256 a	2	3.6 ab
2,4-D IPE G	0.6	6	0 a	22 a	264 a	3	3.4 abc
Thiobencarb – 2,4-D G	1.5	6	2 a	30 a	200 ab	3	3.3 abc
Butachlor – 2,4-D EC	1.0	10	0 a	16 a	272 a	3	3.2 abc
DPX 5384 + 2,4-D IPE G + G	0.05 + 0.5	6	2 a	12 a	256 a	1	3.1 abc
DPX 5384 + butachlor G + G	0.025 + 0.5	6	2 a	30 a	152 b	8	3.0 abc
Untreated check	–	–	4 a	32 a	288 a	0	2.6 bc
Butachlor G	0.75	6	0 a	38 a	232 ab	4	2.5 c

[a] A spaced dash (–) means 2 herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately. [b] Av of 3 replications. [c] Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity, 10 = complete kill.

Table 12. Effect of different herbicide treatments on weed weight and yield of dry-seeded rice. IRRI, 1984.

Treatment[a]	Application[b]		Yield (t/ha)	Total weed wt at 40 DE[c] (g/m^2)
	Rate (kg ai/ha)	Time (DAS)		
HW	–	–	1.9 a	0 a
DPX 5384 + pendimethalin	0.05 + 1.0	3	1.7 ab	79 b
Butachlor	1.0 fb 1.0	3 fb 6	1.6 abc	77 b
Oxadiazon + thiobencarb	0.25 + 1.5	3	1.5 abc	69 b
DPX 5384 + thiobencarb	0.05 + 1.5	3	1.4 bc	105 b
Butachlor	2.0	3	1.4 bc	71 b
DPX 5384	0.1	3	1.3 bc	80 b
DPX 5384 + butachlor	0.05 + 1.0	3	1.3 bc	59 b
Oxadiazon + DPX 5384	0.25 + 0.05	3	1.1 cd	114 b
Untreated check	–	–	0.7 d	259 c

[a] + = tank mixture. [b] fb = followed by. [c] DE = d after crop emergence.

Other herbicides controlled weeds as well as did the HW check, and, except for the sequential propanil applications, yielded as high as the HW check.

Table 13. Effect of herbicide treatments on weed weight and yield of dry-seeded rice. IRRI, 1984.

Treatment[a]	Application		Weed wt (g/m^2)	Yield (t/ha)
	Rate (kg ai/ha)	Time		
Propanil – thiobencarb	1.93 - 1.07	10 DE	61 abc	2.9 a
HW	–	–	24 a	2.8 ab
Butachlor fb (butachlor + propanil)	1.0 fb (1.0 + 2.0)	3 DAS fb 20 DE	25 a	2.7 ab
Butachlor fb propanil	1.5 fb 2.0	3 DAS fb 10 DE	52 ab	2.6 ab
Molinate – propanil	1.9 - 1.9	20 DE	22 a	2.5 abc
Pretilachlor – safener	0.6	3 DAS	22 a	2.3 abc
Propanil + 2,4-D	2.0 + 0.5	20 DE	40 ab	2.2 abc
Propanil	3.0	10 DE	35 ab	2.2 abc
Pendimethalin fb 2,4-D	2.0 fb 0.5	3 DAS fb 20 DE	44 ab	2.0 abcd
Propanil fb propanil	2.0 fb 2.0	10 DE fb 20 DE	65 abc	1.9 bcd
Propanil – MCPA – oxyfluorfen	1.17 - 0.324 - 0.004	20 DE	80 bc	1.7 cd
Pendimethalin + fluazifop-butyl	1.0 + 0.08	20 DE	246 d	1.2 de
Fluazifop-butyl – 2,4-D	0.06 - 0.74	20 DE	152 cd	0.9 ef
Bromoxynil – MCPA	1.0 - 1.0	20 DE	149 cd	0.5 ef
Untreated check	–	–	332 d	0.2 f

[a] A dash (–) means herbicides were applied as a proprietary mixture; + = tank mixture; fb = followed by.

Upland rice. In an advanced trial in a Batangas farmer's field, all herbicide treatments gave significantly lower weed weight and markedly higher upland rice yields than the untreated check (Table 14). Plots treated with propanil yielded significantly less than the HW check.

Deep water rice. Herbicides were tested in a farmer's field of deep water rice variety Khao Puang near Ayutthaya, Thailand. Herbicides did not completely control *Echinochloa colona*, but both preemergence (Table 15) and postemergence herbicides (Table 16) reduced weed populations. The floodwater was deeper than normal (more than 150 cm) and grain yields were not significantly different between treatments.

Table 14. Effect of herbicides applied before weed emergence (4 DAS) on weed control and yield of upland rice IR36 in a farmer's field in Batangas, Philippines, 1984 WS.[a]

Treatment	Rate (kg ai/ha)	Weed wt[b] (g/m^2)	Yield (t/ha)
Dinitramine	1.5	32 cd	4.2 a
HW check[c]	–	7 ab	3.9 ab
Butachlor	2.0	10 ab	3.7 ab
Oxyfluorfen	0.5	4 a	3.7 ab
Oxadiazon	1.0	14 abc	3.6 ab
Pendimethalin	2.0	35 d	3.4 abc
Thiobencarb	3.0	24 bcd	3.4 abc
Butralin	2.0	53 d	3.1 bc
Propanil	2.0	22 bcd	2.7 c
Untreated check	–	191 e	0.7 d

[a] Av of 4 replications. [b] Sampled at 46 DE. [c] HW at 14 and 32 DE. Propanil was applied 14 DE.

PERENNIAL WEEDS AND THEIR CONTROL

Transplanted rice. Research on the long-term effect of tillage level (conventional, minimum, and zero) and cultivar type (IR34, IR40, and IR42) on weed shift continued in the 1984 DS (21st crop) and WS (22d crop). Conventional tillage was one plowing and two harrowings, minimum tillage was one harrowing, and zero tillage was cutting at ground level and removing rice and weed debris. In the 22d crop, the minimum and zero tillage plots were recultivated (prepared conventionally) because of heavy buildup of *Paspalum distichum*.

In the 21st crop, the total dry weed weight (biomass) was very high in the zero tillage plots (Fig. 1), significantly reducing yield (Table 17). However, tillage did not affect *S. maritimus* stand. Regardless of tillage intensity, *S. maritimus* biomass did not differ considerably in most cultivars. The annual weeds did not generally increase with a decrease in tillage level, but were always present in the zero tillage plots.

In the 22d crop, *P. distichum* stand decreased in the minimum and zero tillage plots (Fig. 1).

Table 15. Effect of preemergence herbicides on population density of *Echinochloa colona* in deep water rice in a farmer's field at Phu Khao Thong, Ayutthaya Province, Thailand. 1983 WS.

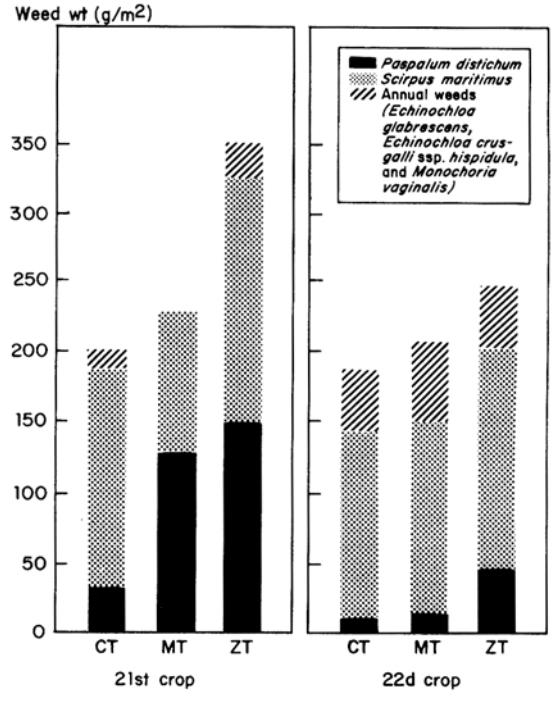
Treatment	Rate (kg ai/ha)	Weeds[b] (no./m^2)
Untreated chech	—	169 d
Oxyfluorfen	0.5	100 c
Thiobencarb	3.0	91 bc
Bifenox	2.0	74 abc
Butachlor	2.0	68 ab
Butachlor + 2,4-D	0.75 + 0.5	62 a
Butachlor + ioxynil–2,4-D	0.75 + 0.5	60 a
Oxadiazon	1.0	48 a

[a]A (+) means two herbicides were tank mixed and applied as a single treatment. A dash (—) means 2 or more herbicides were applied as a proprietary mixture. [b]Counted 70 d after spraying.

Table 16. Effect of postemergence herbicides on population density of *Echinochloa colona* in deep water rice crop in a farmer's field at Phu Khao Thong, Ayutthaya Province, Thailand. 1983 WS.

Treatment	Rate (kg ai/ha)	Weeds[b] (no./m^2)
Untreated check	—	191 d
2,4-D	0.75	206 d
Butachlor + propanil	0.8 + 1.5	88 c
Bromoxynil + MCPA	2.0	85 c
Propanil	2.0	77 bc
Ioxynil — 2,4-D	1.0	67 abc
2,4-D — propanil	2.0	67 abc
Oxadiazon + propanil	0.8 + 1.5	54 ab
Bifenox + propanil	1.5 + 1.5	53 ab
Ioxynil — 2,4-D — propanil	1.0	53 ab
Thiobencarb — propanil	2.0	47 a
Molinate — propanil	2.0	47 a

[a]A (+) means two herbicides were tank mixed and applied as a single treatment. A dash (—) means two or more herbicides were applied as a proprietary mixture.



1. Weed dry weights at harvest as indices of weed control by conventional tillage (CT), minimum tillage (MT), and zero tillage (ZT). Av of 3 cultivars. IRRI, 1984 DS and WS.

Although grain yields did not differ between tillages, the zero tillage plots still had significantly higher *P. distichum* stands than the conventional and minimum tillage plots planted to IR34 and IR40 (Table 17).

Direct seeded flooded rice. The long-term effect of tillage, cultivar, and herbicides applied at postemergence was examined in an experiment initiated in 1984 DS. The experiment used a factorial randomized complete block design replicated 3 times in an area kept in weedy fallow for 3 mo. The tillage levels were one harrowing, two harrowings, and three harrowings, each preceded by one plowing. The cultivars were semidwarf IR36 and intermediate tall IR29723-143-3-2-1. The herbicide treatments consisted of DPX 5384 (0.05 kg ai/ha) applied 10 DAS, propanil + 2,4-D (1.5 + 0.5 kg ai/ha) applied tank-mixed 15 DAS, and an untreated check. Shortly before the trial, 17 weed species were present.

In the first crop (DS), cultivar did not affect weed stand (Fig. 2). As tillage increased from one to three harrowings, *P. distichum* slightly decreased but *S. maritimus* and the annuals increased. *S. maritimus* and the annual weeds were controlled only with DPX 5384 and propanil + 2,4-D significantly increasing yields in IR36 plots that received one and three harrowings and in IR29723 plots that received two and three harrowings.

In the second crop (WS), three harrowings again gave the lowest *P. distichum* stand, but again did not reduce *S. maritimus* and annual weed infestations better than either one or two harrowings (Fig. 3). The IR29723 plots were only slightly less

Table 17. Effect of tillage on weed control and yield of the 21st and the 22d continuous rice crops.[a] IRRI, 1984 DS and WS.

Treatment[b]	IR34				IR40				IR42			
	Weed wt[c] (g/m²)			Yield (t/ha)	Weed wt[c] (g/m²)			Yield (t/ha)	Weed wt[c] (g/m²)			Yield (t/ha)
	Paspalum distichum	*Scirpus maritimus*	Annual weeds		*Paspalum distichum*	*Scirpus maritimus*	Annual weeds		*Paspalum distichum*	*Scirpus maritimus*	Annual weeds	
					21st crop, 1984 DS							
CT	15 a	208 a	11 a	3.0 a	23 a	128 a	0 a	2.5 a	25 a	123 ab	35 b	3.5 a
MT	81 b	117 a	3 a	2.8 a	189 b	91 a	0 a	2.3 a	122 b	91 a	0 a	2.7 b
ZT	92 b	151 a	16 a	0.8 b	282 b	170 a	18 b	0.6 b	81 b	208 b	42 b	0.9 c
					22d crop, 1984 WS							
CT	3 a	145 a	54 a	2.0 a	14 a	142 a	34 a	1.0 a	10 a	118 a	28 a	3.2 a
MT	4 ab	110 a	87 a	2.2 a	19 a	153 a	41 a	1.0 a	27 a	138 a	39 a	2.9 ab
ZT	13 b	186 a	52 a	1.6 a	96 b	167 a	55 a	0.7 a	19 a	129 a	31 a	2.1 b

[a] Av of 4 replications. [b] CT = conventional tillage, MT = minimum tillage, ZT = zero tillage. [c] Taken at rice harvest. Annuals were *Echinochloa glabrescens, E. crus-galli* ssp. *hispidula*, and *Monochoria vaginalis*.

weedy than the IR36 plots. Regardless of tillage level, the herbicide-treated plots had substantially less *S. maritimus* and annual weeds. Yields at both herbicide treatments were significantly higher than yields of the untreated IR36 plots harrowed once and thrice and IR29723 plots harrowed twice and thrice.

Results for both crops indicated no effect of cultivar type on weed control, a slight decrease in *P. distichum* with an increase in tillage level, and very effective control of *S. maritimus* and annual weeds and generally higher yield with DPX 5384 and propanil + 2,4-D.

Management and control of *Scirpus maritimus*. During DS, yield of rotary weeded plots in the continuous TPR pattern was significantly higher than yields of the herbicide-treated and the untreated check. Many *S. maritimus* escaped bentazon treatment and reduced yields, including on the untreated check (Table 18).

Where maize was intercropped with soybean, weeds did not greatly affect maize and soybean yields. Where maize was planted alone, it competed with weeds even in the untreated check.

In the continuous TPR pattern during WS, yields of herbicide-treated and rotary weeded plots were similar, and statistically higher than that of the untreated check of only 0.2 t/ha (Table 19).

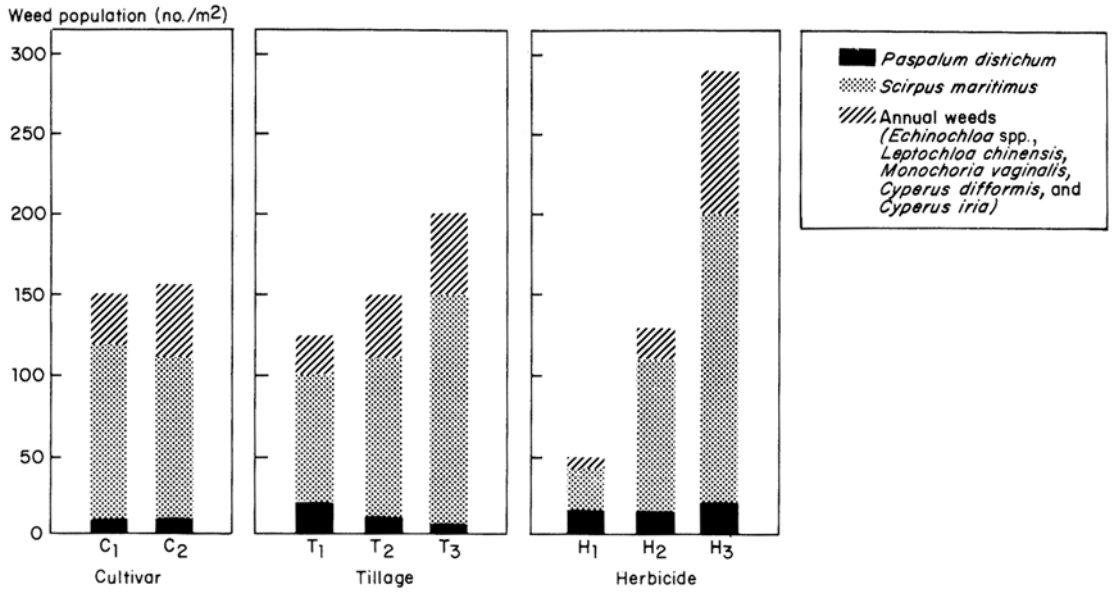
In the upland crop — TPR pattern, yield differences were similar to those in the continuously transplanted system. Yields of the untreated plot were low because of the annual sedge *F. littoralis*.

In the DSR rainfed bunded rice following maize, yields of 3 t/ha were obtained only with HW. The untreated and butachlor plots gave no yields due to buildup of *Macroptilium lathyroides* and *Ipomoea triloba*. *Cyperus* sp. was present only in the HW plots.

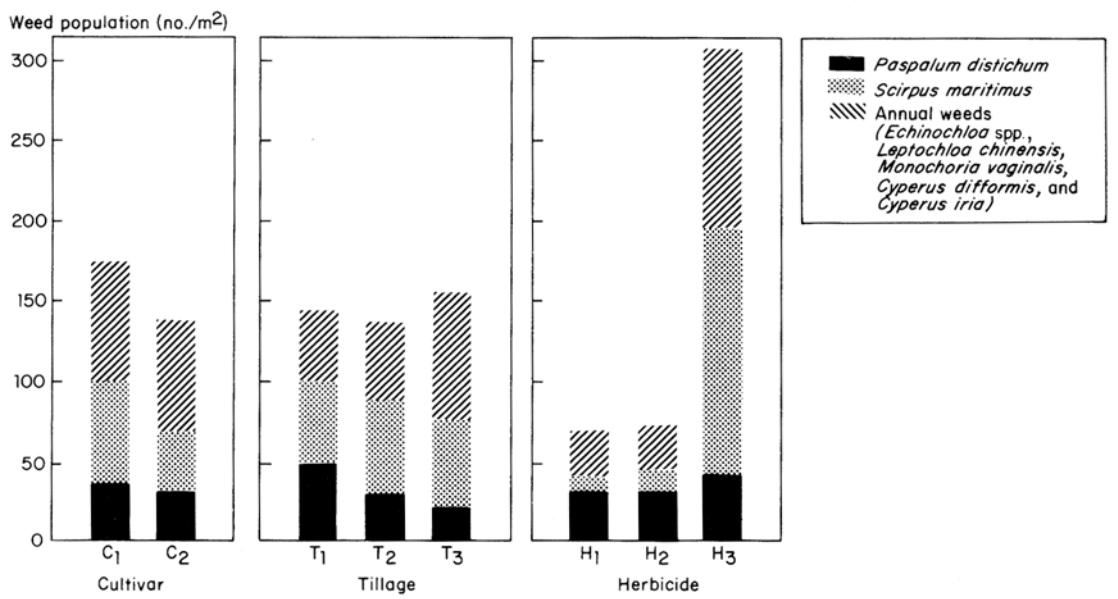
2,4-D LOW-VOLUME APPLICATION TECHNIQUES

Performance of controlled drop applicators. A greenhouse experiment further tested performance of the low-volume herbicide applicators Micronherbi and Birky, also called controlled drop applicators (CDA).

Three formulations of 2,4-D (dimethylamine salt, isopropyl ester [IPE], and isobutyl ester [IBE]) at 0.5 kg/ha were applied on 15-d-old *Ipomoea triloba* seedlings.



2. Weed population in the first crop as affected by cultivar (C_1 = IR36, C_2 = IR29723-143-3-2-1), tillage (T_1 = harrowing, T_2 = 2 harrowings, T_3 = 3 harrowings), and herbicide (H_1 = DPX 5384, H_2 = propanil + 2,4-D, H_3 = untreated). IRRI, 1984 DS.



3. Weed population in the second crop as affected by cultivar (C_1 = IR36, C_2 = IR29723-143-3-2-1), tillage (T_1 = 1 harrowing, T_2 = 2 harrowings, T_3 = 3 harrowings), and herbicide (H_1 = DPX 5384, H_2 = propanil + 2,4-D, H_3 = untreated). IRRI, 1984 WS.

Both sprayer type and 2,4-D formulation individually affected *I. triloba* fresh weight. Averaged over three formulations, 2,4-D applied with the Micronherbi reduced fresh weight better than when applied with the conventional knapsack. Birky performed intermediate between the two (Fig. 4). Averaged over three sprayer types, 2,4-D IPE and 2,4-D IBE performed better than 2,4-D amine.

Table 18. Effect of weeding method and cropping pattern on crop yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1984 DS.

Cropping pattern and weeding treatment	Yield/ha[a]	Weeds (no./m²)				
		Broadleaf weeds	Grasses	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous TPR	*Rice (t)*					
Rotary weeding	3.5 a	3	16	342	77	0
Bentazon (2.0)	1.3 b	0	23	141	367	0
No weeding	0.4 b	8	8	138	445	0
Upland crop — TPR	*Maize (ears) + soybean (kg)*					
HW	30,000 a + 699 a	75	6	0	0	11
Butachlor (1.5)	33,000 a + 752 a	29	14	0	29	3
No weeding	33,500 a + 653 a	46	10	0	21	13
Upland crop — rainfed bunded DSR	*Maize (ears)*					
HW	24,500 a	10	16	1	0	9
Butachlor (1.5)	23,000 a	60	10	0	0	0
No weeding	26,500 a	66	10	196	0	2

[a] Av of 2 replications.

Table 19. Effect of weeding method and cropping pattern on rice yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1984 WS.

Cropping pattern and weeding treatment	Yield[a] (t/ha)	Weeds (no./m²)				
		Broadleaf weeds	Grasses	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous TPR						
Rotary weeding	2.0 a	1	2	240	164	0
Bentazon (2.0)	1.8 a	4	7	89	131	0
No weeding	0.2 b	9	0	139	487	0
Upland crop — TPR						
Rotary weeding	2.4 a	0	0	177	91	0
Bentazon (2.0)	2.2 a	1	2	220	1	0
No weeding	0.3 b	0	2	328	297	0
Upland crop — rainfed bunded DSR						
HW	3.0 a	66	1	11	0	13
Butachlor (1.5)	0 b	97	0	0	0	0
No weeding	0 b	55	0	0	0	0

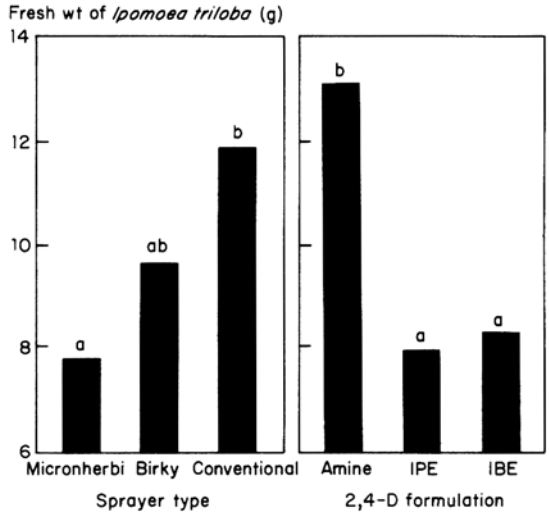
[a] Av of 2 replications.

In terms of dry weight, Figure 5 indicates that 2,4-D amine may be applied using any sprayer and produce similar control of *I. triloba*. With IPE, Birky performed better than the conventional knapsack. With IBE, Micronherbi did better than the conventional.

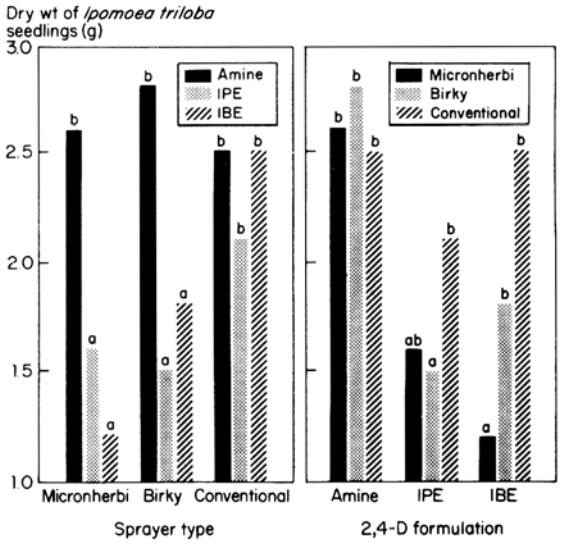
Using the conventional sprayer, the 2,4-D formulations similarly reduced *I. triloba* dry weight (Fig. 5). But with the CDA, 2,4-D IPE and 2,4-D IBE performed significantly better than 2,4-D amine.

Effect on weeds. Greenhouse experiments evaluated the relationship of dose to droplet number, concentration, droplet size, and formulation of 2,4-D on 7-d-old *I. triloba* seedlings. Using the single drop applicator manufactured by the Weed Research Organization at Oxford, UK, all treatments were applied uniformly as 300-μ drops, except where droplet size was a factor, on cotyledonary leaves of *I. triloba*.

Dose or droplet number. Four doses of 2,4-D amine (5.64, 11.28, 22.56, and 45.12 μg/seedling)



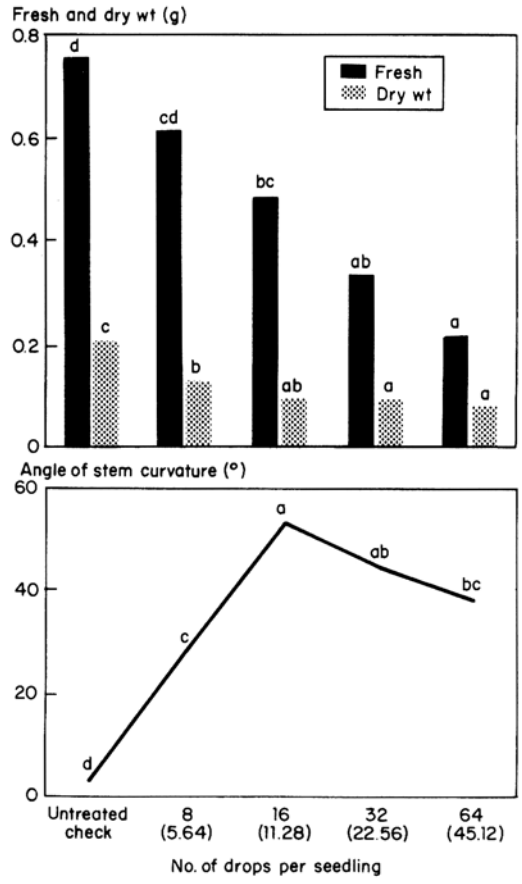
4. Effect of sprayer type and 2,4-D formulation on the fresh weight of *Ipomoea triloba* seedlings 11 d after treatment. IRRI, 1984.



5. Effect of sprayer type and 2,4-D formulation on the dry weight of *Ipomoea triloba* seedlings 11 d after treatment. IRRI, 1984.

were compared. The doses corresponded to 8, 16, 32, and 64 drops/seedling, respectively.

A droplet count of 8 or 5.64 μg/seedling did not affect fresh weight but did dry weight of *I. triloba* seedlings (Fig. 6). A further increase in droplet number proportionately decreased fresh weight. Dry weight, however, remained similar for 16, 32,



6. Effect of droplet count or dose of 2,4-D amine on *Ipomoea triloba* growth. Figures in parentheses refer to corresponding dose (μg/seedling). IRRI, 1984.

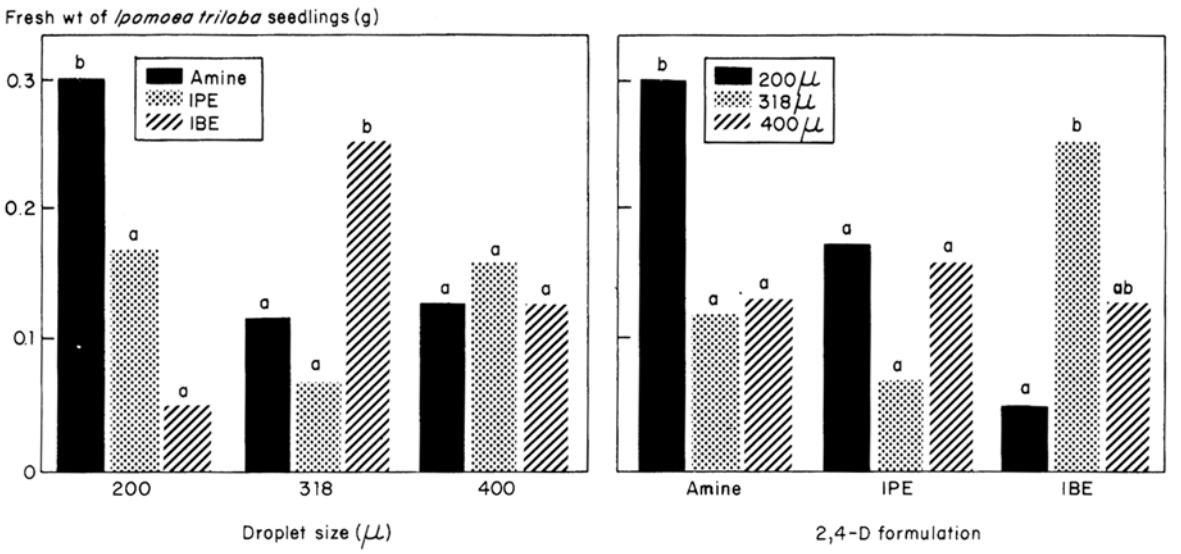
and 64 drops. Greatest stem curvature was attained with 16 drops.

Concentration and dose. Four concentrations (25, 50, 100, and 200 g/litre) and 2 doses (11.28 and 22.56 μg/seedling) of 2,4-D amine were compared.

Dose but not concentration of 2,4-D amine affected fresh weight of the weed. At 50 g/litre, the higher dose reduced fresh weight by 92% while the lower dose decreased it by 74%. Averaged over four concentrations, the higher dose performed better.

Droplet size and dose. Three droplet sizes (200, 318, and 400 μ) and 3 doses (6.7, 13.4, and 26.8 μg/seedling) of 2,4-D amine were evaluated.

Droplet size had similar effect on the fresh and dry weights of *I. triloba* seedlings for all doses. However, higher 2,4-D doses performed better than the lowest dose, indicating the optimum 2,4-D



7. Effect of 2,4-D formulation and droplet size on the fresh weight of *Ipomoea triloba* seedlings 10 d after treatment. IRRI, 1984.

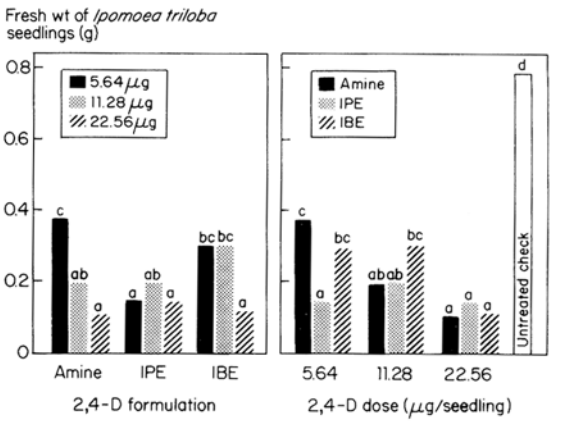
amine dose which could significantly reduce dry matter is about 13.4 μg/seedling. In number per seedling for 200-, 318-, and 400-μ drops, this dose is equivalent to 64, 16, and 8 drops/seedling, respectively.

Formulation and droplet size. Three formulations of 2,4-D (amine, IPE, and IBE) and 3 droplet sizes (200, 318, and 400 μ) were evaluated for their effect on *I. triloba*.

Figure 7 shows an interaction between formulation and droplet size for fresh weed weight. Using 200-μ drops, the ester formulations appeared more effective than amine. With 318-μ drops, amine and IPE performed better than IBE. The formulations performed similarly using 400-μ drops.

Larger drops were more effective with amine. With IPE, droplet size did not matter. Using IBE, 200-μ drops gave the lowest fresh weight.

Formulation and dose. Three formulations (amine, IPE, and IBE) and 3 doses (5.64, 11.28, and 22.56 μg/seedling) were tested on *I. triloba* seedlings (Fig. 8).



8. Effect of 2,4-D formulation and dose on the fresh weight of *Ipomoea triloba* seedlings 12 d after treatment. IRRI, 1984.

Highest doses of 2,4-D amine and IBE were more effective; IPE activity was unaffected by dose.

At lowest dose, IPE was most effective. At higher doses, all formulations performed similarly.

Irrigation water management

Irrigation Water Management Department

EFFECTIVENESS OF FARM IRRIGATION FACILITIES **232**
Testing the models **232**
Cost of the models **235**
Policy implications **236**
LOW-COST DISCHARGE MEASUREMENT DEVICES FOR TURNOUTS **236**
WATER MANAGEMENT FOR IMPROVING CROPPING SCHEDULES **236**
Dry season irrigation scheduling **236**
Land preparation with pump-based irrigation **238**
IMPACT OF FLOODING ON INCOME **239**
ORGANIZATIONAL ASPECTS OF IRRIGATION SYSTEMS **241**
Comparison of national and communal systems **241**
Farmer participation in irrigation systems **242**
HANDWATERING FOR DIVERSIFIED CROPPING **243**

EFFECTIVENESS OF FARM IRRIGATION FACILITIES

Most irrigation agencies use standard designs for irrigation facilities, including regular turnout service areas, uniform ditch capacities and predetermined patterns of water distribution. But farmers often underuse these facilities. In 1978 the National Irrigation Administration (NIA) of the Philippines and IRRI's Irrigation Water Management Department researched different models of turnout service area design and operation to determine ideal investment for efficient water distribution.

Two irrigation systems in Nueva Ecija, Central Luzon, were used in this study: the Camiling River Irrigation System (CamRIS) is a normal diversion system, and the Upper Pampanga River Integrated Irrigation System (UPRIIS) is a reservoir system. Turnout service areas (TSAs) selected for detailed study have relatively uniform size (30-50 ha), involve small farms (less than 2 ha), and have comparatively low cropping intensity (less than 2.0).

Table 1 describes the five models of irrigation facilities and water distribution patterns tested. Model T1 represents the minimal investment: a TSA between 40 and 50 ha with a measuring device and a main farm ditch (MFD), and continuous water delivery. Model T2, with supplementary farm ditches (SFD), a division box, and rotational water deliveries between different sections of the TSA, represents the standard design adopted for the entire 100,000-ha UPRIIS development. Models T3, T4, and T5 represent different combinations of infrastructure and water delivery. In T5, water deliveries within the TSA matched actual water requirements; in T1, farmers allocated water on their own criteria. Two supplementary models (T6 and T7) were tested in six TSAs in the UPRIIS area on consolidated and leveled land.

The five main models involved 45 TSAs in UPRIIS and 30 in CamRIS. Selected sites represented land classes (sloping, flat and dual class) and were clustered to equalize access to water, soil type, and other physical characteristics. A typical cluster of sample TSAs is shown in Figure 1.

A 1978 baseline survey showed most control and measuring devices did not work (63% in the 5-yr-old UPRIIS system and 97% in the older CamRIS system), and in 37 of 81 TSAs (46%) farmers had installed extra turnouts (ETOs) bypassing or supplementing NIA gated turnouts (Table 2).

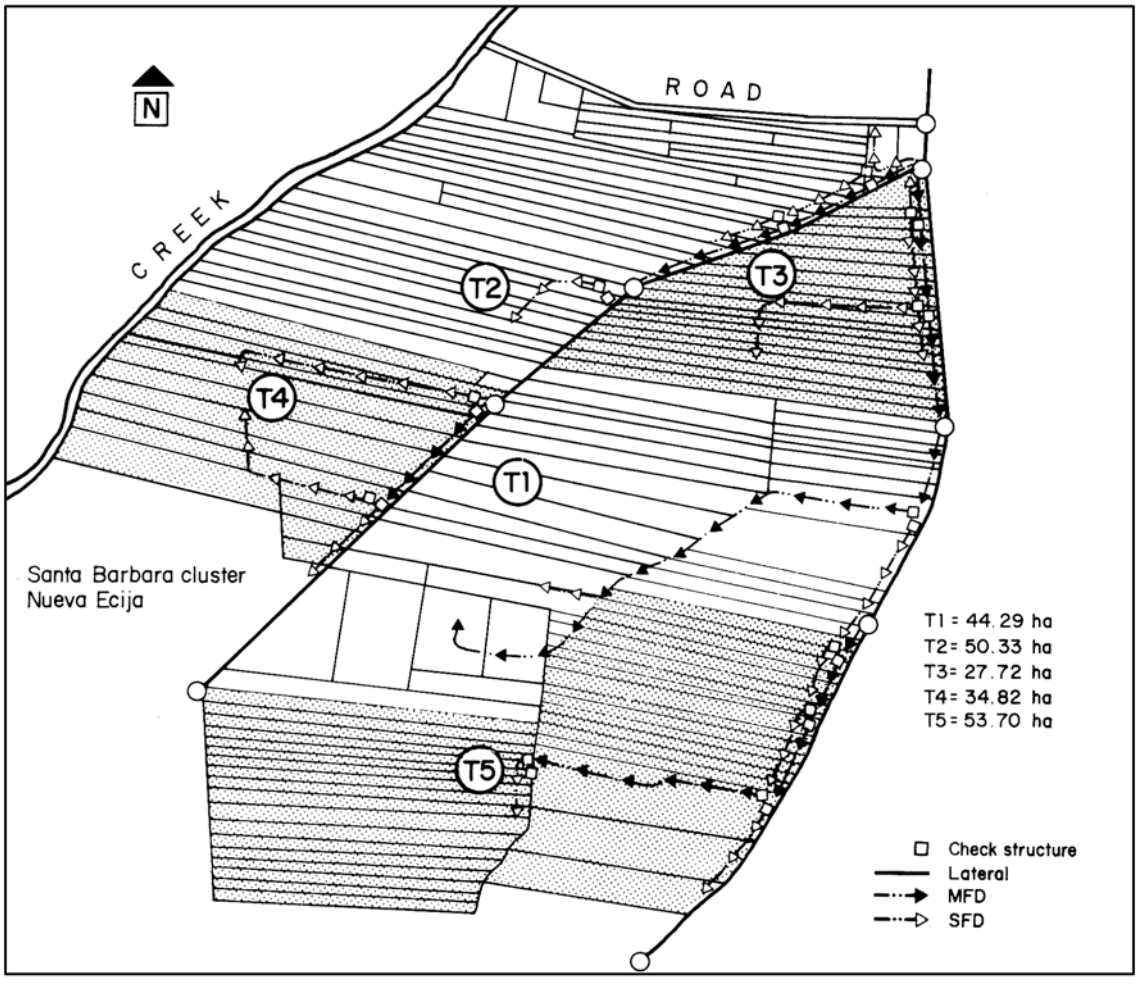
Testing the models. All seven models were tested in both wet (WS) and dry (DS) seasons. In the 1979 and 1980 WS, all models rotating water between sections of TSAs (T2, T3, T4, T6, and T7) were unacceptable. Farmers adopted only the two continuous irrigation models (T1 and T5).

Rotation models failed because WS rainfall meets enough of total crop water requirements so farmers do not need to share irrigation water in any fixed pattern. Further, water was only delivered in the main channel rotationally when rainfall was inadequate. Therefore WS irrigation needs minimal irrigation facilities operated on demand.

Table 1. Details of the seven models used in the on-farm irrigation facilities study, UPRIIS, Central Luzon, Philippines, 1978-83.

	Main models					Supplementary models[a]	
	T1	T2	T3	T4	T5	T6	T7
Area (ha)	40-50	40-50	30	30	40-50	30-50	30-50
Turnout	•	•	•	•	•	•	•
Measuring device	•	•	•	•	•	•	•
Main farm ditch	•	•	•	•	•	•	•
Supplementary		•	•	•	•	•	•
Internal farm ditch				•			
Division box	Minimal	•	•	•	•	•	•
Service roads							•
Land leveling							•
Method of water distribution	Continuous, unmeasured within TSA	Rotational	Rotational	Rotational	Continuous, measured at SFD level	Rotational	Rotational

[a]Supplementary models in Gapan cluster where land consolidation and land leveling had occurred.



1. Location of 5 models in sloping land class, Santa Barbara cluster, UPRIIS, Philippines, 1984.

DS results are complex, differing greatly between CamRIS and UPRIIS. The only similarity was that during land preparation farmers could not rotate water use within their TSA because they did not synchronize their activities. Only during crop maintenance, after all farmers had transplanted, was internal rotation used, and only in UPRIIS.

In CamRIS, farmers did not accept rotations

Table 2. Benchmark information on sites for on-farm irrigation facilities study. Central Luzon, Philippines, May 1978.

System, project	Turnout	Sample service areas (no.)	Total area (ha)	Inventory of control & measuring devices[a]			TSAs (no.) with ETO[e]	Total no. of ETOs
				DGTO[b]	SGTO[c]	PF[d]		
UPRIIS	Models T1-T5	45	1948	31 (15)	14 (9)	14 (3)	20	23
Gapan	Models T6 & T7	6	206	4 (1)	2 (2)	1 (0)	1	1
CamRIS		30	1138	18 (0)	3 (1)	1 (0)	16	48
Total		81	3292	53 (16)	19 (12)	16 (3)	37	72

[a]Numbers in parentheses refer to the number of functional facilities. [b]Double gated turnout. [c]Single gated turnout. [d]Parshall flume. [e]Extra turnout.

internal to the TSA during land preparation or crop maintenance. Because the whole system operated rotationally, farmers found that they could not afford additional rotations within TSA when water was delivered to their section of the lateral channel. They accepted model T1 where all farmers receive water continuously, but not model T5 with water controlled at each SFD.

Similarly, in the six-TSA cluster at Gapan, UPRIIS, with consolidated and leveled land, rotational water deliveries at main and lateral level prohibited internal rotations. In Gapan and CamRIS, farmers built many ETOs; with this further complication, research was discontinued in both sites in 1981.

In 1981, research concentrated in 48 TSAs in UPRIIS, but dropped to 17 TSAs in 1982 to strengthen farmer organizations and make the rotational models work effectively.

In UPRIIS, DS system performance depended on water availability. During 1980 and 1981 DS, water deliveries were higher than field water requirements, and in 1982 DS they matched field water requirements. In 1983 DS, severe deficits in Pantabangan Reservoir restricted water deliveries far below field needs of farmers using traditional irrigation practices. Rice stress was widespread.

In the 1980-82 DS, models performed similarly (water deliveries were at or somewhat above field need). Water use, relative water supply, the number of days without standing water (Table 3) and yield (Table 4) all showed the same trend. Therefore, only simple irrigation infrastructure and water delivery patterns are needed under normal DS conditions.

In 1983 DS, main and lateral channel water deliveries were progressively reduced early to conserve water. The first water delivery for crop maintenance was set to meet 100% of field need, but the next 2 issues dropped to 90% and then 80% of need. As water scarcity increased, NIA rotated lateral level water deliveries but internal rotations among SFDs became progressively more difficult because of the low head of water. Farmers in all areas independently began to adopt model T1

Table 3. Observed water use, relative water supply, and area without standing water by model, UPRIIS, 1980-83 DS.

Model	Water use (mm)	Relative water supply	Water duty (litres/s per ha)	Duration of crop growth (d)	Total ha-day with standing water	Area without standing water		Observation period (d)
						ha	%	
				1980				
T1	659	0.91	0.99	77	175	3.51	7.33	51
T2	826	1.03	1.18	81	79	1.77	3.77	55
T3	704	0.94	0.99	82	93	2.15	7.80	44
T4	834	1.04	1.17	84	131	2.26	7.03	52
T5	761	1.01	1.08	82	146	2.67	5.73	55
				1981				
T1	996	1.07	1.34	86	210	5.25	11.27	43
T2	793	0.89	1.06	88	158	3.33	9.00	46
T3	735	0.92	1.03	83	39	0.75	2.23	49
T4	893	0.95	1.15	90	49	0.98	3.06	51
T5	898	0.99	1.18	87	91	2.10	3.80	50
				1982				
T1	869	1.18	1.05	86	44	0.69	1.47	69
T2	771	1.03	0.99	87	52	0.81	1.80	68
T3	731	1.01	0.98	80	74	1.24	4.30	63
T4	811	1.06	0.98	89	36	0.66	2.07	67
T5	783	1.23	1.03	86	209	3.12	5.90	74
				1983				
T1	539	0.64	0.83	99	251	5.46	11.45	47
T2	772	0.78	0.95	96	156	3.85	9.75	39
T3	687	0.67	0.71	100	76	1.55	5.50	52
T4	789	0.85	0.82	99	71	1.21	3.80	58
T5	789	0.71	0.80	104	43	1.60	3.05	26

Table 4. Yields by model, UPRIIS, 1978-80 WS and 1979-83 DS.

Model	Yield (t/ha)							
	WS			DS				
	1978[a]	1979	1980[a]	1979	1980	1981	1982	1983
T1	2.77	4.35	3.57	4.41	4.75	5.07	5.15	5.30
T2	2.28	3.98	3.57	4.47	4.74	4.97	5.36	4.92
T3	2.36	4.17	3.62	4.21	4.45	4.52	5.49	5.04
T4	3.27	3.64	3.17	4.65	4.02	4.55	5.09	5.61
T5	3.04	4.29	3.23	4.88	4.89	4.96	5.34	5.06
T6	1.34	2.69	2.25	3.54	2.49	3.24	3.30	3.44
T7	2.32	4.28	2.26	4.91	4.40	4.13	4.16	4.61

[a] Typhoons affected most areas.

where irrigation within the TSA was continuous. They also illegally diverted water at night, hampering monitoring. Sloping lands maintained rotations longer than flat lands, and the head end areas continued rotational deliveries longer than tail end areas.

During stage I and stage II, models performed equally. In stage III, model T5 failed to distribute water equally within the turnouts when supply dropped to 80% of need, as did model T3 at 79% of need. Models T1, T2, and T4 performed somewhat better under the same supply conditions in terms of area without standing water.

Yields, however, did not differ significantly (Table 4). As expected, DS yields exceeded WS yields, because of higher solar radiation and absence of damaging typhoons. Although the seasonal water delivery was less than field requirement, yields remained high during 1983 DS because sufficient water was delivered during germination, indicating that early season stress is less damaging to yields.

Cost of the models. Model T1 had the lowest per hectare cost in construction and in operation and maintenance (O&M) because of its simple irrigation infrastructure (Table 5). Models T3 and T4 had the highest costs. CamRIS development costs generally exceeded those in UPRIIS because it had more facility rehabilitation and new facilities for water control and measurement.

O&M costs followed the same pattern. T1 model was by far the cheapest to operate, with less need for rotations within the turnout area. Models T3 and T4 were about three times as expensive.

All models showed higher yields than in the 1978 WS and 1979 DS baseline studies, mostly because of increased N use. Yields increased from 4.5 t/ha in 1979 to 5.2 t/ha in 1983, and fertilizer use rose from approximately 85 kg N/ha in 1979 to 105 kg N/ha in 1983. Perhaps with improved water allocation and distribution, farmers were more prepared to risk investments in fertilizers and other inputs. However, because yields did not significantly differ between models, the most favorable choice is to

Table 5. Total construction, operation and maintenance cost of 5 major models. UPRIIS, 1983 DS.

Model	Costs ($/ha)						
	Construction		Operation	Repairs	Replacements	Maintenance	Total recurrent
	UPRIIS	CamRIS					
T1	4.86	13.14	0.38	0.02	0.00	0.28	0.68
T2	9.93	20.86	0.68	0.04	0.02	0.55	1.29
T3	16.57	29.43	1.04	0.07	0.19	0.53	1.83
T4	16.57	27.29	1.28	0.10	0.10	0.70	2.18
T5	13.50	23.29	0.56	0.05	0.28	0.43	1.32

adopt model T1 because of its lower capital and recurrent costs.

The nonquantifiable costs support this conclusion. Models with internal rotations (T2, T3, and T4) require greater farmer organization and cooperation. Farmers in the simpler T1 and T5 models appeared to perform as well as those in the other models, implying that farmer organizations add little to turnout level water management. However, organizations do play an external role in negotiating with other groups and with NIA to ensure reliable and timely water delivery. During the water-short 1983 DS, farmer organizations attempted to allocate and distribute water within lateral canals as well as within their own turnouts.

Policy implications. Constructing intensive irrigation facilities at the farm level does not appear justified. With enough water to meet field needs, farmers can manage water well with minimal infrastructure. The additional costs of construction and O&M do not seem to improve water distribution or increase production. However, with water supplies below requirements, water must be rotated at main or lateral levels, and this prohibits farmers from rotating water within turnout areas. When turnout areas need additional channels, farmers appear to be prepared to install them themselves. Further, farmers normally abandoned supplementary and internal farm ditches installed with the project.

Thus, capital investment for new irrigation schemes can be substantially reduced below levels normally recommended by donor agencies, but schemes need better management for reliable operation of main and lateral channels.

LOW-COST DISCHARGE MEASUREMENT DEVICES FOR TURNOUTS

If farmers are to be more involved in allocating and distributing water at lateral and turnout levels, they need a simple measurement device to assess water volume delivered to each turnout. Although accurate, Parshall flumes are expensive, difficult to install, and frequently regarded as obstructions to flow. Double-gated turnouts that operate as constant head openings are seldom used to measure flow because it is difficult to properly adjust the gates.

Research indicates that small gated cutthroat flumes can effectively control and measure water. They also are considerably less expensive and are much more acceptable to farmers.

Properly installed, small cutthroat flumes are accurate to 97% of discharge under free flow. For submerged conditions, accuracy falls to approximately 75%, a level comparable to that of more expensive devices. A small gated cutthroat flume costs approximately $285 installed in the field, compared to at least $430 for a single-gated turnout with less capacity for measurements, and $860 for a double-gated turnout.

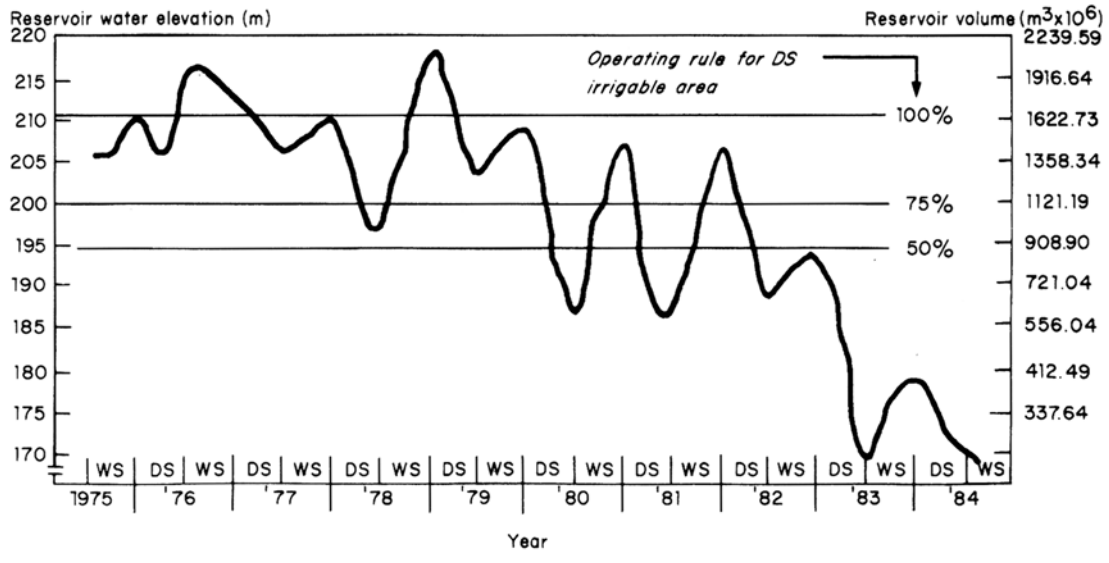
WATER MANAGEMENT FOR IMPROVING CROPPING SCHEDULES

Often irrigation is not efficient because of staggered agricultural activities. Farmers must make independent management decisions that complicate irrigation schedules. Staggered activities mean low distribution efficiency at the start and end of the season: although only a few farmers require water then, the system has to be operated at reasonable head for water to reach farmers at the lower end of the system. Research at several Philippine sites examined this problem.

Dry season irrigation scheduling. Research over several DS in UPRIIS demonstrates the importance of proper planning of irrigation seasons. Although UPRIIS serves 100,000 ha, it is normally impossible to irrigate the entire area in DS because of lack of water and conveyance capacity. Allocation among constituent systems is essential, requiring proper communication of target areas and starting dates, especially in the first few weeks of the season.

Since Pantabangan Reservoir irrigation began in 1975, water available for DS irrigation has gradually declined (Fig. 2). At the end of 1982 WS, water surface elevation was 195 m, providing approximately 900 million m^3 for 1983 DS, and was only 181 m (430 million m^3) at the start of 1984 DS. Desired water surface elevation before DS is 210 m, or 1,623 million m^3 of available water. These deficits severely restricted the area irrigated in the past two DS.

In 1983 DS, 68% of the irrigable area received water, with severe stress to rice in some areas. This performance was reasonably efficient, considering



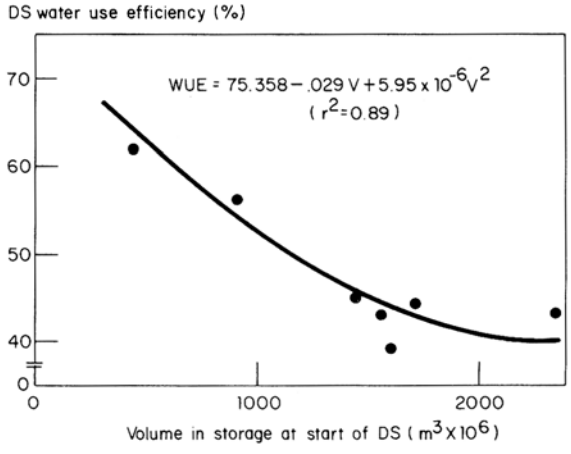
2. Water levels at Pantabangan Reservoir in 1975-84, showing operating rule for DS land allocation.

only 55% of water required for full irrigation was stored. In 1984, with only 26% of desired water in storage, 36% of the area was programmed for irrigation, but only 32% irrigated. During the past seven DSs, efficiency improved as availability decreased (Fig. 3), indicating water management improved with the scarce supply. Efficiencies of 35-45% are typical of large systems operating under reasonably good water conditions, while 65% is high.

Efficiency was not achieved without problems in 1983 and 1984 DS. In 1983, water was strictly rotated between head and tail sections of each UPRIIS district, with careful regulation to limit delivery to the allocated amount. The NIA arranged night patrols, with farmer organization support, to minimize water stealing.

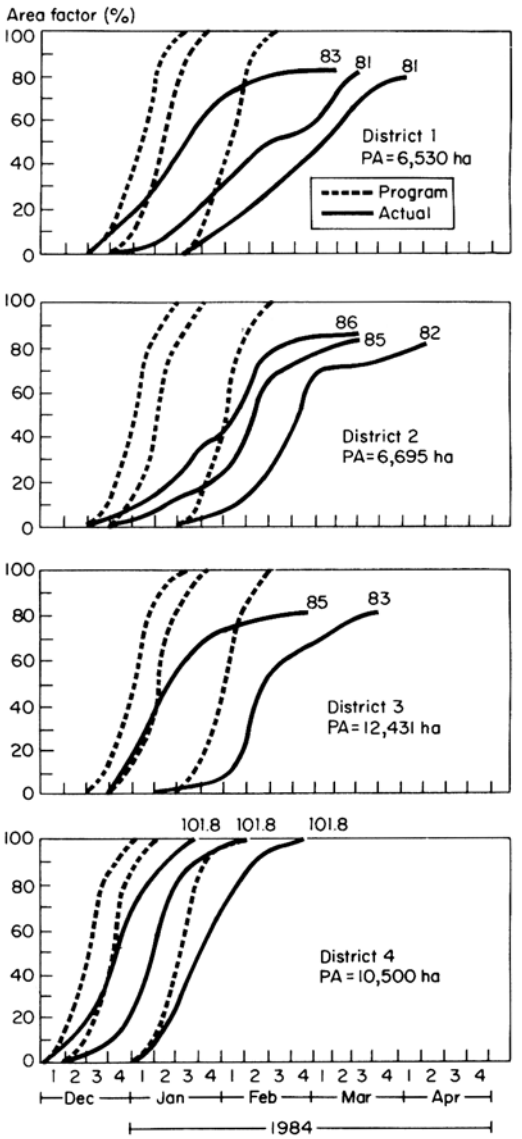
In 1984 DS, with an even greater water shortage, problems were severe at start of DS. Uncertainties over areas to be irrigated and the starting dates led to considerable staggering of land preparation activities. Although NIA aimed to complete land soaking and preparation in 4 wk, spans were between 7 and 12 wk (Fig. 4). In 3 of the 4 districts, water shortages limited the area cultivated to 83% of the programmed area. The tail end district (District 4) performed better because it used drainage water from upper areas of the system.

Uncertainty about water supplies led to conflicts



3. Water use efficiency (WUE) and volume in storage at start of DS, UPRIIS, Philippines, 1978-84.

between farmers and NIA and among farmers at the start of 1984 DS. Also, engineers felt political pressure to deliver water to influential farmers. Some farmers in programmed areas abandoned their plans to grow rice, accounting for the shortfall of over 4,000 ha between the area programmed and the area irrigated. This crisis was short-lived, however, and water soon flowed to participating farmers. This experience stresses need for management control in the first month or two of a water-short season.



4. Programmed and actual rates of land soaking, land preparation, and transplanting, showing final percentage of programmed area (PA) actually completed. UPRIIS, Philippines, 1984 DS.

In 1983 WS, NIA severely curtailed water releases to conserve water for 1984 DS. Although most irrigation systems suspend deliveries during periods of sustained rainfall, suspension is slow, so that more water is available (irrigation plus rainfall) in WS than required. Table 6 shows that WS relative water supplies are considerably greater than those of DS.

During its first few years of operation, Pantabangan made large WS releases, assuming rainfall would replenish the reservoir supply. Relative water supplies, the ratio between releases and field water level requirements, were between 2.5 and 3.0. In 1982 WS, relative water supply rose to 3.13, indicating far greater releases than necessary. In 1983 WS, water was not released for land preparation, forcing farmers to rely on rainfall and flows in local rivers. Even with no releases until September, relative water supply dropped to 1.78, but enough water remained at the close of WS to permit some DS cultivation.

Thus, allocating water from reservoirs requires yearly, not seasonal, planning. If rainfall is below normal, relaxing of good water control in WS will severely reduce areas planted in the following DS.

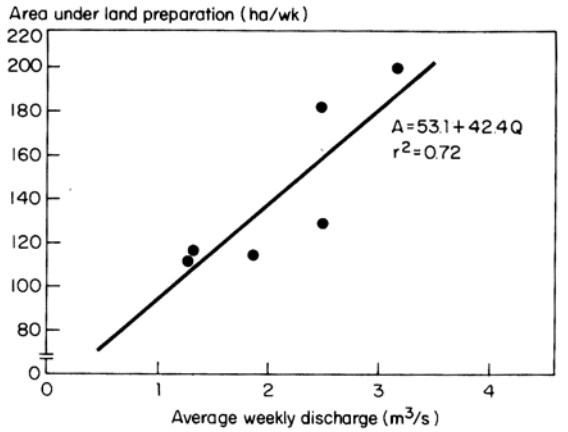
Land preparation with pump-based irrigation. In pump-based systems, the high cost of lifting water is an incentive to use water efficiently, but efficiency depends on human decisions. At the Libmanan-Cabusao Pump-Irrigation System (LCPIS), research into land preparation activities indicates that farmers generally do not use rainfall efficiently if they think irrigation water will be available. Data from three WSs and three DSs show that the rate of land preparation is closely related to water delivery (Fig. 5).

The data also illustrate the importance of delivering high rates of water to avoid severe staggering of land preparation. If all 3 pumps were operated simultaneously (a total discharge of 4.14 m^3/s), as much as 230 ha/wk could be prepared, allowing the

Table 6. Seasonal relative water supplies, UPRIIS, Philippines, 1978-84.

Year	Relative water supply[a]	
	DS	WS
1978	2.27	2.86
1979	2.33	2.86
1980	2.22	2.50
1981	2.33	2.78
1982	2.56	3.13
1983	1.78	1.78
1984	1.61	

[a] Relative water supply = $\frac{\text{irrigation + rainfall}}{\text{field level water requirement}}$



5. Area (A) under land preparation and average weekly discharge, LCPIS, Philippines, 1981-84.

irrigation area to be transplanted within 10 wk. The span now averages 17 wk, partly due to pump breakdowns and electricity brownout. It is difficult to integrate pest management and introduce related technologies because almost all farming activities are taking place simultaneously.

One way to help farmers make maximum use of rainfall is to develop and enforce strict operating rules concerning when to stop pumping following rainfall. In LCPIS, 1 d of pumping can cost over $785, mandating a precise system. Because rainfall is frequently not uniform throughout the irrigated area, suspending irrigation because of rainfall near the water source may mean too little water for more distant areas with less rainfall. Within the 2,500-ha LCPIS area, rainfall was relatively uniform when total daily rainfall exceeded 8 mm/d, close to the systemwide field level water requirement. With rainfall values below 8 mm/d, it was impossible to uniformly distribute water, so suspension of pumping is not recommended.

Suspension of pumping has to be closely related to the irrigation schedule for each part of the system. For example, in an area with water delivered only 2 d/wk, each full day of water issue has to provide enough water for 3 1/2 d of need. Rainfall of 8 mm in 1 d only justifies stopping irrigation deliveries for 7 h because 28 mm/d must be delivered. Irrigation suspension schedules must also consider the hydraulic response time. Where hydraulic response is fast, as in LCPIS, pumps can be turned on and off for as little as 6 h, but larger systems may need to base suspension criteria on 2-3 d rainfall totals to accommodate slower hydraulic response.

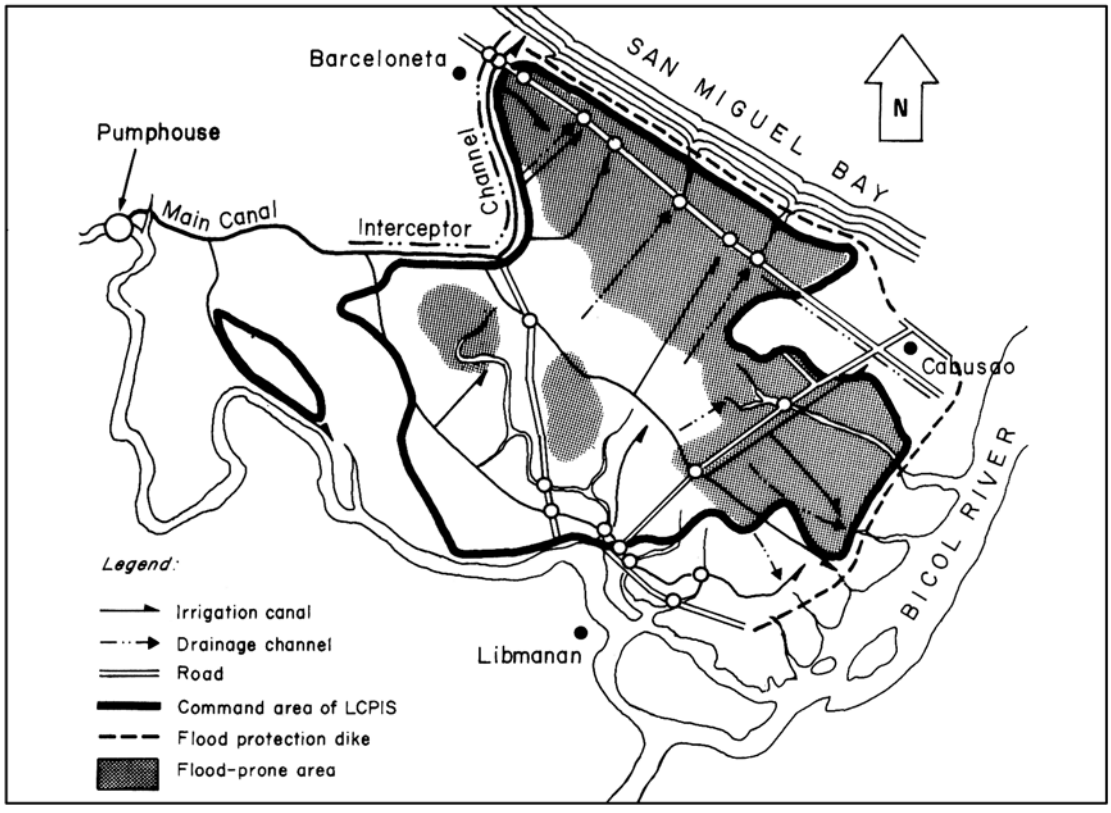
IMPACT OF FLOODING ON INCOME

Flooding hinders production. It delays planting, disrupts cropping schedules, and may wipe out crops entirely. To assess the impact of flooding on farmer incomes, research continued at LCPIS.

The design capacity of the LCPIS drainage network, 98 mm/d throughout the system, is considered adequate to remove floodwater equivalent to a 3-d rainfall of 300 mm. Rainfall of this intensity occurs once in 5 yr. In the upper half of the system, mostly more than 1.5 m above sea level, floods are drained off within 3 d with negligible damage to standing crops (Fig. 6). The lower half of the system, however, floods for 1 to 5 wk following typhoons, significantly damaging crops. The area floods because it has intense typhoonal rainfall, elevations close to sea level, inadequately designed flapgates in the coastal embankment, low-capacity culverts under roads crossing the service area, degraded drainage channels choked with aquatic weeds, backflow from rivers into the service area, and overirrigation in head end areas leading to constant flow in drains. Approximately 600 ha (25% of the irrigated area) suffers from severe floods.

Research over six seasons in LCPIS shows significantly lower WS yields in flood-prone areas than in adjacent flood-free areas (Fig. 7). The average yield difference over 3 consecutive WSs was 0.7 t/ha. Yields did not differ significantly between flood-prone areas and nearby rainfed areas. Because of 2 severe typhoons in 1983 WS (in July at season's start, and in November at harvest), yields in flood-prone areas were 0.5 t/ha lower than those obtained by rainfed farmers. Only in 1982 WS, when no major typhoon struck the area, were yields comparable in flood-free and flood-prone areas. Long-term records indicate that a typhoon-free year is unusual.

In two of three DSs studied, yields in flood-free and flood-prone areas were comparable, and significantly higher than in adjacent rainfed areas. The exception was the 1982 DS when late flooding



6. Extent of the flood-prone areas in LCPIS, Camarines Sur, Philippines.

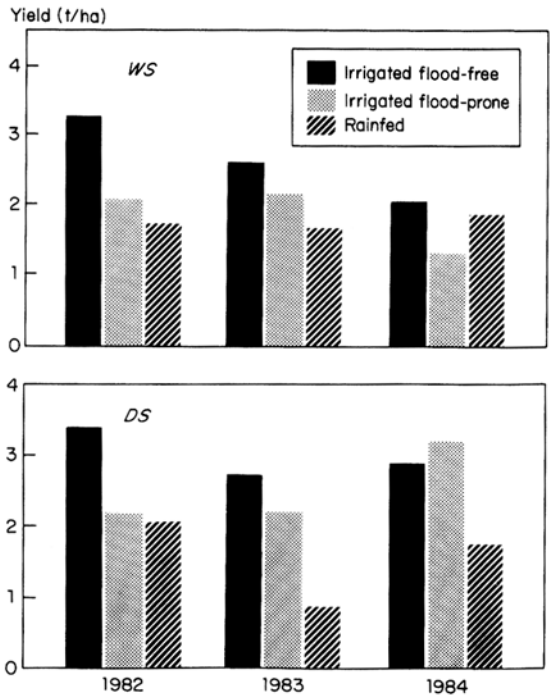
depressed yields. The data from 1984 DS suggest that when water is scarce the flood-prone areas may get higher yields because of greater soil moisture.

Farmers in flood-prone areas respond to flood threat by using fewer inputs, especially N (Table 7). In WS, farmers in flood-free areas used an average of 44 kg N/ha compared to 34 kg N/ha in flood-prone areas; in DS, N inputs were 40 kg/ha in flood-free areas and 29 kg/ha in flood-prone areas. Both differences are significant at the 5% level. By comparison, farmers in flood-prone and rainfed areas did not apply significantly different amounts of N in either WS or DS. Trends in use of P and K were similar but without significant differences.

Farmers in flood-free areas had higher yields and net operating surpluses despite higher input costs. In WS, those farmers averaged $40 net surplus/ha, compared to losses of $17 for farmers in flood-prone areas and $19 in rainfed areas. The DS situation is different: farmers in flood-free and flood-prone areas both made net surpluses ($107 and $82/ha), while rainfed farmers had net losses of $22/ha. The better DS performance underlines the value of maximizing DS production. But many farmers in the flood-prone area cannot obtain a DS crop due to lack of irrigation water; they must rely on one crop a year that is subject to severe risk.

Greater attention to the drainage system can reduce flooding. If drainage channels and control structures are properly maintained and overirrigation in head end areas reduced, the area susceptible to flooding could be greatly reduced. The $82/ha a yr difference in net profit between flood-free and flood-prone areas suggests income available to improve drainage system operation and maintenance.

Typical of coastal irrigation systems, LCPIS frequently faces adverse hydrological conditions. During typhoons, sea and river water levels are higher than the land surface so that flapgates



7. Yields in flood-free, flood-prone, and rainfed areas, LCPIS, Philippines, 1981-84.

remain closed and floodwater cannot drain out of the cultivated area. Only expensive pumping systems could eliminate flooding. One alternative strategy is to introduce rice varieties more adapted to flooding. Such varieties must either tolerate prolonged submergence (up to 2 wk) or be able to elongate through undrained floodwater. Future research will evaluate the prospects for such varieties and identify the floodwater management requirements for improving yields in flood-prone areas.

ORGANIZATIONAL ASPECTS OF IRRIGATION SYSTEMS

Comparison of national and communal systems. In 1982-84, 36 national and communal irrigation systems were studied to determine the relationships between the organizational structure and system performance. In national systems, government agencies operate and maintain the main and secondary channel network with farmers responsible at the turnout level; farmers wholly operate communal systems. Research examined five aspects

Table 7. Fertilizer use, rainfed and irrigated farms average of 3 WS and 3 DS crops. LCPIS, Philippines, 1981-84.

	Level of fertilizer use (kg/ha)								
	N			P			K		
	Irrigated		Rainfed	Irrigated		Rainfed	Irrigated		Rainfed
	Flood-free	Flood-prone		Flood-free	Flood-prone		Flood-free	Flood-prone	
WS crop 1981[a]	34	0	28	16	0	6	13	0	7
1982	50	33	35	18	15	12	15	7	11
1983	41	35	27	17	17	16	15	12	13
Mean	44	34	30	17	16	13	15	10	12
Significance tests of means:									
Flood-free vs flood-prone	10*			1^{ns}			5^{ns}		
Flood-prone vs rainfed	4^{ns}			3^{ns}			-2^{ns}		
DS crop 1982	39	24	50	16	12	16	11	8	16
1983	41	30	33	18	15	13	13	5	13
1984	39	29	33	17	11	17	14	10	13
Mean	40	29	38	17	13	16	13	9	14
Significance tests of means:									
Flood-free vs flood-prone	11*			4^{ns}			4^{ns}		
Flood-prone vs rainfed	-9^{ns}			-3^{ns}			-5^{*}		

[a] In 1981 WS, only 4 farmers in the flood-prone area were able to plant. None applied fertilizer. Hence, the flood-prone means are only for 1982 and 1983.

of organizational structure: size, vertical differentiation, horizontal differentiation, decentralization, and formalization. System performance was measured in four ways: yield, ratio between O&M costs and free repayment, percentage of area irrigated, and percentage of irrigation fees paid.

Table 8 shows no significant differences between national and communal systems in the number of personnel involved in O&M (size) or in the number of separate divisions within the organization (horizontal differentiation). However, the number of job types (vertical differentiation) differed significantly, indicating that national systems had more clearly defined hierarchies. National systems averaged 15.6 job positions in roughly 3 divisions, while communal systems averaged 5.1.

National systems, as expected, are significantly more formalistic. They averaged 39 rules and regulations compared to 8 in communal systems. Communal systems are more decentralized, with an average of 145 people making decisions compared to 8 in national systems.

Analysis of irrigation performance showed no significant differences in yield or in percentage of irrigable area actually irrigated. National systems had significantly higher O&M expense ratios than communals, because of more paid employees. National systems averaged collections of only 57% of fees due, compared to 69% in communals, although fees were lower in communal systems. Overall, the communal systems appear to have performed better than national systems.

Although the number of divisions (horizontal differentiation) did not differ significantly between national and communal systems, it did affect yields in both systems. Therefore it is more efficient to have divisions with clearly defined tasks (operations, maintenance, fee collection) than to place all tasks in one division. This implies that systems, especially communal systems, could increase productivity by more clearly defining O&M activities and adopting a task-oriented organizational structure.

Farmer participation in irrigation systems. In a separate study, 25 small-scale irrigation systems in Camarines Sur, Bicol Region, were evaluated to determine the relationship between system type and farmer involvement in O&M. Three system types were identified: government assisted communal schemes (GA) (assistance usually in technical improvements to irrigation infrastructure), unassisted communal systems (NA), and unassisted private systems (PVT).

Hours of maintenance differed significantly: GA systems averaged 8,297 h of labor (12 persons/mo); NA systems, 3,381 h; and PVT systems, 679 h. On maintenance materials, GAs averaged $89; NAs, $46; and PVTs, $15. These differences are mainly due to type and source of materials. For example, GAs purchased cement not available in the community. NAs and PVTs relied on diversion structures made from free or low-cost local materials.

Most farmers in the three systems felt it reasonable to pay an irrigation fee (Table 9). The least willing were NA farmers: only 80% favored fee payment; 100% of GA farmers were prepared to pay fees. This is consistent with paying irrigation fees for service rather than for water rights. Private

Table 8. Structural characteristics of 36 Philippine national and communal irrigation organizations, 1982-84.

Variable	National (n = 18)			Communal (n = 18)		
	Mean	Standard deviation	Standard error	Mean	Standard deviation	Standard error
Size (no. of employees)	126.83^{ns}	149.69	35.28	55.78^{ns}	55.62	13.10
Vertical differentiation (no. of job types)	15.56**	8.49	2.00	5.11**	1.71	0.40
Horizontal differentiation (no. of divisions)	3.22^{ns}	1.00	0.24	3.28^{ns}	4.04	0.95
Decentralization (no. of decision-makers)	5.94**	5.22	1.23	145.39**	115.23	27.16
Formalization (no. of rules and regulations)	39.00**	0.0	0.0	8.11**	4.54	1.07
Effectiveness						
Productivity (yields in t/ha per yr)	7.74^{ns}	0.81	0.19	7.59^{ns}	1.81	0.43
O&M expenses ratio	1.72*	0.81	0.19	1.11*	0.89	0.21
% of area irrigated	0.71^{ns}	0.19	0.04	0.67^{ns}	0.28	0.06
% of fees collected	0.57*	0.19	0.05	0.67*	0.29	0.07

Table 9. Farmer attitudes toward irrigation fee payment in 3 types of irrigation systems, Camarines Sur, Philippines, 1983.

	Responses					
	GA		NA		PVT	
	No.	%	No.	%	No.	%
Farmer opinion on whether they should pay irrigation fees						
Should pay	248	99.6	148	79.9	24	87.1
Should not pay	1	0.4	37	20.1	6	12.9
Farmer willingness to pay irrigation fees						
Amount considered reasonable (kg rice/yr)	62		50		105	
Amount actually paid (kg rice/yr)	50		7		103	

system farmers were willing to pay as much as 105 kg of rice per year, compared to 62 kg for PA farmers and 50 kg for NA farmers (but no NAs surveyed were the expensive pump type).

Farmers in private systems were willing to pay high irrigation fees because they lacked water rights; system owners can refuse to deliver water to farmers who do not pay. In contrast, farmers in unassisted systems paid only 13% of what they considered a reasonable fee. In these noncoercive systems, many farmers feel their labor contributions represent payment for water. In assisted systems, fee repayments were about 80% of what was considered reasonable, indicating successful government fee collection.

As in the previous study, yields were not significantly different between system types. This raises a question about government assistance to communal systems. If production does not increase, then the higher irrigation fees represent an additional production cost that farmers do not recoup through increased income.

HANDWATERING FOR DIVERSIFIED CROPPING

The value of irrigation water in DS is clearly demonstrated by handwatering of upland crops in many areas of the world. Despite the labor required and associated drudgery, farmers are prepared to invest their energy in producing profitable crops. To examine this type of irrigation, handwatering was studied in 2 sites in Tarlac and Pangasinan, Central Luzon, with 97 farm families in the 1984 DS.

In both sites, farmers derived water from dug wells, averaging 90 cm in diameter, with a typical groundwater depth of 2-3 m at start of DS. Although groundwater drops during DS, total lift is rarely more than 4 m. The two main crops are native tobacco and vegetables. The tobacco requires about 4 irrigations over the season; vegetables require watering every 3 d. Usually, all family members handwater, especially women and children.

Handwatered crops yield higher incomes than rainfed crops. At Tarlac, the typical cropping pattern is rainfed rice followed by eggplant. Net income per ha was $452 for rainfed rice but $730 for eggplant. On the average, however, farmers cultivated only 0.09 ha of eggplant compared to 1.44 ha of rice. Farms in this area receive irrigation water from CamRIS every second WS, accounting for the reasonably high income from rice. The low area planted to profitable eggplant reflects the lack of assured market and the difficulties of handwatering large areas.

In Pangasinan the typical cropping pattern studied was rainfed rice - tobacco - white maize. Net benefits per ha were $106 for rice, $891 for tobacco, and $101 for maize. The average area cultivated was 0.83 ha of rice, 1.10 ha of tobacco, and 0.67 ha of maize, indicating the value of tobacco production. Tobacco marketing is highly organized and fairly certain. The fewer waterings of tobacco enable families to irrigate a larger area than that with vegetables.

At both sites, farmers perceived benefits from handwatering: dietary improvements, cash for children's education, improvement of material living conditions, and supplementation of rice-based incomes. Without the additional income, families in both areas would find it difficult to cover regular expenses throughout DS.

To save labor, inexpensive irrigation technology could be introduced. A bamboo treadle pump, costing only about $53, is being tested in both locations to determine its acceptability for irrigating upland crops where groundwater is close to the surface.

Soil and crop management

Soil characterization

Soil Chemistry/ Physics and Plant Physiology Departments

SIMPLE SOIL TESTS FOR WETLAND RICE **246**
- Response to N **246**
- Response to P **247**
- Response to K **247**
- Conclusions **247**

FLOODWATER CHEMISTRY **248**
- Temperature changes **248**
- pH changes **248**
- Eh changes **248**
- EC **249**
- Alkalinity **249**
- P_{CO_2} **249**
- O_2 concentration **249**
- Reducing substances **249**
- NH_4^+-N **249**
- NO_3^--N **250**
- NO_2^- **250**
- Water-soluble P **250**
- Water-soluble SO_4^{2-} **250**
- K, Ca, Mg **250**
- Water-soluble Fe^{2+} and Mn^{2+} **250**
- Water-soluble Zn^{2+} and Cu^{2+} **250**
- Practical significance **250**

DEEP WATER SOILS **250**

TAILORING N FERTILIZERS **251**

ACID UPLAND SOILS **251**
- Nutrient availability and yield **251**
- Aluminum toxicity **251**
- Plant growth under nutrient deficiencies **252**

CHEMICAL KINETICS OF TWO AEROBIC AND ANAEROBIC SOILS AND RICE GROWTH **253**

SOIL FERTILITY CONSTRAINTS IN ASIAN RAINFED LOWLAND RICE AREAS **254**

SIMPLE SOIL TESTS FOR WETLAND RICE

Soil Chemistry/Physics Department

To ascertain the usefulness of simple soil tests as a guide to fertilizer use on small farms, fertilizer experiments were installed in 125 farmers' fields in 12 Philippine provinces in 1984 dry season (DS) and wet season (WS). Before the experiments, topsoil samples were collected and analyzed.

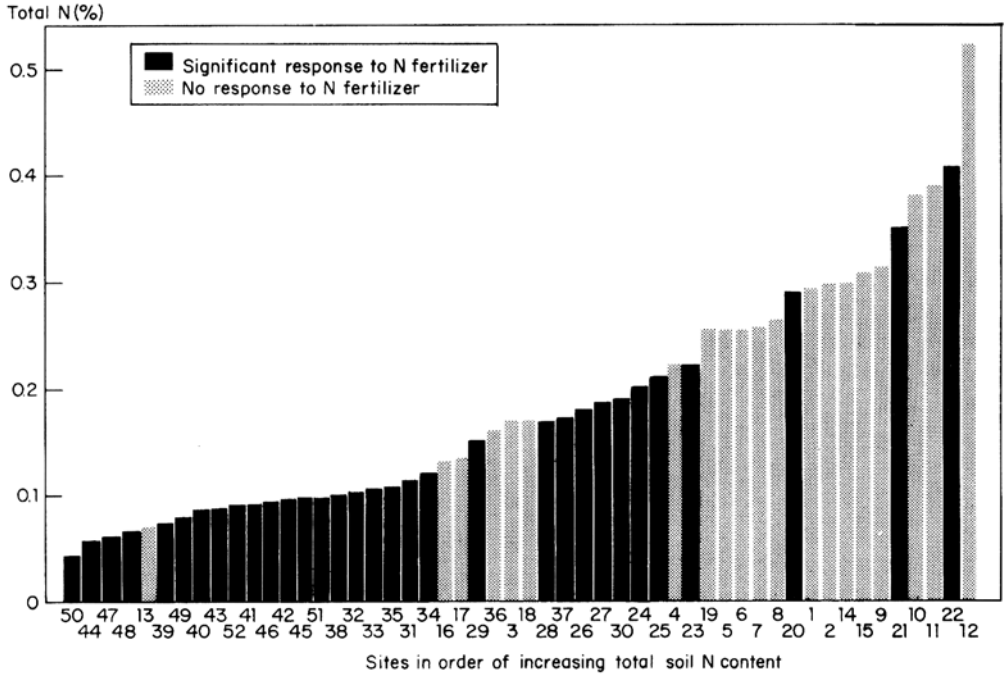
The fertilizer treatments, in kg NPK/ha, were 80-0-0, 80-13-0, and 80-13-25 in DS and 57-0-0, 57-13-0, and 57-13-25 in WS. Zinc was applied as 10 kg $ZnSO_4$/ha or as 4% ZnO seedling dip where needed. IR36 was planted at most sites in DS and IR56 at all sites in WS. Table 1 summarizes the soil analyses. Over 65% of the soils were N deficient and over 57% Zn deficient. Less than 20% were deficient in P or K.

Response to N. In 34 of 52 sites in DS, 80-0-0 NPK significantly increased yields 0.4-2.0 t/ha with a mean of 1.3 t/ha. Of 18 sites not significantly responding to N, 13 had a soil N content of over 0.2% (Fig. 1). In WS, 30 of the 73 sites showed no N response (Fig. 2). Twenty-two of these sites con-

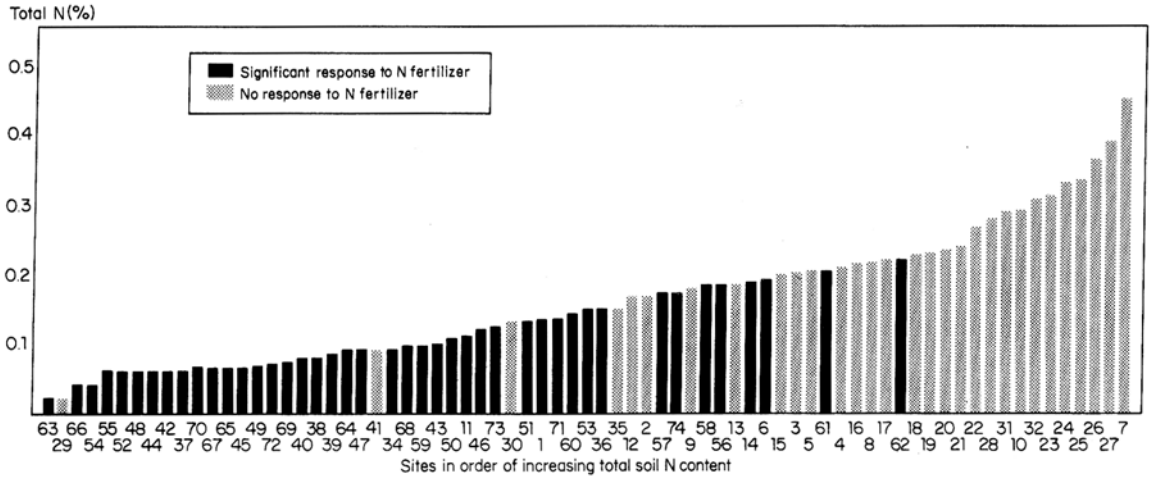
Table 1. Summary of chemical analysis of soils from 125 experimental sites in Philippine farmers' fields, 1984 DS and WS.

Characteristic	Range	Mean	Critical limit	No. below critical limit
pH	4.6-8.3	6.3	5.5-6.5[a]	58[b]
Organic C (%)	0.32-6.0	1.8	2.0	83
Total N (%)	0.02-0.52	0.18	0.2	81
Olsen P (mg/kg)	2-74	18	5	25
Exchangeable K (meq/100 g)	0.03-4.8	0.64	0.2	22
Available Zn	0.0-9.0	1.2	1.0	71

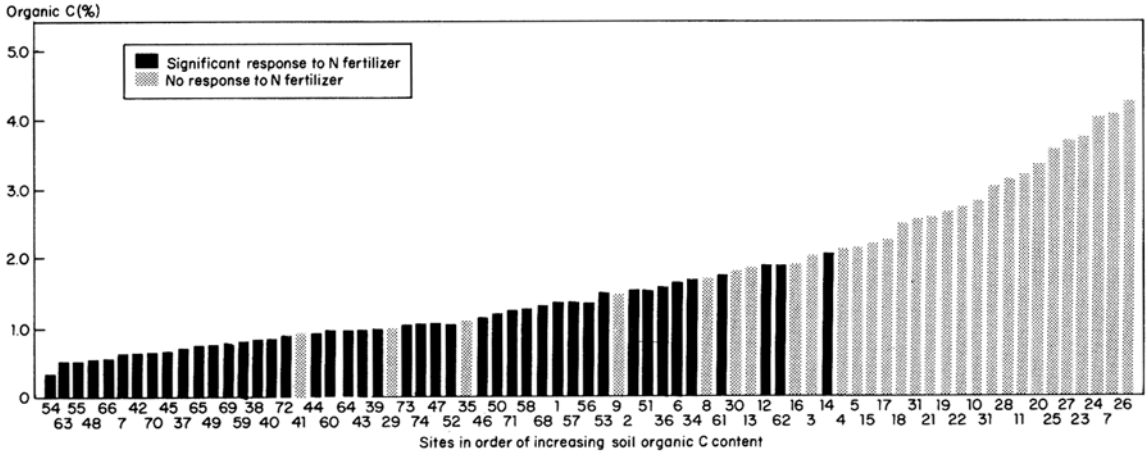
[a]Optimum range. [b]No. outside optimum range.



1. Relationship between total soil N content and presence or absence of a significant response to 80 kg N/ha in Philippine farmers' fields, 1984 DS.



2. Relationship between total soil N content and presence or absence of a significant response to 57 kg N/ha in Philippine farmers' fields, 1984 WS.



3. Relationship between soil organic C content and presence or absence of a significant response to 57 kg N/ha in Philippine farmers' fields, 1984 WS.

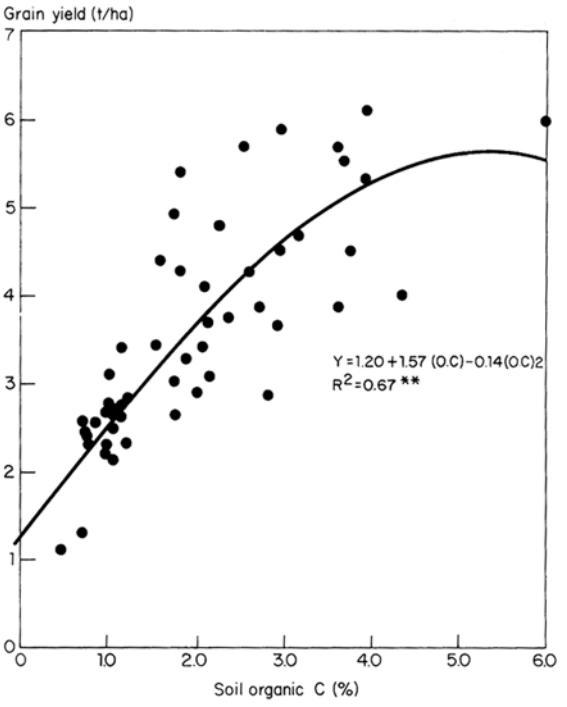
tained more than 0.2% N or 2% C. Late planting i.e. after 17 Jul, reduced yield by more than 1 t/ha even in soils rich in N.

Nearly 75% of sites not significantly responding to 80 kg N/ha in DS or 57 kg N/ha in WS contained more than 2% C (Fig. 3). The organic C content of a soil is a simple and inexpensive guide to N fertilization (Fig. 4).

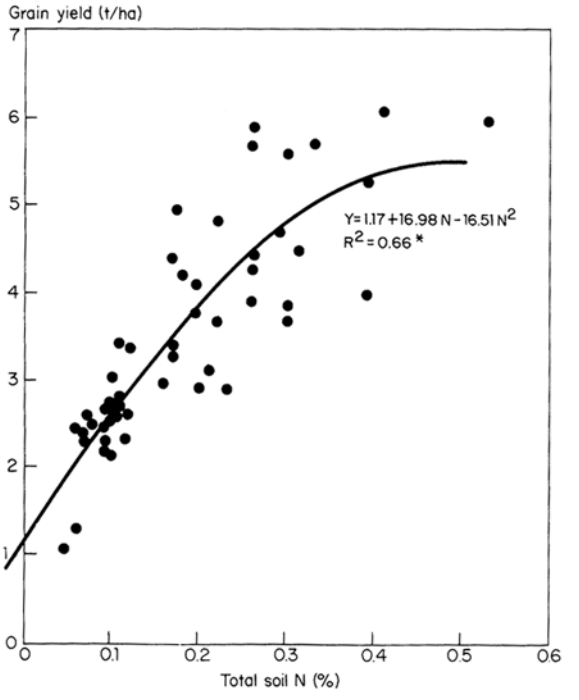
Response to P. Only 6 of 125 sites significantly responded to 13 kg P/ha in the presence of N. Three of them had Olsen P values below the critical level of 5 mg/kg. The varieties at the six sites were early-maturing ones.

Response to K. Only 2 sites significantly responded to 25 kg K/ha in the presence of N and P. At one site, exchangeable K was less than 0.2 meq/100 g.

Conclusions. Total N or C content is a good index of the need for N fertilizer (Fig. 4, 5). If the soil N is less than 0.2% or C less than 2.0%, significant



4. Relationship between yield and organic C content of soil in the 0-0-0 plots in farmers' fields in 8 Philippine provinces, 1984 DS.



5. Relationship between yield and total N content of soil in the 0-0-0 plots in farmers' fields in 8 Philippine provinces, 1984 DS.

responses to N are likely. Soils containing less than 5 mg Olsen P/kg may need P fertilizer especially for early-maturing varieties. The critical level of 0.2 meq K/100 g for K deficiency may be too high. At yield levels of 5 t/ha, most soils may not need K fertilizer. In sandy soils containing less than 1% C, 80-13-25 kg NPK/ha is inadequate for a yield of even 4 t/ha. N and Zn deficiencies were the commonest yield limiting factors in the soils studied.

FLOODWATER CHEMISTRY

Soil Chemistry/Physics Department

The chemical composition of the floodwater in rice fields profoundly influences loss and gain of nutrients as well as the growth and activity of blue-green algae and azolla. This research examined the influence of soil properties and flooding duration on chemical changes in floodwater. The chemical kinetics of floodwaters of 6 soils with pH values ranging from 3.5 to 8.6 (Table 2) were studied in the greenhouse in the presence of rice. Soils were collected wet; air-dried; crushed; treated with 50 mg N, 25 mg P, and 25 mg K per kg; mixed with 0.15% of a 1:1 mixture of chopped straw and dried *Glyricidia sepium*; and placed in 16-litre porcelain pots. The soils were flooded, puddled, and submerged in 10 cm of deionized water. Deionized water was also added daily to replace evapotranspiration losses. The measurements were made at 1400 h when algal activity was highest.

Temperature changes. During the 10 wk experiment, temperature of floodwater in pots was 25-37° C compared with 26-36° C in Block UY4 at IRRI during the same period.

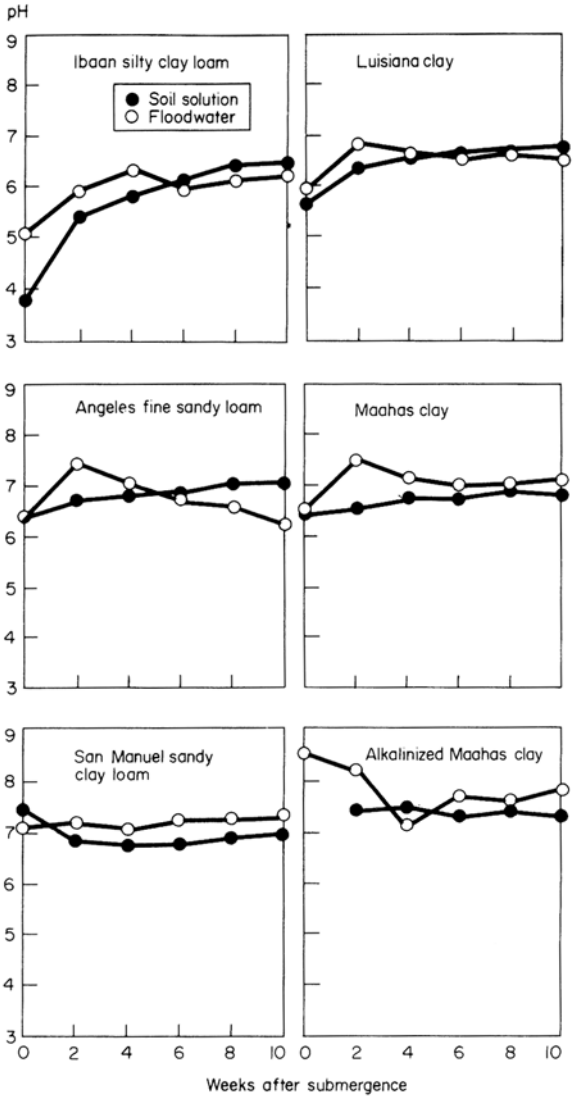
pH changes. On flooding, pH values of the floodwater of the acid soils increased, reached peaks, and decreased thereafter, whereas pH values of the soil solution increased progressively during submergence. Floodwater pH decreased with time in the alkali soil and remained unaltered in the calcareous soil (Fig. 6). Algal growth was highest in the alkali soil but did not change the weekly pH.

Eh changes. Eh of floodwater decreased on flooding, reached a minimum about 4 wk later, and

Table 2. Properties of soils used in floodwater chemistry studies. IRRI, 1984.

Soil	pH	Organic C (%)	N (%)	CEC[a] (meq/100 g)	Olsen P (mg/kg)	Exchangeable K (meq/100 g)
Ibaan silty clay loam	4.0	3.6	0.22	38	92	0.28
Luisiana clay	5.2	2.5	0.26	40	3	0.49
Angeles sandy loam	6.6	0.9	0.07	8	34	0.31
Maahas clay	7.7	1.9	0.16	58	22	0.54
San Manuel sandy clay loam	8.0	0.6	0.05	32	7	0.46
Alkalized Maahas clay[b]	8.6	1.6	0.16	53	46	0.28

[a]Cation exchange capacity. [b]Treated with 1.3% Na_2CO_3 to give a pH of 8.6 and an exchangeable sodium percentage (ESP) of about 25.



6. Kinetics of pH in soil solution and floodwater of 6 soils. IRRI greenhouse, 1984.

then tended to increase. The fairly stable values for all soils, except Luisiana clay, were 0.0-0.1 V. The solution Ehs were usually negative. Despite access to air, floodwater potentials were considerably lower than those of the O_2-H_2O system at pH values of 6-7. Luisiana clay had the lowest floodwater Eh, apparently because of the presence of reducing substances.

EC. The EC values of the floodwater in all soils were always below 1.0 dS/m although those of the underlying soil solution were 1-3 dS/m higher for all soils except the alkali soil.

Alkalinity. Floodwater alkalinity ranged from 0 meq/litre in the acid sulfate soil to 10 meq/litre in the alkali soil. Alkalinity was 20-80 meq/litre higher in the interstitial solution than in the floodwater.

P_{CO_2}. The partial pressure of CO_2 in the floodwater ranged from 1.0 kPa for the alkali soil to 5.0 kPa for the acid sulfate soil and was virtually constant throughout submergence. Peak P_{CO_2} values in the soil solution ranged from 15 kPa for the alkali soil to 80 kPa for the acid sulfate soil.

O_2 concentration. Despite daily addition of water exposed to air, the O_2 concentration in the floodwater fluctuated between 1 and 6 mg/litre in all soils except Luisiana clay where O_2 was absent.

Reducing substances. Reducing substances in floodwater increased on flooding, reached a maximum of 8-18 meq/litre 2 wk later, and then decreased. The concentration was highest in floodwater on strongly acid soils and in their soil solutions. Apparently water-soluble Fe^{2+} and organic substances diffused into the floodwater from the underlying soil.

NH_4^+-N. The NH_4^+ concentration in floodwater never exceeded 7 mg/litre in any soil although the soil solution concentration attained values as high

as 50 mg/litre. This suggests that the NH_4^+ diffusing from the soil into the floodwater is partially lost, or used by algae.

NO_3^--N. Two weeks after flooding, NO_3^- had disappeared from all soil solutions but it was present up to 1 mg/litre in the floodwater. Two weeks later, NO_3^- had disappeared from the floodwater as well.

NO_2^-. Two weeks after flooding, the NO_2^--N concentration was less than 0.01 mg/litre in the floodwater and the soil solution.

Water-soluble P. Figure 7 shows the kinetics of P. During the greater part of the period of submergence, water-soluble P concentration was 0.5-1.0 mg/litre for most soils. The concentration might have been lower if soils had not been treated with 25 mg P/kg at the start of the experiment. Floodwater contained less P than the soil solution.

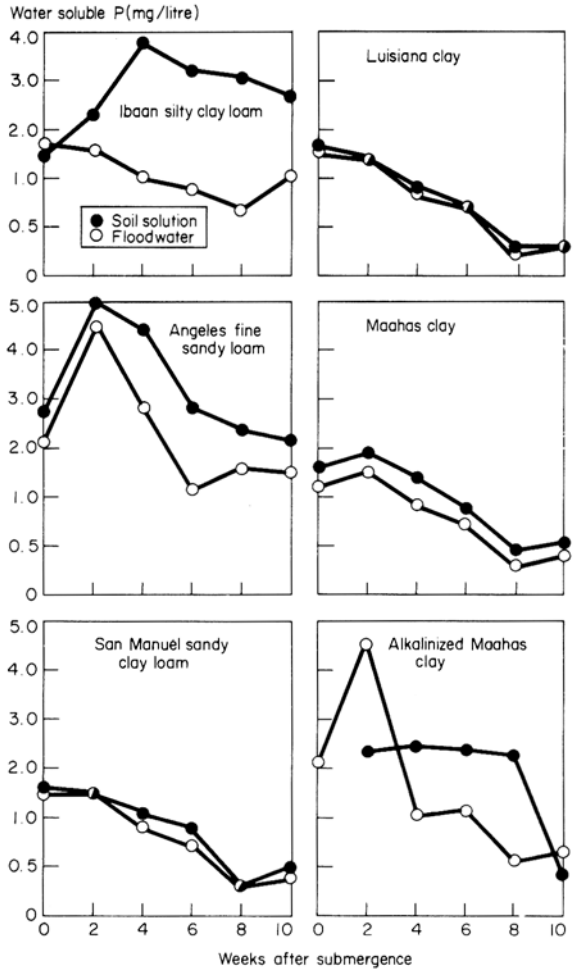
Water-soluble SO_4^{2-}. SO_4^{2-} decreased during submergence, both in floodwater and soil solution. Except in the acid sulfate soil, SO_4^{2-} concentration was about 25 mg/litre during the greater part of the period of submergence. Soil solution SO_4^{2-} concentrations were higher.

K, Ca, Mg. K, Ca, and Mg in floodwater and soil solution increased during the first 2 wk of submergence and then declined. Four weeks after flooding, most soils contained 10 mg K, 50 mg Ca, and 25 mg Mg per litre of floodwater.

Water-soluble Fe^{2+} and Mn^{2+}. Water-soluble Fe^{2+} during the greater part of the period of submergence ranged from 1 mg/litre for the alkali soil to 10 mg/litre for the 2 strongly acid soils. The corresponding Mn^{2+} concentrations were one order lower.

Water-soluble Zn^{2+} and Cu^{2+}. From 4 to 10 wk after flooding, Zn^{2+} was 0.05 mg/litre in the floodwater of most soils. That of Cu was 0.01 mg/litre.

Practical significance. The concentrations of ecologically important substances except O_2 are much lower in floodwater than in the underlying soil solution, but they (except N) are adequate for plant growth. The oxidized soil and floodwater interface traps some of the water-soluble substances diffusing into floodwater. Substances diffusing into floodwater from soil may be lost by volatilization or surface runoff, or be used by aquatic plants.



7. Kinetics of water-soluble P in soil solution and floodwater of 6 soils. IRRI greenhouse, 1984.

DEEP WATER SOILS

Soil Chemistry/Physics Department

More than 50 cm of floodwater cover over 5 million ha of rice lands for most of the season in India and Bangladesh. But little is known about the chemical effects of this deep water on soil and crop.

Using 200-litre drums, deep water (40 cm) was compared to shallow water (10 cm) on 3 soils (collected wet and air-dried before flooding, with and without 50 mg N, 25 mg P, and 25 mg K per kg) (Table 3). Deep water increased plant height but drastically reduced tillering and yield (Table 4). Yield decreased least in the soil well supplied with P.

Table 3. Properties of soils of the deep water experiment, IRRI, 1984.

Property	Luisiana clay	Maahas clay	San Manuel clay loam
pH	4.5	6.0	7.7
CEC (meq/100 g)	40.3	47.4	40.6
Organic C (%)	2.7	2.1	1.0
Total N (%)	0.25	0.20	0.18
Olsen P (mg/kg)	4.6	27	8.9
Exchangeable K (meq/100 g)	0.33	1.5	0.33
Available Zn (mg/kg)	5.4	1.4	0.9

Table 4. Influence of water depth and NPK fertilizers on the growth and yield of IR42 in 200-litre drums, IRRI, 1984.

Water depth (cm)	NPK	Plant ht (cm)	Tiller no.	Straw (g/drum)	Grain (g/drum)
		Luisiana clay			
10	No	102	11	127	57
40	No	108	5	55	40
10	Yes	89	8	62	55
40	Yes	103	6	42	32
		Maahas clay			
10	No	113	18	157	130
40	No	119	8	106	75
10	Yes	119	24	175	190
40	Yes	121	11	136	88
		San Manuel clay loam			
10	No	107	11	80	55
40	No	104	4	57	46
10	Yes	112	15	104	105
40	Yes	116	7	73	56

The deep water plants contained less N, P, K, and Mg than the shallow water plants, although the chemical composition of the soil solutions was almost identical.

Results in the previous section indicated lower concentration of ecologically important substances, except O_2, in floodwater than in soil solution. This experiment confirms that and also shows that the pH and Eh differencces between shallow and deep water were negligible. The concentration of plant nutrients, however, was slightly lower in deep water than in shallow water with all soils throughout submergence. The lower concentration is probably due to the larger sink effect of deep water.

TAILORING N FERTILIZERS

Soil Chemistry/ Physics Department

This analysis tested the validity of the equation: FN = 40 Y − 1000 N. FN is the amount of N fertilizer in kg/ha which needs to be applied to produce a yield of Y t/ha in a soil with its total N percentage denoted by N. The equation was tested 1980-84 on 6 IRRI blocks with N contents from 0.104 to 0.237%. Despite insect, disease, and soil problems, and the absence of corrections for bulk density and soil depth differences, the regression of Y on (FN + 1000 N) was highly significant in 6 of 8 seasons (Table 5).

ACID UPLAND SOILS

Soil Chemistry/ Physics and Plant Physiology Departments

Nutrient availability and yield (*Soil Chemistry/ Physics and Plant Physiology*). Ten rices were grown on 2 sloping Tropudults (pH 4.6 and 4.8, exchangeable Al 1.9 and 1.1 meq/100 g, O.C. 2.1 and 2.2%, total N 0.21 and 0.19%) fertilized with 50 kg N, 25 kg P, and 25 kg K per ha in 1984 WS. Because of rat damage, the highest yield was 2.3 t/ha. Straw analyses of the 10 rices revealed a mean Ca content of 0.11% (the critical limit is 0.15%) and a mean Al content exceeding the toxic limit of 300 mg/kg.

Al toxicity and deficiencies of P and Ca often limit rice yields on acid upland soils.

Aluminum toxicity (*Plant Physiology*). Acid soils from two upland sites in Iloilo and four in Brazil were investigated. Soil solution analysis indicates these soils are not potentially Al toxic with concentrations far below the critical level of 2 ppm.

Table 5. Regression of yield (Y) on FN + 1000 N(x) in 8 seasons at IRRI, 1984.

Season	Regression	r
1980 DS	$\hat{Y} = 0.475 + 0.0222x$	0.81**
1981 DS	$\hat{Y} = 0.555 + 0.135x$	0.67**
WS	$\hat{Y} = 3.312 + 0.0054x$	0.41*
1982 DS	$\hat{Y} = 1.566 + 0.0127x$	0.80**
WS	$\hat{Y} = 3.009 + 0.00365x$	0.26^{ns}
1983 DS	$\hat{Y} = 1.079 + 0.0173x$	0.95**
1984 DS	$\hat{Y} = 1.793 + 0.0137x$	0.68**
WS	$\hat{Y} = 2.055 + 0.0062x$	0.43**

Table 6. Chemical properties of soils from Iloilo (Philippines) and Brazil. 1984.

Soil no.[a]	pH	Available P-Bray	Exchangeable cations (meq/100 g)					Effective CEC (meq/100 g)	CEC (meq/100 g)	Al saturation (%)
			Na	K	Mg	Ca	Al			
1	5.4	4.8	0.07	0.83	6.1	21.0	0.18	28.2	38.6	0.6
2	5.2	2.1	0.05	0.42	3.0	29.4	0.54	33.4	46.6	1.6
3	4.2	5.5	Nil	0.02	0.05	0.03	3.23	3.33	12.1	97
4	4.3	3.6	Nil	0.02	0.06	0.01	0.59	0.68	3.9	87
5	4.5	2.0	0.01	0.02	0.06	Nil	0.62	0.72	5.2	86
6	4.4	3.1	Nil	0.01	0.03	Nil	0.62	0.66	2.2	94

[a]Soils 1, 2 = Iloilo upland; 3 = Brazil dark red Latosol, clay 0-20 cm; 4 = Brazil dark red Latosol, medium 0-20 cm; 5 = Brazil red yellow Latosol, clay 0-20 cm; 6 = Brazil red yellow Latosol, medium 0-20 cm.

Table 7. Suspected Al-toxic soils.[a]

Country	Site	pH	Exchangeable Al (meq/100 g)	Al saturation (%)	Al in soil solution (ppm)
Philippines	Albay	3.5	8	66	152
Thailand	Nakornnayok	3.4	9	49	102
Thailand	Patumtani	4.2	6	29	17
Thailand	Nakornnayok	4.3	6	31	5
Thailand	Nakornnayok	4.2	7	61	20
Thailand	Nakornnayok	4.3	5	60	11
Thailand	Nakornnayok	4.4	12	65	11
Thailand	Pracheenburi	4.4	10	59	8
Thailand	Ongkarak	3.4	13	82	45
Brazil	Camaca	4.4	6	81	5

[a]Based on soil solution analysis.

The Iloilo soils are definitely not Al toxic also because the exchangeable Al and Al saturations are extremely low (Table 6). The soil pH, 5.2-5.4, is high enough to render the Al insoluble. The Iloilo soils are low in available P, a potentially greater problem.

Although the Al saturation of the Brazilian soils is extremely high, 86-97%, the soils may not be potentially Al toxic because of low soil solution Al. Deficiencies of K, Mg, Ca, and P are potential problems of these highly weathered soils.

Based on the soil solution analysis of 15 Philippine acid soils, 21 Thailand acid soils, 2 Indonesian acid soils, and 1 Brazilian acid soil, several were suspected to have Al toxicity (Table 7). The pHs of these soils are below 4.5. The exchangeable Al is equal to or greater than 5 meq/100 g soil while Al saturation ranges from 29 to 82%. The acid sulfate soils of Albay, Nakornnayok, and Ongkarak have the highest Al concentration in the soil solution.

Plant growth under nutrient deficiencies (*Plant Physiology*). Preliminary investigation on acid soil from Myligan, Aborlan, Palawan, indicated possible P, K, Ca, and Mg deficiencies (Table 8).

To verify potential nutrient problems, IR45 and Moroberekan seedlings were grown for 5 wk in pots in the phytotron glasshouse. Seven fertilizer treatments were applied: control, no N, no P, no K, no Ca, no Mg, and complete. The nutrient was applied at 0.175 g/700 g soil.

Plants receiving no N, P, nor K grew poorly (Table 9). Without N, IR45 showed chlorosis of leaves. Plant growth without Ca or Mg was improved or similar to that with the complete fertilizer treatment.

IR45 and Moroberekan growth responses were similar; Moroberekan was taller than IR45, but IR45 had more tillers.

Table 8. Chemical properties of acid soil from Myligan, Aborlan, Palawan. IRRI, 1984.

pH	Available P-Bray (ppm)	Exchangeable bases (meq/100 g)				Soil solution (ppm)		
		Na	K	Mg	Ca	Al	Ca	Mg
4.6	3.1	0.04	0.08	0.31	Nil	0.3	2.7	2.3

Table 9. Tillering, plant height, and shoot dry weight of IR45 and Moroberekan. IRRI, 1984.

Treatment	Tillers (no.)	Plant ht[a] (cm)		Shoot dry wt[a] (g)	
		IR45			
Control	1	23	(55)	0.07	(16)
No N	2	31	(74)	0.16	(37)
No P	1	23	(55)	0.06	(14)
No K	3	32	(76)	0.29	(67)
No Ca	4	40	(95)	0.38	(88)
No Mg	4	42	(100)	0.45	(105)
Complete	4	42	(100)	0.43	(100)
		Moroberekan			
Control	1	29	(47)	0.07	(16)
No N	1	40	(65)	0.12	(27)
No P	1	32	(52)	0.07	(16)
No K	2	45	(73)	0.23	(52)
No Ca	2	72	(116)	0.39	(89)
No Mg	3	66	(106)	0.46	(105)
Complete	3	61	(100)	0.44	(100)

[a] Figures in parentheses are relative values.

Plants in the no-P treatment grew similar to controls, denoted by plant height and shoot dry weight.

The lower leaves of the no-Mg plants had interveinal chlorosis, and Mg was critically low in the shoot.

Soil solution and exchangeable Ca were extremely low. Although shoot growth was good in the no-Ca plants, the critically low shoot Ca concentration indicates a possible Ca deficiency problem (Table 10).

In addition to N deficiency, deficiencies in P, Mg, Ca, and K are disorders in the acid upland soil from Palawan.

CHEMICAL KINETICS OF TWO AEROBIC AND ANAEROBIC SOILS AND RICE GROWTH

Soil Chemistry/ Physics Department

IR43 (an upland rice) and IR52 (a lowland variety) were grown in pots in Luisiana clay (pH 4.7, O.C. 2.6%) and Maahas clay (pH 6.6, O.C. 1.0%) under aerobic (field capacity) and anaerobic (submerged) conditions. The kinetics of Eh, pH, EC, and important nutrients were monitored.

The Ehs of the aerobic soils were 0.55-0.65 V in Luisiana clay and 0.45-0.55 V in Maahas clay for most of the season while the anaerobic Ehs were 0.0 to −0.1 V and −0.1 to −0.2 V. Aerobic Ehs were consistently higher in IR43 soils than in IR52 soils, suggesting less O_2 consumption by IR43 roots.

The pH of anaerobic Luisiana clay rose to 6.6 within 8 wk of submergence while that of Maahas clay was virtually constant. In contrast, pH decreased in aerobic Luisiana clay and increased in Maahas clay.

The concentration of water-soluble Fe, in consonance with high Eh, was <1 mg/litre for the aerobic soils throughout the season. In anaerobic soils, it peaked at 308 mg/litre in Luisiana clay and 27 mg/litre in Maahas clay. The water-soluble Mn concentration in aerobic Luisiana clay ranged from 1 to 7 mg/litre; in Maahas clay it was <0.01 mg/litre. In both anaerobic soils, peak Mn concentrations were 26-28 mg/litre.

Two weeks after flooding, NO_3^- was absent in Maahas clay; 2 wk later it disappeared from Luisiana clay. In aerobic soils, peak NO_3^- was 330 mg/litre for Luisiana clay and 140 mg/litre for Maahas clay.

Within 2 wk, water-soluble NH_4^+ in aerobic soils dropped to <1 mg/litre. Anaerobic Luisiana clay maintained a NH_4^+ concentration of 15-30 mg/litre throughout the season; in Maahas clay it disappeared after 4 wk.

Water-soluble P concentrations ranged from 0.5 to 1 mg/litre for the 2 soils under aerobic and anaerobic conditions the first 4 wk. Four weeks later, the concentrations were <0.1 mg/litre in all treatments.

Table 10. Nutrient concentration in the shoot of IR45 and Moroberekan. IRRI, 1984.

Treatment	N (%)	P (%)	K (%)	Mg (%)	Ca (%)
		IR45			
Control	1.77	0.044	1.32	0.198	1.163
No N	1.00	0.240	2.15	0.222	0.198
No P	2.49	0.055	1.74	0.174	0.158
No K	3.90	0.406	0.34	0.414	0.166
No Ca	4.03	0.290	2.87	0.211	0.134
No Mg	3.45	0.278	2.47	0.158	0.134
Complete	3.55	0.257	2.61	0.197	0.127
		Moroberekan			
Control	1.44	0.049	1.37	0.287	0.241
No N	1.07	0.604	2.54	0.318	0.288
No P	2.18	0.051	2.20	0.222	0.215
No K	4.62	0.586	0.384	0.434	0.186
No Ca	3.27	0.272	2.77	0.199	0.134
No Mg	3.15	0.247	2.16	0.163	0.147
Complete	3.01	0.250	2.35	0.195	0.139

Table 11. Influence of aerobic and anaerobic conditions on growth of IR43 and IR52 on 2 soils in the greenhouse. IRRI, 1984.

Condition	Variety	Tiller no.	Straw (g/pot)	Grain (g/pot)
		Luisiana clay		
Aerobic	IR43	25 b	46 c	13 d
Anaerobic	IR43	22 b	60 ab	60 a
Aerobic	IR52	28 ab	46 c	5 e
Anaerobic	IR52	33 a	65 a	60 a
		Maahas clay		
Aerobic	IR43	26 ab	52 bc	13 d
Anaerobic	IR43	14 c	49 bc	46 b
Aerobic	IR52	26 ab	52 bc	5 e
Anaerobic	IR52	26 ab	67 a	30 c

Differences in plant reactions to the 2 water regimes began to appear about 5 wk after seeding. Vegetative growth was better in anaerobic soils than in aerobic soils. Two weeks later, plants in aerobic soils began showing Fe deficiency, more severe in Maahas clay than in Luisiana clay. Both IR43 and IR52 flowered 2-3 wk later in aerobic soils. Growth and yield data are in Table 11.

Aerobic conditions depressed yield severely in both IR43 and IR52, compared to anaerobic conditions. Low yield was due to high sterility. The only nutritional disorders observed were Fe deficiency in both aerobic soils (induced apparently by high NO_3^- concentrations) and N deficiency in anaerobic Maahas clay. Anaerobiosis prevented Fe deficiency by destroying NO_3^- and increasing the water-soluble Fe concentration.

Anaerobic conditions favor yield even of upland rice. Contour bunding (reduces surface runoff) and soil compaction (retards O_2 diffusion) aid anaerobiosis.

SOIL FERTILITY CONSTRAINTS IN ASIAN RAINFED LOWLAND RICE AREAS

Soil Chemistry/Physics Department

A computer data base was developed to classify shallow rainfed lowland rice (SRLR), using FAO soil mapping units for South Asia and Southeast Asian regions. The Fertility Capability Classification (FCC) was correlated with the FAO soil mapping units to interpret the major adverse soil fertility and physical conditions. Table 12 shows

Table 12. Fertility Capability Soil Classification system modifiers used for upland rice. IRRI, 1984.

	Modifier	Criteria	Interpretation
e	low cation exchange capacity (CEC)	Applies to plow layer or surface 20 cm: CEC <4 meq/100 g soil by sum of bases + KCl ext. Al (effective CEC), or CEC <7 meq/100 g soil by sum of cations at pH 7, or CEC <10 meq/100 g soil by sum of cations + Al + H at pH 8.2	Reflects less gradual N release, more exacting N management; low ability to retain nutrients against leaching, mainly K, Ca, and Mg.
a	aluminum toxicity	Applies within 50 cm of the soil surface: >60% Al-saturation of the effective CEC, or >67% acidity saturation of CEC by sum of cations at pH 7, or >86% acidity saturation of CEC by sum of cations at pH 8.2, or pH <5.5 in 1:1 H_2O except in organic soils where pH must be <4.7.	Aluminum toxicity will occur; soil test for P deficiency recommended.
i	high P-fixation by iron	Applies to plow layer or surface 20 cm: % free Fe_2O_3/% clay = >0.15 and >35% clay, or hues of 7.5 YR or redder and granular structure.	Potential Fe toxicity; requires high level of P fertilizer or special P management practices.
b	basic reaction	Applies within 50 cm of the soil surface: free $CaCO_3$ (effervescence with HCl); or pH >7.3	Calcareous soils; high pH may induce Fe deficiency.
s[a]	shallow soils	Lithic soil mapping units of the FAO-UNESCO Soil Maps.	
f[a]	fertile	No major soil constraints.	

[a] Added to FCC system for purposes of this study.

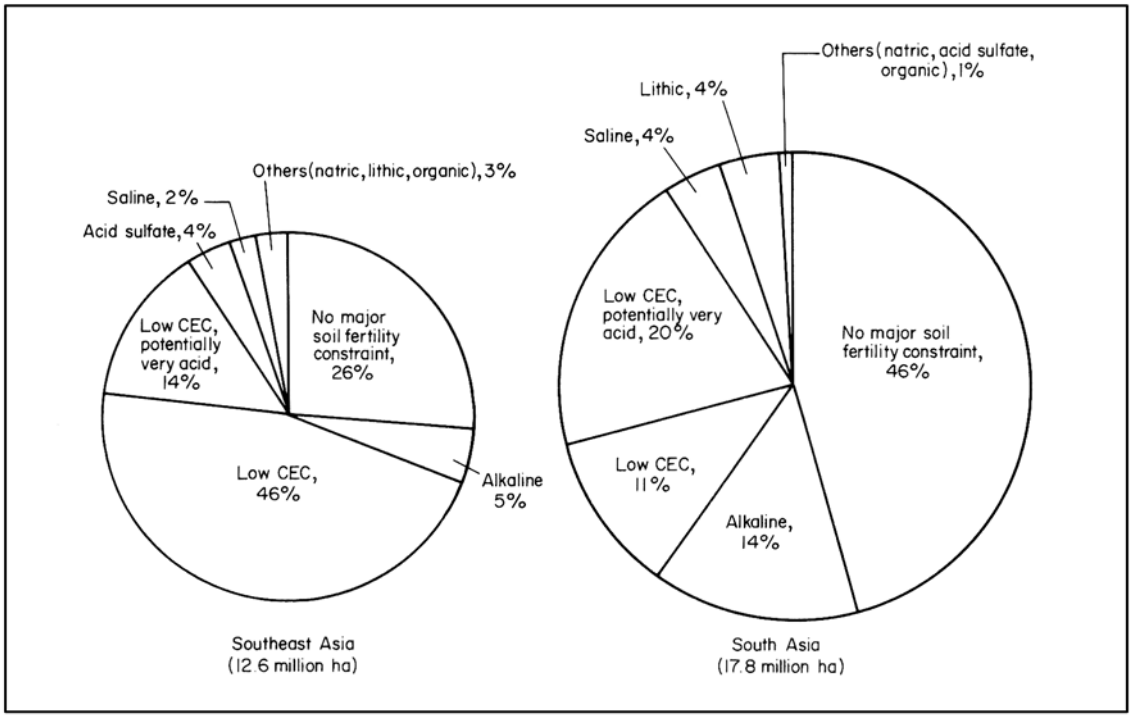
Table 13. FCC modifiers assigned for each of the soil mapping units of the FAO-UNESCO Soil Maps of the World for South and Southeast Asia.[a] 1984.

FAO Mapping Unit	Associated FCC modifiers	
	Lowland[b]	Upland
Acrisols		
Ag Gleyic Acrisol	e	ae
Af Ferric Acrisol	ie	aie
Ah Humic Acrisol	e	ae
Ao Orthic Acrisol	ie	aie
Ap Plinthic Acrisol	ie	aie
Cambisols		
Bc Chromic Cambisol	e	e
Bd Dystric Cambisol	e	e
Be Eutric Cambisol	–	–
Bf Ferralic Cambisol	ie	aie
Bg Gleyic Cambisol	–	–
Bh Humic Cambisol	–	–
Bk Calcic Cambisol	–	b
Bv Vertic Cambisol	–	–
Ferralsols		
Fh Humic Ferralsol	ie	aie
Fo Orthic Ferralsol	ie	aie
Fr Rhodic Ferralsol	ie	aie
Fx Xanthic Ferralsol	ie	aie
Gleysols		
Gd Dystric Gleysol	e	e
Ge Eutric Gleysol	–	–
Gh Humic Gleysol	e	ae
Gc Calcaric Gleysol	–	b
Phaeozems		
Hh Haplic Phaeozem	–	–
Fluvisols		
Jc Calcaric Fluvisol	–	b
Jd Dystric Fluvisol	e	e
Je Eutric Fluvisol	–	–
Jt Thionic Fluvisol	c	c
Luvisols		
Lc Chromic Luvisols	–	–
Lf Ferric Luvisols	ie	aie
Lg Gleyic Luvisols	–	b
Lk Calcic Luvisols	–	b
Lo Orthic Luvisols	–	–
Lv Vertic Luvisols	–	b
Nitosols		
Nd Dystric Nitosols	e	e
Ne Eutric Nitosols	–	–
Nh Humic Nitosols	e	e
Histosols		
Od Dystric Histosols	o	o
Podzols		
Pg Gleyic Podzols	e	ae
Ph Humic Podzols	e	ae
Po Orthic Podzols	e	ae
Arenosols		
Qa Albic Arenosols	e	ae
Qc Cambic Arenosols	e	ae
Qf Ferralic Arenosols	ie	aie
Regosols		
Rd Dystric Regosols	e	e
Re Eutric Regosols	e	e
Andosols		
Th Humic Andosols	i	ai
Tm Mollic Andosols	–	–
To Ochric Andosols	–	–
Tv Vitric Andosols	e	e
Vertisols		
Vc Chromic Vertisols	–	b
Vp Pellic Vertisols	–	b

[a]See Table 12 for explanation of modifiers. [b]Since pH is buffered toward neutral values in lowland rice situations, the a and b modifiers are deleted. Some soils have associated k modifier but this was not considered because of lack of chemical data to judge available potassium amounts.

FCC modifiers describing adverse conditions. Table 13 correlates the FCC system and the FAO soil map legend. The proportion of SRLR with certain adverse conditions varies greatly among countries and regions.

A high proportion of the SRLR in South and Southeast Asia (Fig. 8) is found on adverse soils: 55% or 9.9 million ha in South Asia, 74% or 9.2 million ha in Southeast Asia. Constraints include low CEC (in 7.7 million ha), high P fixation (5.3 million ha), alkaline and potentially Zn-deficient soils (3.3 million ha), and saline soils (1.2 million ha). Locally significant adverse soil types are acid sulfate (Vietnam, 0.4 million ha), high organic matter (Bangladesh, 0.2 million ha), natric (Burma, 0.1 million ha), and shallow soils.



8. Comparative distribution of SRLR areas by soil fertility constraint for South (Bangladesh, Bhutan, India, Nepal, Sri Lanka) and Southeast Asia (Burma, Indonesia, Kampuchea, Laos, North Vietnam, Philippines, Sabah, Sarawak, South Vietnam, Thailand, West Malaysia).

Although proportionally large areas of fertile rice soils occur in South Asia (8.03 million ha or 45% of SRLR in that region) (Fig. 8) low rainfall and short growing season often limit productivity.

Soil fertility constraints for other rice cultural types such as those in deep (50-100 cm), very deep (>100 cm), and irrigated areas are being analyzed on a regional scale using the same approach.

Soil and crop management

Management of soil and fertilizer nitrogen

Agronomy, Plant Physiology, and Training and Technology Transfer Departments

GROWTH DURATION AND NITROGEN UPTAKE **258**
NITROGEN MANAGEMENT IN EARLY MATURING RICE **258**
MANAGEMENT OF EARLY MATURING CULTIVARS **259**
Type of seedbed and N source **260**
Response of IR58 to prilled urea and urea supergranules **260**
Effect of seedling age and N source **261**
Seedling age and N application in seedbed **262**
Seedling age and seedlings per hill **262**
UREA SOURCES AND APPLICATION METHODS **263**
SUPPLEMENTARY SOURCES OF N FERTILIZERS IN LOWLAND RICE **263**
WATER DEPTH EFFECTS ON N USE IN LOWLAND RICE **263**
Floodwater chemistry **263**
Grain yield **266**
EFFECTS OF WATER DEPTH AND MANAGEMENT ON NH_3 LOSS **268**
Grain yield **271**
APPLICATION METHOD AND N EFFICIENCY IN UPLAND RICE **271**
EFFICIENCY OF N SOURCES IN DEEP WATER RICE **272**
FERTILIZER FOR DEEP WATER RICE ON ACID SULFATE SOIL **272**
N FERTILIZER EFFICIENCY IN RAINFED RICE **272**

GROWTH DURATION AND NITROGEN UPTAKE

Agronomy Department

Cooperative studies with University of California (Davis, USA) continued to evaluate modern varieties' ability to efficiently use soil N, a major N source in lowland rice culture.

Two experiments were established in dry (DS) and wet (WS) seasons. One used labeled ^{15}N-depleted ammonium sulfate (AS) with 24 varieties or lines. The other used ordinary AS with 42 varieties and lines in 3 maturity groups.

With ^{15}N-labeled AS, total N and atom % ^{15}N were determined from leaf and culm samples collected at 30 d after transplanting (DT) and at panicle initiation (PI). At harvest, grain, straw, and roots were analyzed for total N and subsequently for atom % ^{15}N. N uptake analysis for 1983 WS appears in Figure 1. The results suggest that without added inorganic N, N uptake of modern rices is gradual; initially slow at 20 kg N/ha from 1 DT to 30 DT, about 50-60 kg N/ha during PI, and almost 100 kg N/ha at maturity. As plants mature, N uptake in the leaf increases and is higher than in the culm. At harvest, most adsorbed N is in grain, followed by straw and least in roots. Patterns were identical for N uptake without added fertilizer N.

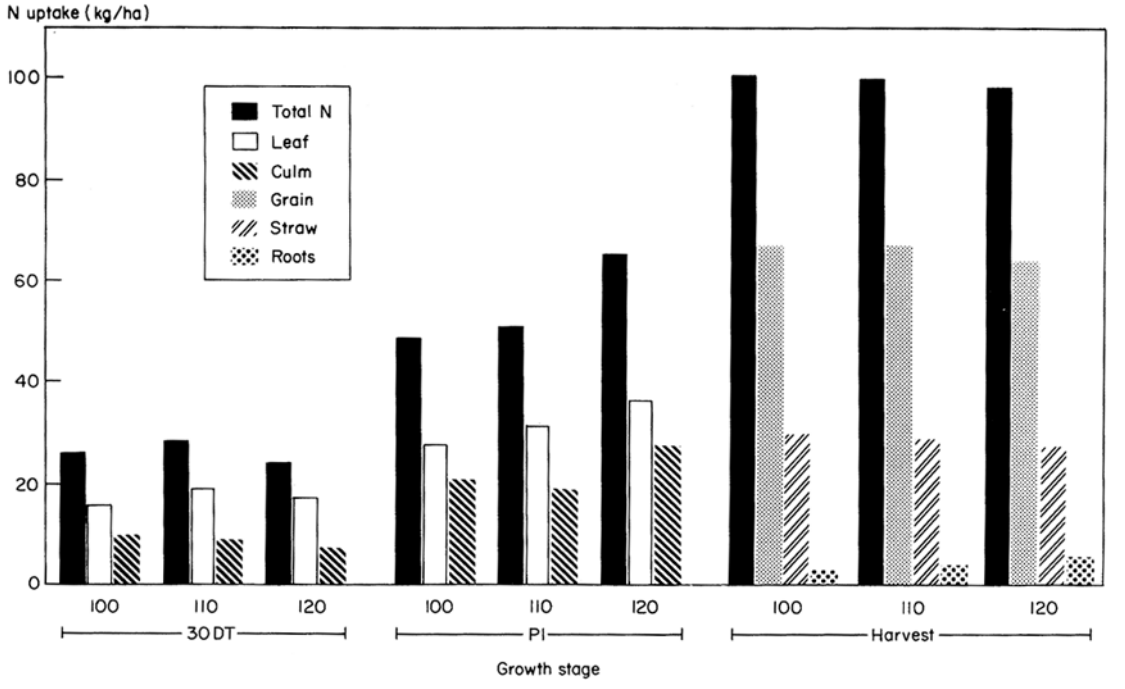
The 1984 DS yields were related to growth duration. Long-duration rices usually yielded higher than short- and medium-duration rices (Table 1).

NITROGEN MANAGEMENT IN EARLY MATURING RICE

Agronomy Department

Research continued to evaluate productivity, brown rice protein content, and lodging resistance of IR varieties and promising early maturing breeding lines as affected by application methods and N rates.

In DS, IR29692-94-2-1-3 produced the highest yield of 7.5 t/ha when fertilized with urea in split doses at 150 kg N/ha (Table 2). This line also averaged 74 kg rough rice/ha per day. The earlier maturing entries produced more (in kg/ha per day)



1. Soil N uptake by rices of 3 maturity groups (100, 110, 120 d) at different growth stages. The rices received 30 kg N/ha as ^{15}N depleted ammonium sulfate. IRRI, 1983 WS.

Table 1. Grain yield, tillers, and panicle numbers by growth duration, with and without ordinary AS, and with and without ^{15}N-depleted AS. IRRI, 1984 DS.

Maturity group (d)	Ordinary AS		^{15}N-depleted AS					
	Grain yield (t/ha)		Grain yield (t/ha)		Tillers (no./m^2)		Panicles (no./m^2)	
	No fertilizer N	60 kg N/ha	No fertilizer N	60 kg N/ha	No fertilizer N	60 kg N/ha	No fertilizer N	60 kg N/ha
100	3.6 b	5.3 c	3.4 b	5.3 a	250 b	297 b	243 a	291 b
110	3.7 b	5.9 b	3.4 b	5.6 a	266 b	324 ab	242 a	319 ab
120+	4.6 a	6.3 a	3.9 a	5.5 a	315 a	365 a	285 a	333 a

Table 2. Field duration and productivity of 4 varieties and 10 early maturing IR rices by rate and method of N application.[a] IRRI, 1984 DS.

Entry	Field duration (d)	Grain yield (t/ha)					Av yield		Brown-rice protein (%)
		No N	87 kg N/ha			150 kg N/ha	t/ha	kg/ha per day[b]	
			Urea split	SCU	USG	Urea split			
IR8	106	3.1 bc	4.9 f	4.6 e	5.2 c	5.1 e	4.6	43	7.0 f
IR36	89	3.0 bc	6.3 a-d	6.6 abc	5.9 bc	6.8 a-d	5.7	64	8.5 a
IR42	109	4.1 a	6.1 b-e	7.1 a	6.6 ab	7.0 abc	6.2	57	7.4 e
IR58	81	3.0 bc	5.8 de	6.3 a-d	6.6 ab	7.0 abc	5.7	71	8.3 ab
IR25588-7-3-1	86	3.5 abc	6.9 ab	7.1 a	6.6 ab	6.8 a-d	6.2	72	7.7 cde
IR29670-15-2-3	85	3.1 bc	5.9 cde	6.0 cd	6.7 ab	6.0 d	5.6	65	7.8 cde
IR29692-94-2-1-3	85	3.5 abc	7.0 a	6.9 ab	6.7 ab	7.5 a	6.3	74	7.9 bcd
IR29692-99-3-2-1	86	3.2 bc	6.3 a-d	6.9 ab	6.5 ab	7.0 abc	6.0	69	8.0 bc
IR29708-41-2-2-3	85	3.8 ab	6.7 abc	7.1 a	6.7 ab	7.4 ab	6.3	75	7.8 cde
IR29725-3-1-3-2	89	2.8 c	5.7 de	5.8 d	6.0 ab	6.5 cd	5.4	60	7.8 cde
IR29725-22-3-3-3	85	3.3 bc	5.9 cde	6.1 bcd	5.9 bc	6.1 d	5.5	64	7.5 de
IR29725-109-1-2-1	86	2.9 c	5.4 ef	6.1 bcd	6.1 ab	6.6 bcd	5.4	63	7.7 cde
IR31851-63-1-2-3-2	86	3.3 bc	6.7 abc	6.8 abc	6.6 ab	7.0 abc	6.1	71	7.8 cde
IR31868-64-2-3-3-3	88	3.6 abc	6.7 abc	6.7 abc	6.8 a	6.5 cd	6.1	69	7.3 cde

[a] Av of 4 replications. SCU = sulfur-coated urea, all basal broadcast and incorporated into mud before transplanting; USG = urea supergranule, hand point-placed at 10-15 cm deep. [b] Excluding 20 d in seedbed.

and had equal or higher protein content in brown rice than did longer duration IR8 and IR42. Six lines averaged yields of 6.0-6.3 t/ha, comparable to IR42's 6.2 t/ha. IR42, however, produced the highest yield (4.1 t/ha) without fertilizer N.

A single basal incorporation of slow-release sulfur coated urea (SCU) and hand placement of urea supergranules (USG) significantly increased the percentage of brown rice protein in DS (Fig. 2). These findings match results since 1981.

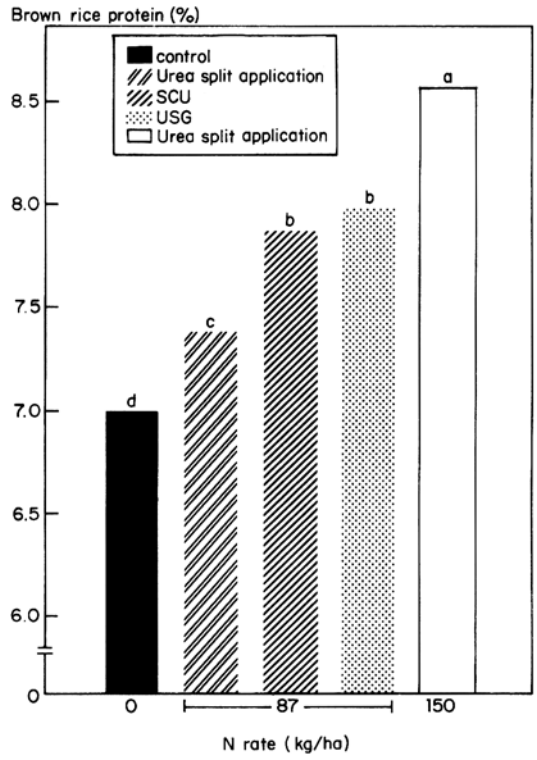
Heavy N application increased lodging, based on the lodging resistance factor (cLr) measured in DS (Table 3). As previously, IR8 resisted lodging better than did IR42. However, both longer duration varieties resisted lodging better than did early maturing rices.

In WS (Table 4), 3 lines yielded slightly higher (4.7-4.9 t/ha) than IR42 (4.5 t/ha). IR32429-47-3-2-2 produced the highest yield of 5.3 t/ha with USG at 58 kg N/ha or urea in split doses at 90 kg N/ha. This entry also averaged the highest productivity per day.

MANAGEMENT OF EARLY MATURING CULTIVARS

Plant Physiology Department

Early maturing cultivars can produce high yields per day, adapt to progressive farming, and fit areas



2. Effect of urea sources, application methods, and application rates on the protein content of brown rice (av of 14 rices). IRRI, 1984 DS.

with shorter periods of available water. Experiments examined the response of short-duration varieties (105 d) to seedling type and N source, and to increasing rates of USG and prilled urea (PU).

Type of seedbed and N source. IR58 and three promising early maturing cultivars were sown in 1984 DS. Fertilizer N at 146 kg/ha as AS and as USG was applied: 116 kg basal or deep placed 4 DT and 30 kg topdressed PU 30 DT. Dapog seedlings and 20-d-old seedlings were used.

AS and USG were similarly effective as N source for grain production. Use of 12-d dapog seedlings slightly improved grain yield over 20-d-old seedlings because of better grain filling. Use of 20-d-old seedlings increased panicle number per square metre and spikelets per panicle, but resulted in decreased grain filling, compared to 12-d dapog seedlings.

IR58 gave the best grain filling and yield.

The dapog seedlings were raised on concrete pavement (similar to some farmer's practice), making the seedlings thin and yellowish. Had they been raised on paddy as the 20-d type, yield might have been higher.

Response of IR58 to prilled urea and urea supergranules. PU was basally applied and USG deep-placed (10 cm) 4 DT, without topdressing.

Table 3. Lodging resistance factor (cLr) of 4 rice varieties and 10 early-maturing IR rices by rate and method of N application. IRRI, 1984 DS.

Entry	cLr[a]					
	No N	87 kg N/ha			150 kg N/ha	
		Urea split	SCU	USG	Urea split	Mean
IR8	0.243 a	0.223 a	0.213 a	0.203 a	0.213 a	0.219
IR36	0.157 cde	0.110 f	0.102 fg	0.112 ef	0.101 g	0.116
IR42	0.219 b	0.189 b	0.174 b	0.174 b	0.164 b	0.184
IR58	0.136 f	0.119 ef	0.117 ef	0.109 efg	0.105 efg	0.117
IR25588-7-3-1	0.172 c	0.132 de	0.128 de	0.135 cd	0.129 cd	0.139
IR29670-15-2-3	0.152 def	0.105 f	0.095 g	0.093 g	0.078 h	0.105
IR29692-94-2-1-3	0.148 ef	0.122 ef	0.117 ef	0.125 de	0.122 de	0.127
IR29692-99-3-2-1	0.152 def	0.106 f	0.094 g	0.096 fg	0.091 gh	0.108
IR29708-41-2-2-3	0.170 c	0.141 cd	0.140 cd	0.142 cd	0.144 c	0.148
IR29725-3-1-3-2	0.174 c	0.152 c	0.149 c	0.148 c	0.139 cd	0.153
IR29725-22-3-3-3	0.172 c	0.135 cde	0.131 cde	0.133 cd	0.122 de	0.139
IR29725-109-1-2-1	0.172 c	0.143 cd	0.133 cde	0.143 cd	0.122 de	0.142
IR31851-63-1-2-3-2	0.152 def	0.118 ef	0.109 fg	0.108 efg	0.099 g	0.117
IR31868-64-2-3-3-3	0.167 cd	0.145 cd	0.137 cd	0.137 cd	0.123 de	0.142
Mean	0.170	0.139	0.131	0.133	0.125	0.140

[a] Av of 4 replications. SCU = all basal, broadcast and incorporated into mud before transplanting; USG = hand point-placed at 10-15 cm deep.

Table 4. Field duration and productivity of 4 varieties and 10 early maturing IR rices, by rate and method of N application. IRRI, 1984 WS.

Entry	Field duration (d)	Grain yield[a] (t/ha)					Av yield	
		No N	58 kg N/ha			90 kg N/ha	t/ha	kg/ha per day[b]
			Urea split	SCU	USG	Urea split		
IR8	102	3.0 f	3.7 g	3.7 g	3.7 d	4.1 cde	3.6	36
IR36	90	3.6 b-e	4.5 a-d	5.0 ab	4.6 bc	4.4 bcd	4.4	49
IR42	112	4.1 ab	4.8 abc	4.7 a-d	4.5 bc	4.3 cde	4.5	40
IR58	81	3.5 c-f	3.9 efg	4.5 b-e	4.5 bc	4.5 bc	4.2	51
IR29670-15-2-3	86	3.3 def	4.1 d-g	4.2 d-g	4.1 cd	4.2 cde	4.0	46
IR29692-94-2-1-3	85	3.9 abc	4.9 ab	5.0 ab	5.0 ab	4.6 bc	4.7	55
IR29692-99-3-2-1	84	3.5 c-f	4.5 a-d	4.4 c-f	4.5 bc	4.6 bc	4.3	51
IR29725-3-1-3-2	86	3.3 def	3.6 g	3.9 fg	3.8 d	3.8 e	3.7	43
IR29725-22-3-3-3	86	3.5 c-f	4.0 d-g	3.8 g	3.7 d	3.9 de	3.8	44
IR29725-109-1-2-1	85	3.2 ef	4.3 c-f	4.5 b-e	4.2 cd	4.9 ab	4.2	50
IR31802-48-2-2-2	90	3.8 bcd	4.4 b-e	4.4 c-f	4.5 bc	4.3 cde	4.3	48
IR31851-63-1-2-3-2	84	3.3 def	3.8 fg	4.0 efg	3.8 d	3.9 de	3.8	45
IR31868-64-2-3-3-3	90	4.4 a	5.0 a	4.9 abc	4.8 ab	4.5 bc	4.7	52
IR32429-47-3-2-2	85	3.8 bcd	4.8 abc	5.1 a	5.3 a	5.3 a	4.9	57

[a]Av of 4 replications. SCU = all basal broadcast and incorporated into mud before transplanting; USG = hand point-placed at 10-15 cm deep. [b]Excluding 20 d in seedbed.

Yields responded to increased N, but not to N source (Table 5). Grain yield in PU treatment increased up to 116 kg/ha. In USG plots, yields leveled off at 58 kg/ha. No N source-rates interaction was detected. Therefore for very early maturing rices, PU can perform as well as USG.

USG plants had higher dry weight, more tillers at maximum tiller stage, and more panicles per square metre than the PU plants. But percentage filling decreased with increased USG application.

Increasing USG increased panicles per square meter and the increase was slightly higher than for PU. Spikelets per panicle increased with higher levels of USG but not with PU. However, sterility greatly increased and 1,000-grain weight decreased with more USG and not with PU. This is probably because plants with USG had high N content at flowering as shown in plant sample analysis.

Effect of seedling age and N source. Neither seedling age nor kind of N fertilizer significantly affected grain yield of IR58 in DS.

Although the yields of PU and USG plots did not significantly differ, the USG plots' significantly fewer spikelets per panicle, percent filled spikelets, and 1,000-grain weight should be studied. Although USG produced more panicles, it did less well than PU in other yield components.

Tillering pattern shows earlier and more tillers in PU plots than USG plots and for younger seedlings (15-d-old) than old seedlings (Fig. 3). At maturity, USG plants had more tillers than PU plants but fewer grains per panicle. The lower percent productive tillers of USG should be studied.

Dry matter production and leaf area index (LAI) were initially high for older seedlings, but younger seedlings were more vigorous by 40 DT and significantly higher in dry matter and LAI at flowering.

The N content of the USG fertilized plants was higher than that of the PU plants at flowering. The high N content may account for the higher sterility and lower weight per grain of the USG plants.

Table 5. Effect of different N rates applied as PU and as USG on yield of IR58. IRRI, 1984 WS.

N rates (kg/ha)	Yield[a] (t/ha)	
	PU	USG
0	2.80 d	2.84 d
29	3.74 c	3.63 c
58	4.28 b	4.51 ab
116	4.71 a	4.54 ab

[a]In the same column or row, means followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Seedling age and N application in seedbed. Grain yields of 15-d-old seedlings were consistently higher than those of 30-d-old seedlings in early maturing IR58 and IR36 in DS (Fig. 4). In late maturing IR42, seedling age made no significant difference in grain yield. In IR58 and IR36, the younger seedlings produced 3 t more.

Adding N in the seedbed did not increase grain yield, suggesting that this practice is not essential at IRRI farm, especially with late maturing varieties.

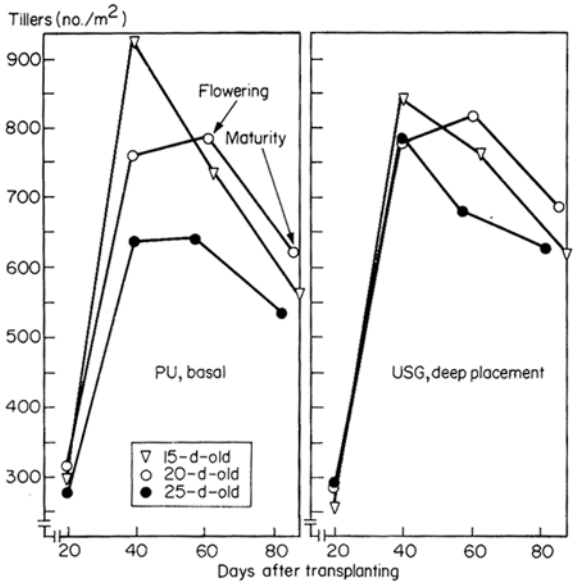
Younger seedlings' higher yields derived from more panicles and partly from the higher percent of filled spikelets.

Younger seedlings tillered earlier; this effect continued to maturity except for long-duration IR42. Percent effective tillers was always higher with younger seedlings. Dry matter and LAI were initially higher with the old seedlings but the younger seedlings caught up by 30 DT.

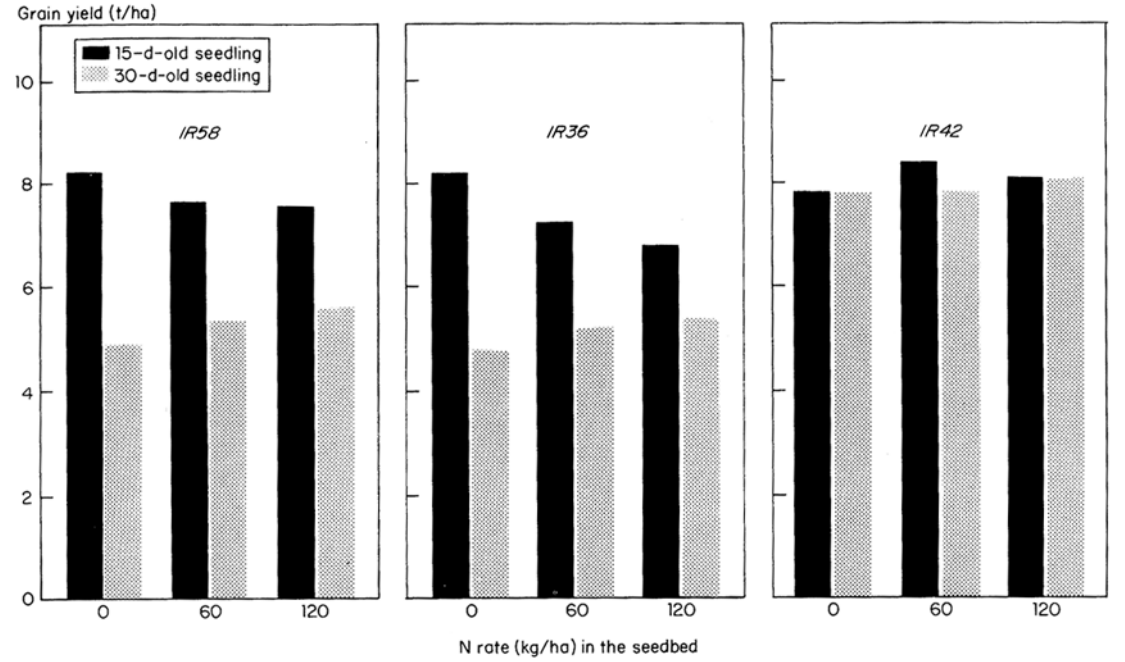
For early maturing rice varieties, young seedlings should be used.

Seedling age and seedlings per hill. Seedlings per hill did not significantly affect grain yields of early maturing IR58 or late maturing IR42. Young IR58 seedlings had higher yields than old seedlings during DS, but not during WS. In IR42, old seedlings gave higher yields than young seedlings.

During WS, the percent effective tillers increased with seedling age, the reverse of DS results. Higher IR42 grain yields with older seedlings were mainly due to more panicles.



3. Tiller number of IR58, as affected by seedling age and kind of N fertilizer. IRRI, 1983-84 DS.



4. Relationship between grain yield and N rate in the seedbed of IR58, IR36, and IR42 seedlings at 2 ages. IRRI, 1983-84 DS.

UREA SOURCES AND APPLICATION METHODS

Agronomy Department

During DS and WS, the improved method and timing of urea application (2/3 broadcast and incorporated [B & I]) into mud during the final harrowing + 1/3 topdressed at 5-7 d before panicle initiation [DBPI]) produced yields comparable to those with single basal incorporation of slow-release SCU and deep placement of USG (Table 6). On the other hand, topdressed urea at 10 DT and 10 d after panicle initiation (DAPI) was inferior to the former treatments. Delaying first broadcast of urea to 20 DT gave yields comparable to those from application at 10 DT. With early maturing IR58 (100 d), split application of urea at 20 DT plus topdressing before PI produced yields comparable to those from the recommended improved method and timing of application.

A single dose or split doses of modified sources of urea (SCU, Super 60/urea, Osmocote, and PU + 10% DCD) did not show yield advantage over the improved method and timing of application (Table 6). A single basal incorporation of slow-release Osmocote gave higher yields than split application. In contrast, single basal incorporation of Super 60/urea produced lower yields than split application.

SUPPLEMENTARY SOURCES OF N FERTILIZERS IN LOWLAND RICE

Agronomy Department

Grain yields of the fourth (DS) and fifth (WS) consecutive crops were higher in farmers' fields than at IRRI farm (Table 7). At both sites in DS, fresh soil-incorporated azolla either alone or with PU or USG was comparable with PU alone. Soil-incorporated rice straw compost was no better than the control. However, fresh soil-incorporated rice straw in both sites proved superior to the control. Usually, combinations gave higher yields than single sources.

In WS, organic sources alone often were better than the control. At IRRI farm and usually in farmers' field, combined sources were comparable to PU alone or USG.

WATER DEPTH EFFECTS ON N USE IN LOWLAND RICE

Agronomy Department

Floodwater chemistry. Potential N loss through volatilization can be measured by the ammoniacal N (AN) and equilibrium vapor pressure of NH_3 (pNH_3) in floodwater. Losses are generally high with high AN or pNH_3 in floodwater.

In DS and WS, concentrations of AN in floodwater were higher when urea was B & I with 5 cm standing water than when B & I directly into mud (Fig. 5, 6). Maximum concentration of ~10 g/m^3 was obtained 2 d after urea application in DS (Fig. 5). At PI, AN in the floodwater 1 d after topdressing was ~6 g/m^3 in both seasons. In DS, AN increased to ~9 g/m^3 2 d after application, then sharply declined. In WS, AN gradually diminished up to 5 d after application.

Table 6. Grain yield of IR58 by source of urea and application method. IRRI, 1984 DS and WS.

Urea source	N rate (kg/ha)		Application method[a]	Grain yield (t/ha)	
	DS	WS		DS	WS
–	0	0	No fertilizer N	3.3 d	2.5 g
PU	87	58	1/2 at 10 DT + 1/2 at 10 DAPI	4.0 c	3.6 f
PU	87	58	1/2 at 20 DT + 1/2 at 10 DAPI	4.3 bc	3.7 ef
PU	87	58	2/3 B&I + 1/3 at 5-7 DBPI	4.9 ab	4.2 abcde
SCU	87	58	All basal, B&I	5.3 a	4.4 abc
Super 60/urea[b]	87	58	All basal, B&I	4.2 c	3.8 def
Super 60/urea[b]	87	58	2/3 B&I + 1/3 at 5-7 DBPI	5.2 a	4.3 abcd
Osmocote[c]	87	58	All basal, B&I	5.2 a	4.4 abc
Osmocote[c]	87	58	2/3 B&I + 1/3 at 5-7 DBPI	4.5 bc	4.1 bcdef
Supergranule	87	58	All basal, deep point placement at 5 DT	5.2 a	4.6 ab
PU + 10% DCD[d]	87	58	All basal, B&I	4.9 ab	4.0 cdef
PU	150	90	2/3 B&I + 1/3 at 5-7 DBPI	5.3 a	4.7 a

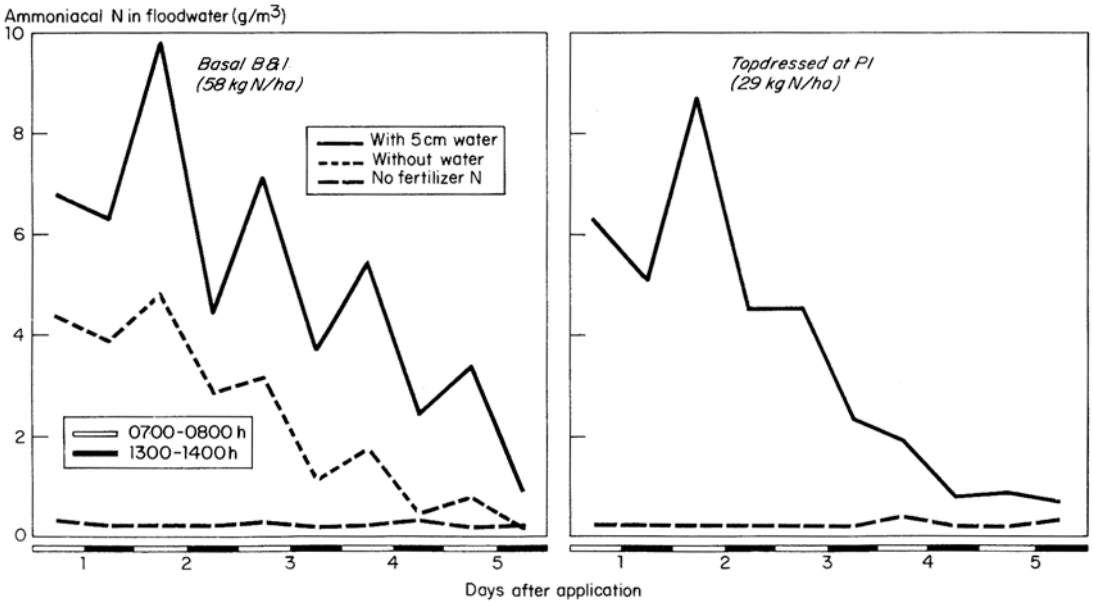
[a]DAPI = d after panicle initiation, B&I = broadcast and incorporated into mud, DBPI = d before panicle initiation. Topdressing at 10 DT and before or after PI were done with about 5 cm standing water. [b]Super 6 (2, 4, 6 triamino 1, 3, 5 triazine) is 75% and urea is 25%. [c]3 to 4 mo formulation. [d]Dicyandiamide, a nitrification inhibitor.

Table 7. Effect of supplementary N sources on grain yield of IR36 at IRRI, and at farmer's field, Victoria, Laguna, Philippines, 1984.

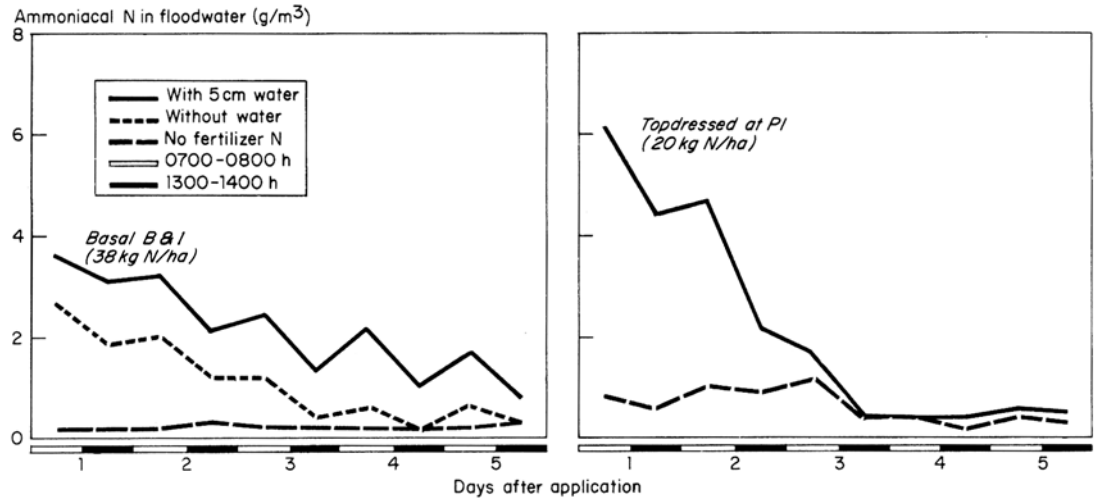
N source[a]	Grain yield (t/ha)			
	DS (fourth crop)		WS (fifth crop)	
	IRRI	Farmer's field	IRRI	Farmer's field
No fertilizer N (control)	3.3 d	4.1 b	3.2 d	3.4 c
Single sources				
PU, best split	5.5 b	6.3 a	3.8 ab	4.1 ab
USG	6.1 a	6.3 a	3.9 a	4.2 a
Fresh azolla, soil incorporated	5.3 b	6.4 a	3.3 cd	4.0 ab
Fresh rice straw, soil incorporated	4.0 c	5.8 a	3.5 bc	3.7 bc
Rice straw compost, soil incorporated	3.8 cd	4.6 b	3.5 bc	4.0 ab
Combined sources[b]				
Fresh azolla + PU, best split	5.2 b	6.4 a	3.8 ab	4.0 ab
Fresh rice straw + PU, best split	5.7 ab	6.6 a	3.8 ab	3.7 bc
Rice straw compost + PU, best split	5.2 b	6.1 a	3.8 ab	4.2 a
Fresh azolla + USG	5.7 ab	6.2 a	3.9 a	4.0 ab
Fresh rice straw + USG	5.5 b	6.4 a	3.9 a	4.0 ab
Rice straw compost + USG	5.3 b	6.7 a	4.0 a	4.0 ab

[a]For best split application, 2/3 urea was B&I at planting, and 1/3 was topdressed 5-7 DBPI. N rates = 58 kg N/ha in WS and 116 kg N/ha in DS. [b]For combined applications, 29 kg N/ha each of organic and inorganic sources in WS, and 58 kg N/ha in DS.

Ammonia vapor pressure in both seasons showed similar trends: B & I with 5 cm water gave higher pNH_3 than B & I without standing water (Fig. 7, 8). In DS, pNH_3 was high from 1 to 4 d after application in plots where urea was B & I with 5 cm water, suggesting greater volatilization then. In WS, highest pNH_3 of 0.26 Pa occurred 2 d after application. At PI, ammonia vapor pressure was high during the first 2 d after topdressing. Although less N was applied in WS than in DS, the high



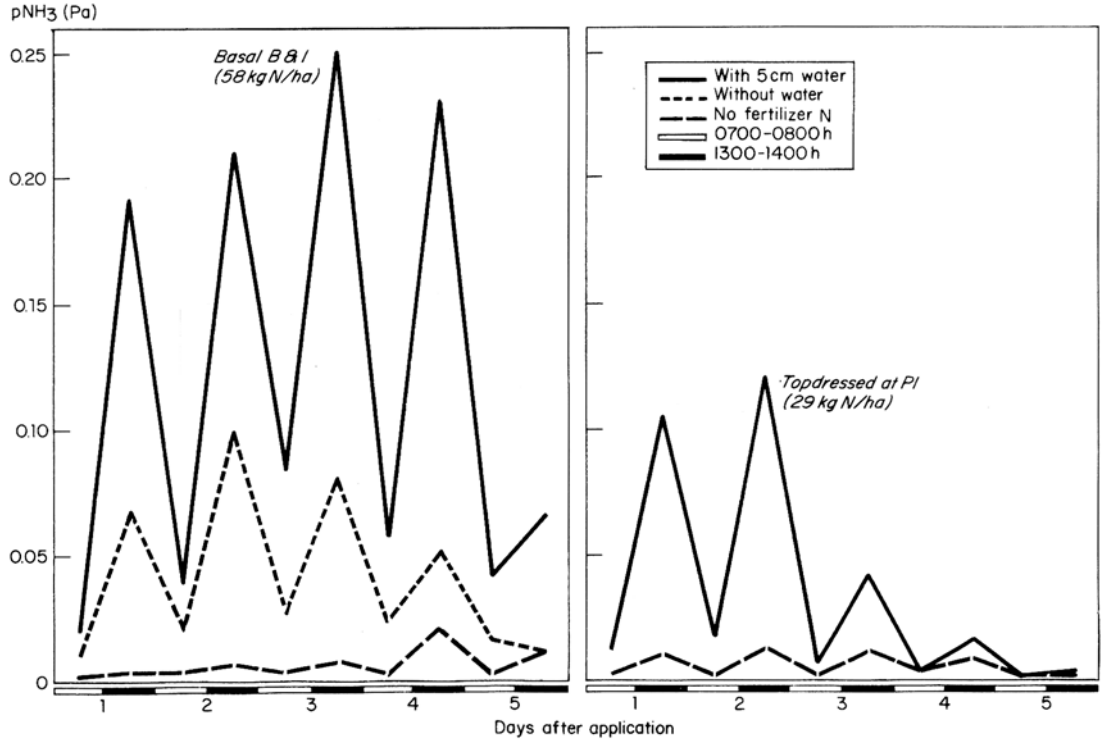
5. Ammoniacal N in floodwater as affected by water depth during application of urea by the researchers' split. Topdressing data are the mean of 2 treatments. IRRI, 1984 DS.



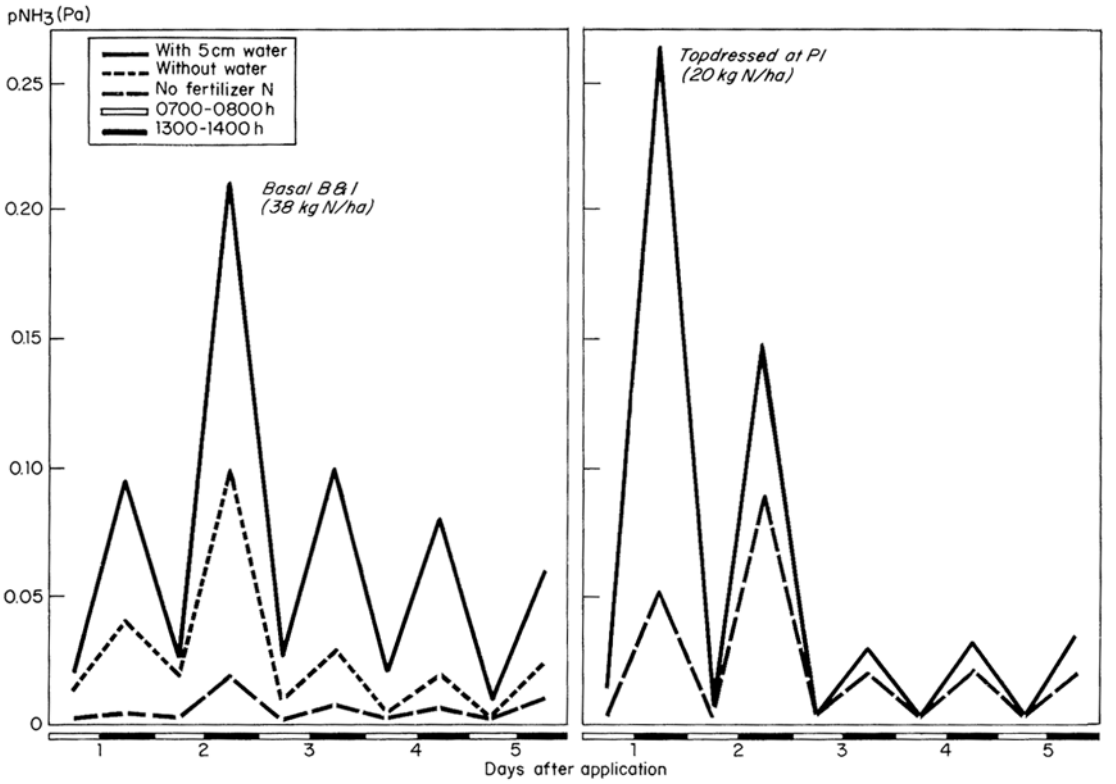
6. Ammoniacal N in floodwater as affected by water depth during application of urea by the researchers' split. Topdressing data are the mean of 2 treatments. IRRI, 1984 WS.

pNH_3 in WS could be attributed to higher pH and floodwater temperature during sampling.

With urea applied by the farmers' split, appreciable N ended in floodwater. In DS and WS, floodwater AN at 10 DT was highest when water during N application was 5 cm deep and lower as water depth increased to 15 cm (Fig. 9, 10). Highest N concentration at 5 cm water depth occurred 2 d



7. Equilibrium vapor pressure of NH_3 in floodwater as affected by water depth during researchers' split urea application. Topdressing data are the mean of 2 treatments. IRRI, 1984 DS.



8. Equilibrium vapor pressure of NH_3 in floodwater as affected by water depth during researchers' split urea application. Topdressing data are the mean of 2 treatments. IRRI, 1984 WS.

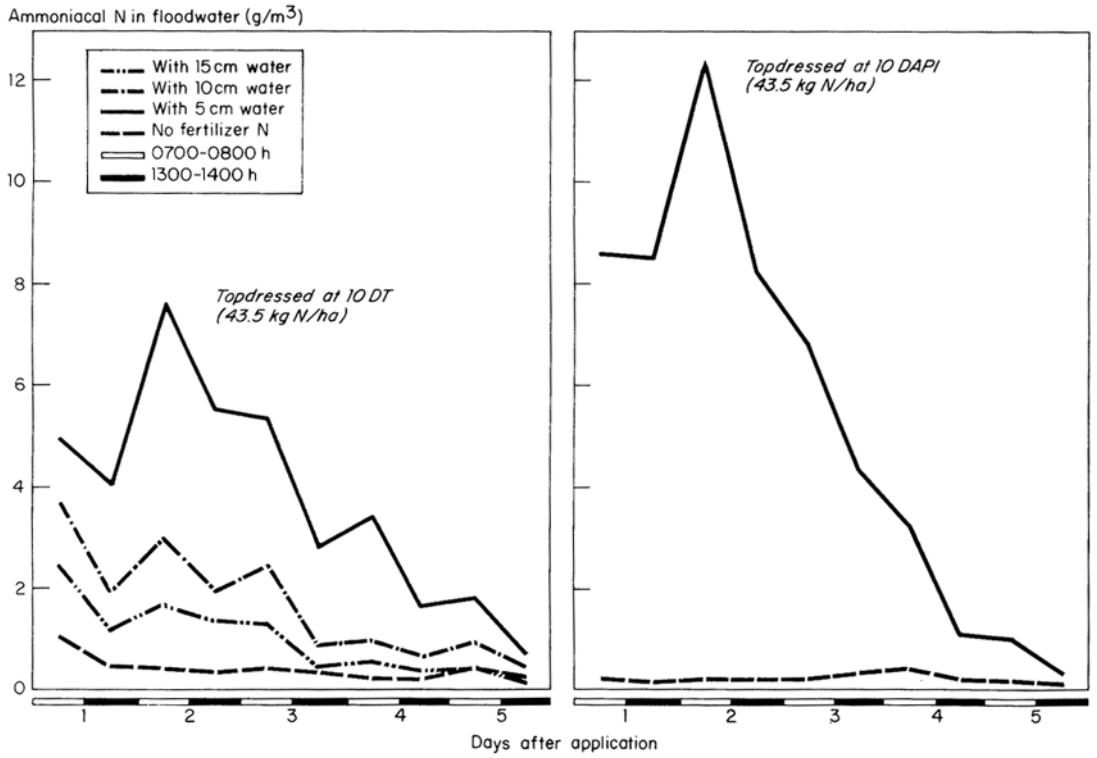
after urea topdressing. Topdressing at 10 DAPI showed highest floodwater AN 2 d after application, 12 g/m^3, in DS and 8 g/m^3 in WS.

Ammonia vapor pressure was highest with topdressing at 10 DT in 5 cm standing water (Fig. 11, 12). Regardless of water depth, maximum pNH_3 came 2 d after N application in DS (Fig. 11). In WS, pNH_3 was high the first 3 d after application, then decreased from day 4 onwards. After N topdressing at 10 DAPI, pNH_3 was high the first 3 d in DS. In WS, a high pNH_3 of 0.36 Pa came 1 d after topdressing. Lower pNH_3 was noted at 10 DAPI, when the rice canopy is already well-developed, minimizing volatilization.

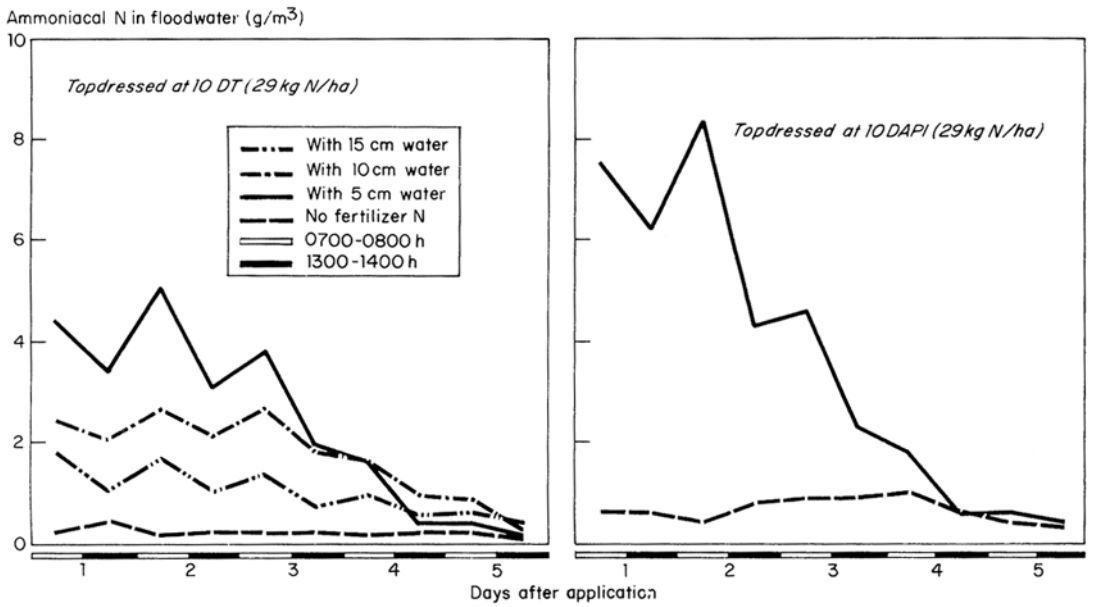
Floodwater AN and pNH_3 were measured from plots with B & I SCU and USG placement. Results indicated low N in floodwater. Low ammonia vapor pressures implied minimal N loss.

Grain yield. The researchers' split (RS) application of PU (2/3 B & I + 1/3 at PI) without standing water produced grain yields comparable to single basal incorporation of slow-release SCU or hand point-placed USG (Table 8). Applying fertilizer with 5 cm standing water reduced yields by 0.9 t/ha in DS and 0.5 t/ha in WS. Urea broadcast in equal splits at 10 DT and 10 DAPI or by farmers' split (FS), irrespective of water depth, yielded less than RS applied without water. Topdressing at 10 DT without standing water was not better than into 5- to 15-cm water. Yield did not differ when urea was band-placed by machine or applied as RS or FS with 5 cm water. High application of urea by RS without standing water gave yields similar to those with SCU, USG, or RS without water at lower rates.

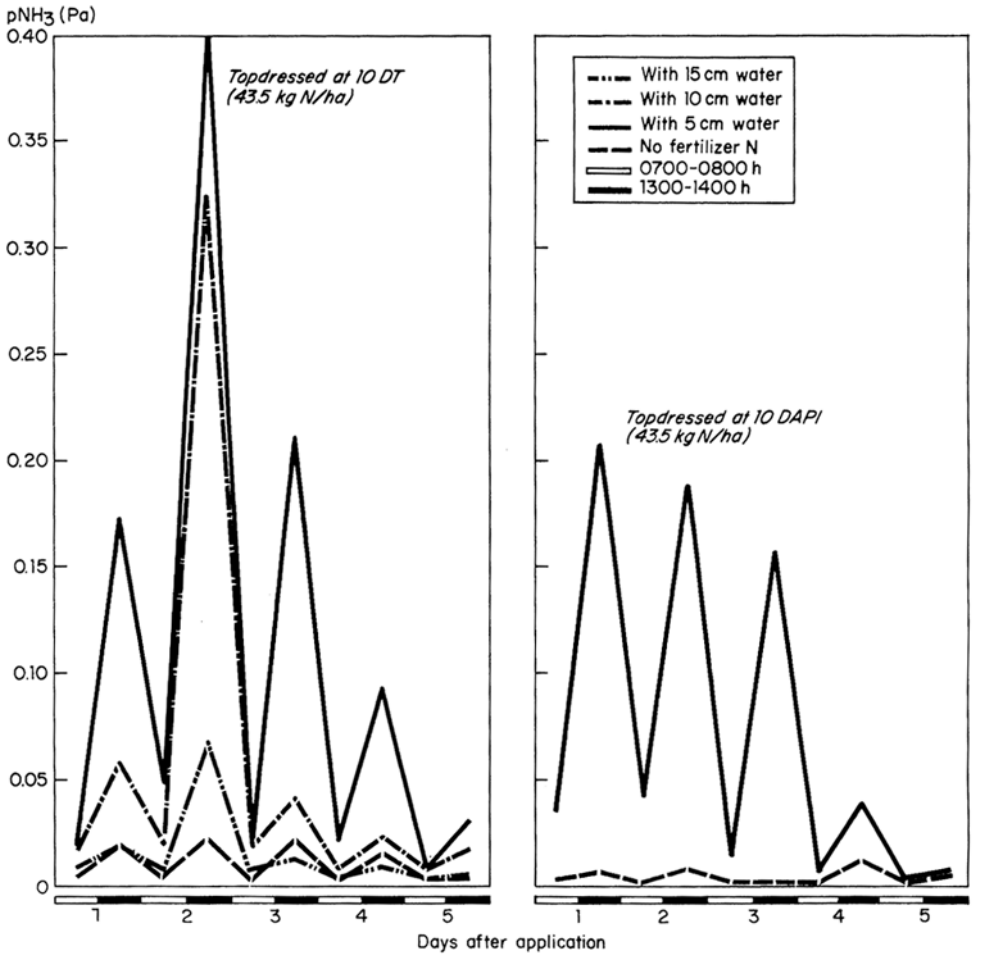
Results show that proper water management during N application greatly increased N use efficiency. For increasing grain yield and minimizing N loss, N B & I directly into mud was as effective as SCU B & I and USG placement. Low ammoniacal N and pNH_3 in floodwater were noted with this method.



9. Ammoniacal N in floodwater, by water depth, during farmers' split urea application. Data for 10 DAPI are the mean of 4 topdressing treatments. IRRI, 1984 DS.



10. Ammoniacal N in floodwater, by water depth, during farmers' split urea application. Data for 10 DAPI are the mean of 4 topdressing treatments. IRRI, 1984 WS.



11. Equilibrium vapor pressure of NH_3 in floodwater, by water depth, during farmers' split urea application. Data for 10 DAPI are the mean of 4 topdressing treatments. IRRI, 1984 DS.

Farmers' practice of applying N with 5 cm standing water leads to excessive N losses. Although AN and pNH_3 in floodwater are low at 10- and 15-cm water depths, this does not benefit rice, since at 10 DT, seedling growth and tillering are inhibited and plants do not efficiently use applied N.

EFFECTS OF WATER DEPTH AND MANAGEMENT ON NH_3 LOSS

Agronomy Department

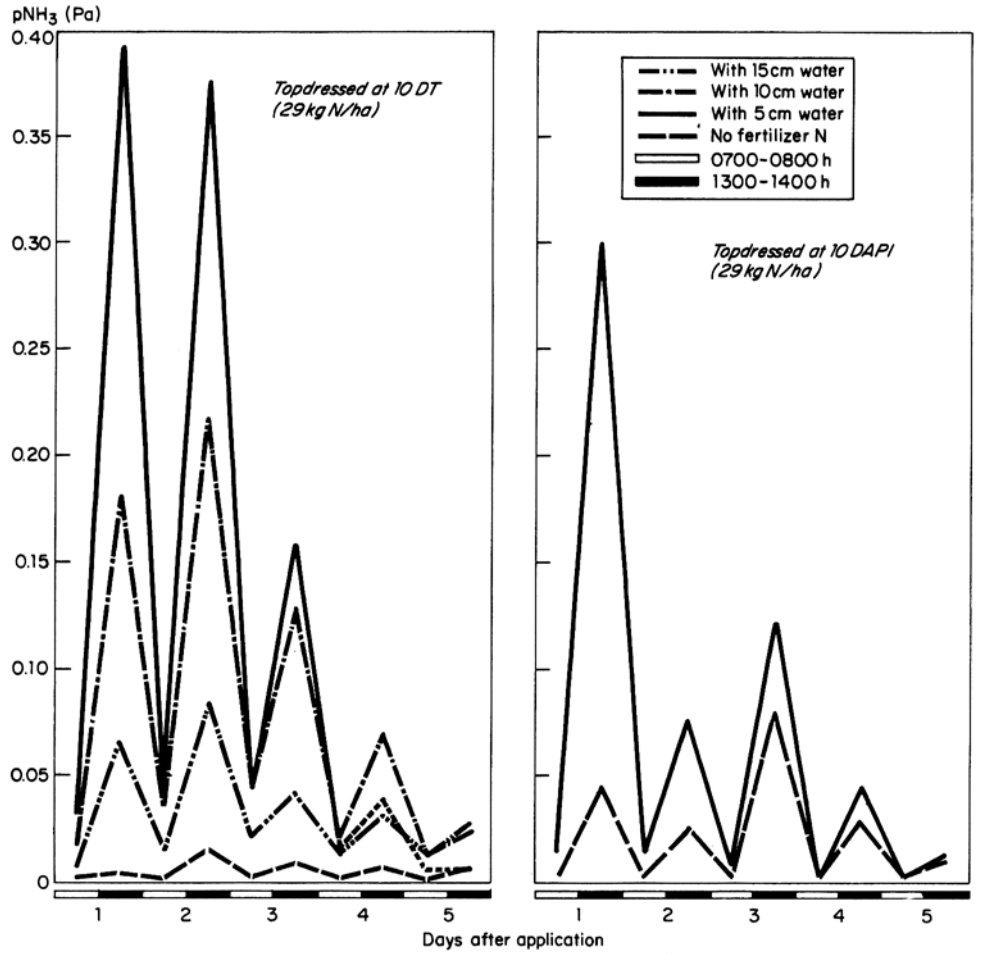
Effects of water depth and fertilizer application method on floodwater urea-N + NH_4^+-N concentrations and pH were evaluated in a farmer's field in San Jose City, Nueva Ecija. NH_3 volatilization was measured using the acid trap method.

Highest floodwater pH value of 9.6 was obtained with basal and incorporated N fertilizer at 2.5 cm water depth. With other N treatments, floodwater pH ranged from 9.0 to 9.5.

When N was applied basal and incorporated without standing water, NH_4^+-N was negligible 1 d after flooding. With the same treatment with 2.5 cm standing water, NH_4^+-N in floodwater was 0.3 g N/ m^2 on 1st and 2d day, rising to 0.4 g N/ m^2 on the 3d and dropping to almost zero on the 5th day. The trend was similar with 5 cm standing water.

Using the acid trap method, NH_3 loss from incorporated fertilizer was 10.3% with 2.5 cm standing water, 5.1% without standing water, and 7.2% with 5 cm water.

When fertilizer was topdressed 10 DT without

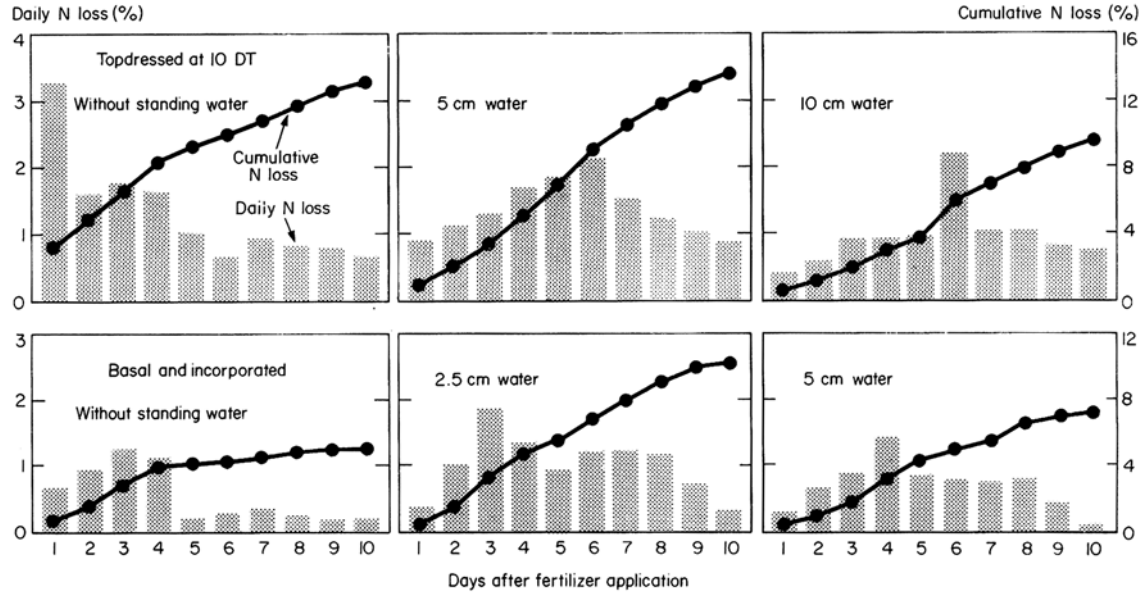


12. Equilibrium vapor pressure of NH_3 in floodwater, by water depth, during farmers' split urea application. Data for 10 DAPI are the mean of 4 topdressing treatments. IRRI, 1984 WS.

Table 8. Effects of water depth, application method, and urea source on IR58 grain yield.[a] IRRI, 1984 DS and WS.

Urea source	Application method	Nitrogen applied (kg/ha)		Water depth during basal fertilizer application (cm)	Grain yield (t/ha)	
		DS	WS		DS	WS
–	No fertilizer N	0	–	–	2.9 c	2.7 g
SCU	All basal, B&I	87	58	0	6.6 a	4.6 abc
PU	Researchers' split	87	58	0	6.4 a	4.4 bcd
PU	Researchers' split	87	58	5	5.5 b	3.9 e
PU	Farmers' split	87	58	0	5.4 b	4.1 de
PU	Farmers' split	87	58	5	5.2 b	3.8 ef
PU	Farmers' split	87	58	10	4.7 b	3.4 f
PU	Farmers' split	87	58	15	5.1 b	3.4 f
USG	All basal, hand point-placement	87	58	5	6.6 a	4.5 abcd
USG/PU	Basal plus at PI[b]	87	58	5	6.6 a	4.7 ab
PU	All basal, band placement by oscillating plunger machine	67	58	5	5.5 b	4.2 cde
PU	Researchers' split	150	115	0	6.6 a	4.9 a

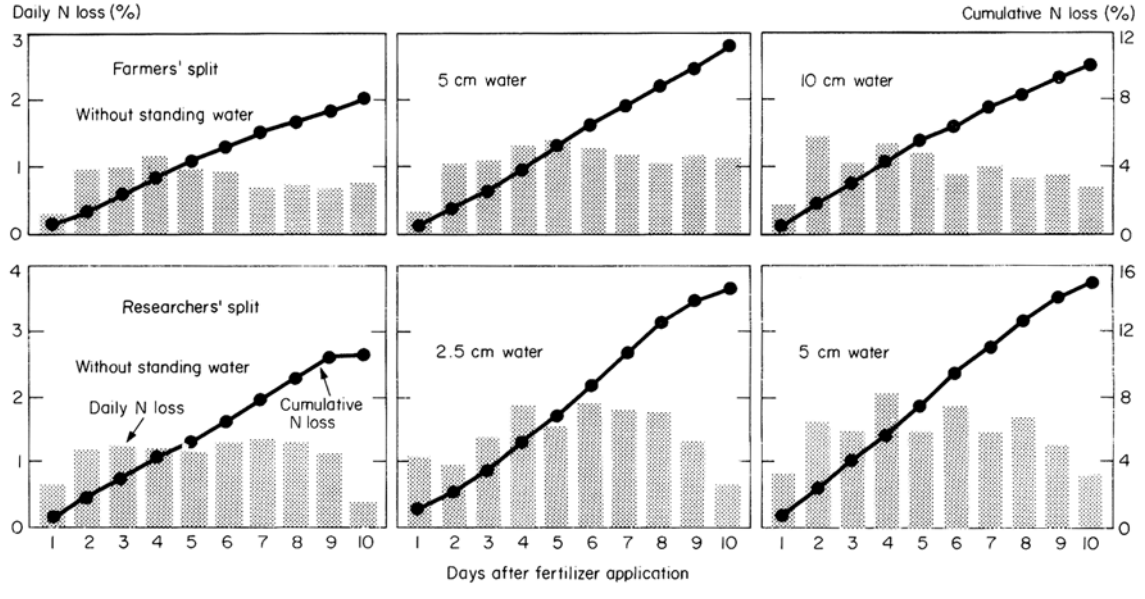
[a] Av of 4 replications. [b] In DS, 2/3 basal as USG plus 1/3 at PI as PU, and in WS, 1/2 basal as USG plus 1/2 at PI as PU.



13. Daily and cumulative NH_3 loss, by water depth and fertilizer application method: topdressed or basal and incorporated. San Jose, Nueva Ecija, Philippines, 1984 DS.

standing water, floodwater had low NH_4^+-N 1 d after flooding. However, the rate of NH_3 loss was highest (3.3%) on the 1st day, 1.6 and 1.8% on the 2d and 3d days and totaled 13.1% (Fig. 13). Topdressing at 10 DT with 5 cm water produced about 1 g N/m^2 of NH_4^+-N in floodwater on the 2d day, decreasing to negligible level on the 6th day. With 10 cm water, NH_4^+-N in floodwater was somewhat lower.

Rate of NH_3 loss with topdressing at 5 cm water



14. Daily and cumulative NH_3 loss, by water depth and fertilizer application method: farmers' or researchers' split. San Jose, Nueva Ecija, Philippines, 1984 DS.

depth was similar to that without standing water (Fig. 13). With topdressing at 10 DT into 10 cm water, NH_3 loss continued gradually up to 5th day, rose to 2.2% on the 6th day, with total loss of 9.7%.

Both farmers' and researchers' split methods recorded high NH_4^+-N in floodwater, resulting in 11 and 15% NH_3 losses (Fig. 14).

Although the measured NH_3 loss with topdressing at PI and booting stages amounted to 9.9-13.4%, the large canopies of the rice plants can trap the NH_3 so the N losses then may not hurt N use efficiency.

Grain yield. The yield response of IR58 to fertilizer was about 3 t/ha (Table 9).

Grain yield with point placement was similar to that with B & I treatment without standing water and with 2.5 cm water. With B & I fertilizer, grain yield was significantly lower with 5 cm water than with no standing water or 2.5 cm water. Topdressing of N at 10 DT at different water depths gave similar grain yields that were significantly lower than for B & I fertilizer.

APPLICATION METHOD AND N EFFICIENCY IN UPLAND RICE

Agronomy Department

The effect of application methods on yield of two varieties was evaluated in an upland farmer's field in Santo Tomas, Batangas, in 1984 WS. With both varieties, applying urea always produced yields significantly better than without fertilizer (Table 10). Highest yield of 2.9 t/ha was obtained when urea was applied in 2 equal doses at 30 d after seeding (after first weeding) and at 5-7 DBPI. However, this treatment produced yield similar to that with urea 2/3 B & I before seeding + 1/3 5-7 DBPI. Applying all urea in furrows and covering with dry soil yielded lowest. IR43 yielded 0.6 t/ha more than UPL Ri-5 irrespective of application method.

Table 9. Grain yield of IR58 by water depth and method of fertilizer N application.[a] San Jose City, Nueva Ecija, Philippines, 1984 DS.

Treatment	Urea source	Water depth (cm) during basal fertilizer application	Grain yield (t/ha)
Unfertilized control	–	–	3.4 d
Researchers' split[b]	PU	0	6.0 a
Researchers' split[b]	PU	2.5	5.9 a
Researchers' split[b]	PU	5	5.3 b
Farmers' split[c]	PU	0	4.6 c
Farmers' split[c]	PU	5	4.6 c
Farmers' split[c]	PU	10	4.3 c
Point-placement at 10 cm soil depth	USG	0	6.3 a

[a]87 kg N/ha. [b]2/3 B&I + 1/3 at 5-7 DBPI. [c]2/3 at 10 DT + 1/3 at booting stage.

Table 10. Effect of urea-N application (70 kg N/ha) on grain yield of IR43 and UPL Ri-5 under upland conditions. Santo Tomas, Batangas, Philippines, 1984 WS.

Application method	Grain yield (t/ha)		
	IR43	UPL Ri-5	Mean
No fertilizer N	1.4 c	1.0 c	1.2 d
2/3 B&I before seeding + 1/3 topdressed 5-7 DBPI	2.7 ab	2.1 a	2.4 ab
1/2 topdressed 30 DAS[a] (after 1st weeding) + 1/2 topdressed 5-7 DBPI	2.9 a	2.3 a	2.6 a
All basal in furrow, covered with dry soil	2.4 b	1.6 b	2.0 c
1/2 basal in furrow, covered with dry soil + 1/2 topdressed 5-7 DBPI	2.5 b	2.1 a	2.3 b
Mean	2.4	1.8	2.1

[a]Days after seeding.

Volatilization after N application before seeding and at 5-7 DBPI was minimal.

EFFICIENCY OF N SOURCES IN DEEP WATER RICE

Agronomy Department

This research examined ways to improve N availability in lowland rice fields by different sources and pellet sizes of N carriers, different coating materials on the pellets, or nitrification inhibitors such as dicyandiamide (DCD) to block the conversion of ammonium nitrogen to nitrate.

The efficiency of N fertilizer for deep water rice with such materials and methods was tested in a farmer's field near Ayutthaya, Thailand. The treatments and grain yields are shown in Table 11.

The water was deeper than normal (maximum depth over 150 cm), but slow to rise. Plot variability was high. The best treatments were basal incorporation of forestry-grade SCU and a split application of 80 kg PU/ha.

Table 11. Response of deep water rice SPR7270-18 to N sources in a farmer's field, Ayutthaya, Thailand, 1983 WS.

N source	N rate (kg/ha) and method[a]	Yield (t/ha)
Forestry grade SCU	40 BBI	2.30 a
PU	40 BBI + 40 at 30 DARE	2.11 a
Ammonium sulfate	40 BBI + 40 at 30 DARE	1.95 ab
Ammonium sulfate	20 BBI + 20 at 30 DARE	1.80 ab
Forestry grade SCU + PU	20 BBI (SCU) + 20 PU at 30 DARE	1.79 ab
Ammonium sulfate + 10% DCD	40 BBI	1.77 ab
PU	40 BBI	1.66 abc
PU + 10% DCD	40 BSB	1.51 abcd
PU	20 BBI + 20 at 30 DARE	1.46 abcd
PU + 10% DCD	40 BBI	1.12 cd
Ammonium sulfate + 10% DCD	40	0.87 cd
Check	Nil	0.69 d

[a]BBI = basal broadcast and incorporated, DARE = d after rice emergence, BSB = basal surface broadcast.

Table 12. Effect of P and N on grain yield of deep water rice RD19, grown on an acid sulfate soil under severe flood conditions. Prachinburi Research Station, Thailand, 1983 WS.

Phosphate	Grain yield (t/ha) at indicated rate (kg/ha) of N					
	Nil	25[a]	50[b]	75[c]	100[d]	Mean
Nil	0.04	0.14	0.50	0.30	0.13	0.13
20, drill	0.28	0.31	0.42	0.51	0.57	0.42
40, drill	0.11	0.45	0.04	0.71	0.82	0.62
20, broadcast	0.11	0.30	0.77	0.45	0.50	0.50
40, broadcast	0.31	0.30	0.65	0.57	0.69	0.50
Mean	0.17	0.30	0.58	0.51	0.54	

LSD (0.01) = 0.27 for P means, = 0.21 for N means

[a]14 Jun. [b]25 kg N/ha 14 Jun + 25 kg 7 Jul. [c]25 kg N/ha 14 Jun + 25 kg 7 Jul + 25 kg 7 Aug. [d]50 kg N/ha 14 Jun + 25 kg 7 Jul + 25 kg 7 Aug.

FERTILIZER FOR DEEP WATER RICE ON ACID SULFATE SOIL

Agronomy Department

Yield response of RD19 was tested on an acid sulfate soil at Prachinburi, Thailand. Phosphate was drilled with the seed in rows, or broadcast immediately after seeding. N was broadcast thrice to give combinations shown in Table 12. Seedlings emerged on 27 May and plants matured early December.

Flooding commenced 5 Aug and water depth reached 100 cm within 18 d. Plants were completely submerged by clear water for over 15 d. Recovery was poor and yields low (Table 12), with high variability (CV over 60%), but P and N significantly increased yield. Eight of 20 plots with zero P failed to survive, and 6 of 16 plots with no fertilizer N also failed. There was no clear difference between drilling and broadcasting.

Samples for dry weight were taken on 3 Aug, just before flooding. Mean dry weight ranged from 106 g/m^2 with zero P to 272 g/m^2 with high P and high N. Any treatment with dry weight less than 150 g/m^2 at that date produced less than 0.2 t grain/ha at maturity.

N FERTILIZER EFFICIENCY IN RAINFED RICE

Training and Technology Transfer Department

In Iloilo and South Cotabato, Philippines, field experiments in rainfed areas evaluated application methods (2 splits, 3 splits, all topdressed, and all basal) at 15, 30, and 60 kg N/ha.

Increasing N level from 15 kg N/ha to 60 kg N/ha correspondingly increased yield.

In New Lucena, Iloilo, urea applied basally gave significantly more yield at 30 and 60 kg N/ha than all topdressed, 3 splits, and 2 splits. No significant differences were observed in Cabatuan (Iloilo) and South Cotabato.

Soil and crop management

Nitrogen fixation and azolla management

Soil Microbiology, Entomology, and Training and Technology Transfer Departments

ASSOCIATIVE NITROGEN FIXATION **274**
- Presence of N_2-fixing *Pseudomonas* **274**
- Inoculation of N_2-fixing bacteria to aseptically grown rice seedlings **274**
- Ecology of N_2-fixing bacteria **275**
- ARA assay with field-grown rice **275**
- Distribution of ARA values among rice hills **275**
- N_2 fixation of 5 rice varieties as related to plant growth and straw incorporation **276**
  - ARA related to growth characters **276**
  - Effect of straw on ARA, bacterial enumeration, and plant growth **277**
- ^{15}N dilution techniques **278**

PHOTODEPENDENT NITROGEN FIXATION **278**
- Standardization of ARA measurement **278**
- N_2-fixing BGA in lowland rice soils **279**
- Fate of inoculated BGA in different soils **281**
- Invertebrate fauna of lowland rice fields **282**

AZOLLA-ANABAENA SYMBIOSIS **283**
- Azolla collection **283**
- Response of azolla to high temperature **283**
- Growth in the field **283**
- Azolla growth under rice canopy **285**
- Nutrient supply from soils to azolla **286**
- Culture of rice and azolla in wide-narrow row spacing **287**

AZOLLA ADAPTIVE RESEARCH TRIAL **287**

AZOLLA INSECT PESTS **287**
- Confirmed azolla insect pests **287**
- Insect prevalence and effect on azolla **289**
  - Light trap catches **289**
  - Larval and pupal populations **289**
  - Standing biomass and yield loss **290**
  - Screening insecticides for spinning worm and caseworm **291**

ASSOCIATIVE NITROGEN FIXATION

Soil Microbiology Department

Presence of N_2-fixing *Pseudomonas*. N_2-fixing and hydrogen-utilizing *Pseudomonas* sp. was isolated at high frequency from rice root only in IRRI fields. IR42 was grown in six soils to determine the presence of this Pseudomonad. This bacterium was found only in one IRRI field soil. Among the IR42 roots examined, the bacterium was found more often on brownish roots than on young white or old brackish ones.

Inoculation of N_2-fixing bacteria to aseptically grown rice seedlings. The ability of diverse types of N_2-fixing bacteria to associate with and to fix N in the root zone of rice was studied using germinating rice seedlings grown aseptically under light or in darkness and inoculated with different bacteria.

The research examined the acetylene-reducing activity (ARA), and total bacterial and *Pseudomonas* sp. counts of excised roots of 5-wk-old rice seedlings grown under light and inoculated with a mixture of 3 bacterial strains belonging to *Pseudomonas* H8, *Azospirillum lipoferum* 34H, and *Klebsiella planticola* LL4. ARA after 24 h was significantly higher in the seedlings inoculated with bacteria than in uninoculated seedlings. Total bacteria and *Pseudomonas*, *Azospirillum*, and *Klebsiella* associated with roots were counted based on their colony morphology on TSA plates. *Pseudomonas* sp. H8 accounted for 86% of bacteria associated with roots.

The interaction of genotypes of bacteria and rice was studied using seedlings grown in the dark. Rice varieties of different seed weights were inoculated with different bacterial strains and ARA was determined. ARA results based on seed dry weight are shown in Table 1. All varieties tested showed higher ARA with strains A1 34H and lower ARA with strains Ab RO7, but none of the rice variety and bacterial strain combinations exhibited universally higher ARA.

Bacterial strains of diverse genera and sources were tested for ARA with seedlings of IR42 and OS4 grown in the dark (Table 2). Differences in ARA among bacterial strains were large irrespective of source. Most strains belonging to *A. brasilense* and acid and gas-producing (*Enterobacter* and *Klebsiella*) bacteria showed very low ARA. Rhizobia from *Sesbania rostrata* showed high ARA, and

Table 1. ARA of seedlings of different rice varieties inoculated with N_2-fixing bacteria using the spermosphere technique. IRRI, 1984.

Variety and strain[a]	C_2H_4[b] (nmol/mg seed per day)					
	Pseudomonas H8	*Pseudomonas* KLH76	*A. lipoferum* 34H	SGBP4[c]	*A. lipoferum* FS	*A. brasilense* RO7
Kap Nhay (40.8)	5.55 cd	10.4 a	17.3 a	—	5.20 e	1.71 a
KU 79-1 (38.0)	19.1 a	5.13 a	11.0 b	7.74 d	6.44 d	7.20 a
Giza (14.7)	14.3 ab	7.68 a	21.4 a	15.9 b	29.4 b	4.51 a
Tulakhi (11.2)	8.99 c	5.95 a	25.2 a	41.3 a	32.9 a	7.14 a
Motta (8.00)	2.50 d	0.33 b	7.63 b	12.1 c	10.1 c	0 b

[a]Figures in parentheses indicate seed weight (mg/seed). [b]Values are averages of 5 replications ± SEM. [c]An unidentified slow-growing black pigmented #4.

Table 2. ARA of inoculated seedlings of IR42 and OS4 grown aseptically using the spermosphere technique. IRRI, 1984.

Bacterial species and strain	Source	Country	C_2H_4[a] (nmol/tube per 7 d)	
			IR42	OS4
Azospirillum lipoferum 34H	Rice	Philippines	10,237 ab	9,153 a
A. lipoferum 4T	Rice	France	10,750 a	6,792 ab
A. lipoferum Sp USA 5	Grass	USA	6,212 bc	8,873 a
A. lipoferum Sp 107	Wheat	Brazil	437 ef	2,382 defg
A. lipoferum KR 77	Rice	Senegal	1,514 def	1,049 fg
Azospirillum brasilense Sp 34	Digitaria	Brazil	195 f	4,629 bcde
A. brasilense Sp 13	Digitaria	Brazil	167 f	17.6 g
A. brasilense Sp 7	Digitaria	Brazil	2.7 f	4.56 g
Pseudomonas Sp H8	Rice	Philippines	2,874 cdef	2,889 cdefg
Alcaligenes latus DSM 1124	Soil	Australia	367 f	650 fg
Derxia gummosa ATCC 15994	Soil	India	2,041 cdef	1,681 efg
Klebsiella oxytoca 4Abl	Rice	France	4,020 cdef	5,793 abc
Klebsiella planticola DW UL2	Rice	Philippines	526 ef	1,402 fg
Rhizobium sesbania	Sesbania	China	5,189 cd	3,559 bcdef
Rhizobium sesbania ORT 571	Sesbania	Senegal	4,633 cde	4,847 bcd
Unidentified SGBP4	Rice	Philippines	3,098 cdef	4,938 bcd
Unidentified Re2	Rice	Japan	103 f	361 g

[a]Separation of means by Duncan's multiple range test at the 1% level.

the highest activity was with *Azospirillum lipoferum* strains.

Ecology of N_2-fixing bacteria. To follow the ecology of N_2-fixing bacteria which associate with rice roots, double antibiotic (Str. Rif) resistant strains of *A. lipoferum* and *Pseudomonas* sp. H8 were made. Their N_2-fixing activities in free-living conditions and with rice seedlings grown in the dark do not differ from those of parent strains. The absorption of these bacteria into seedling root and their survival in certain carrier materials were studied. Peat was the best carrier, followed by bagasse.

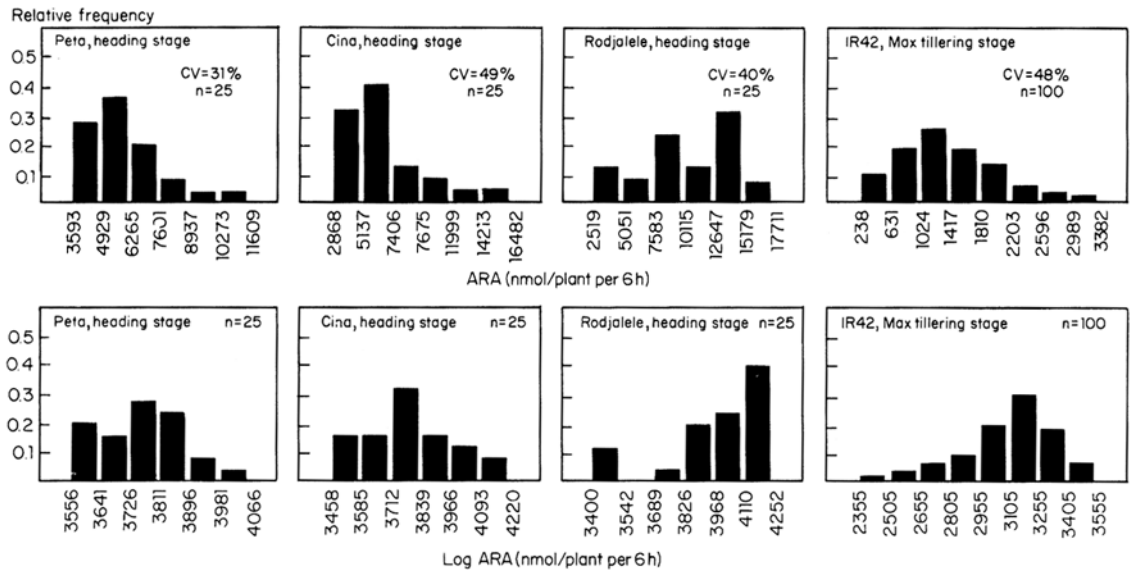
ARA assay with field-grown rice. A simple ARA assay method was developed for measuring N_2 fixation in field-grown plants. The assay involves digging the plant from the field, removing the surface soil and soil adhering to the roots, cutting the stem to leave about 5 cm of submerged portion of the plant, and placing the excised plant-soil in a plastic bag. The plastic bag is then double heat-sealed and appropriate amounts of C_2H_2 and propane with air are introduced, and then incubated at 35° C in the dark for 6 h. Ethylene evolved is calculated based on propane as an internal standard.

The excised plant-soil assay has several advantages over the excised root, field, water culture, and pot assays:

- it has all the components (rhizosphere soil, root, and basal stem and leaf sheath) of the associative N_2-fixing system in rice;
- it suits any type of rice, short or tall, grown in the field where N_2 fixing should be evaluated;
- it eliminates the problem of dissolved C_2H_2 and C_2H_4 that remain in the field after *in situ* assay;
- samples can easily be shaken to release gases from liquid to gas phase;
- an aerobic atmosphere is quicker to prepare than microaerobic and anaerobic atmospheres, which require evacuations and flushings;
- constant temperature and dark incubation eliminate variations in ARA from one assay period to another because of atmospheric changes in pot and *in situ* field assays; and
- the removal of surface soil and incubation in the dark reduce the input from photodependent ARA such as from epiphytic blue-green algae (BGA).

Distribution of ARA values among rice hills. The probability distribution of rice plant-associated ARA (measured by excised plant-soil technique) was studied using 100 field-grown hills of IR42 at tillering stage and 25 hills each of Rodjalele, Cina, and Peta at early heading stage.

Histograms (Fig. 1) and cumulative percentage distributions by normal probability scale (actual

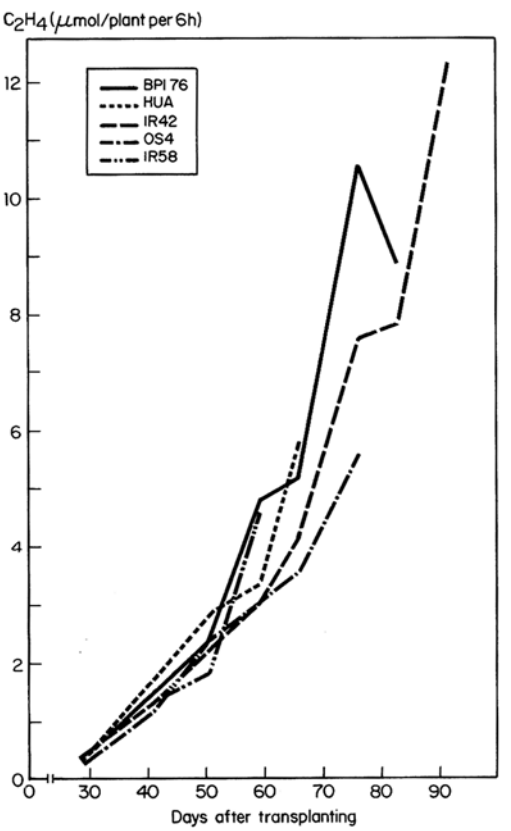


1. Relative frequency distribution of untransformed and logarithm transformed ARA values. IRRI, 1984.

and log-transformed ARA values) showed that ARA of Peta and Cina follow log normal distribution while that of Rodjalele follows normal distribution. In IR42, it is difficult to conclude whether distribution is normal or log normal. Calculations of skewness and chi-square also suggest that distribution patterns of ARA in Peta and Cina were close to log-normal, but not in IR42 and Rodjalele. In all cases, coefficients of variation (CV) were near 40%. If CV is assumed to be 40%, the error of estimating mean caused by assuming a normal distribution for a log normal would be 20%.

N_2 fixation of 5 rice varieties as related to plant growth and straw incorporation. In IRRI fields starting in 1983 DS, five varieties of different growth duration (IR42 and BPI 76, 125-135 d; OS4, 115-120 d; Hua-chou-chi-mo-mor and IR58, 105-110 d) were studied with and without straw incorporation. The experiment used a randomized complete block design with four replications. Straw (5 t/ha) was chopped and incorporated 10 d before transplanting. The study measured plant-associated ARA (by excised plant-soil technique), soil ARA (by soil core technique), bacteria numbers and plant growth parameters for a dry season (DS) and a wet season (WS).

ARA related to growth characters. ARA of the five varieties increased slowly from early vegetative



2. ARA of 5 rice varieties from vegetative to heading stages in soil without straw amendment. IRRI, 1984 DS.

Table 3. Analysis of variance among ARAs of 5 rice varieties at different growth stages with and without straw amendment. IRRI, 1984 DS and WS.

Stage (DT)	F[a]			
	With straw		Without straw	
		DS		
29	5.67*	(41%)	1.36^{ns}	(41%)
41	4.60*	(26%)	1.64^{ns}	(23%)
51	2.46^{ns}	(18%)	4.08*	(17%)
59	2.33^{ns}	(22%)	4.14*	(21%)
Heading	28.15**	(13%)	24.11**	(17%)
		WS		
39	0.896^{ns}	(43%)	4.06*	(41%)
49	8.64**	(20%)	2.296^{ns}	(36%)
61	3.39*	(31%)	0.852^{ns}	(44%)
Heading	19.44**	(33%)	6.51**	(36%)

[a] Figures in parentheses are the coefficients of variation among plots of the same variety.

stage to around panicle initiation and then more rapidly toward heading (Fig. 2). Values were lower during WS.

ARA of IR42 abruptly declined from heading to maturity in DS.

Like ARA, shoot dry weight increased exponentially until heading. Root dry weight of short-duration varieties also increased exponentially up to heading, but that for long-duration varieties leveled off and then declined before heading.

ARAs among varieties differed most at heading stage with and without straw incorporation in DS and WS (Table 3), mainly because of dry weight differences. The mean ARAs and root and shoot dry weight were significantly correlated at heading stage in DS (Table 4). In WS, however, ARA correlated significantly only with root dry weight. Regardless of variety, growth stage, and straw treatment, ARA was related to total dry weight. Deviations are greater in WS than in DS, showing ARA depends less on total dry weight during WS, and that, most probably, light intensity becomes limiting. Unlike in DS, therefore, plant biomass in WS may not predict ARA.

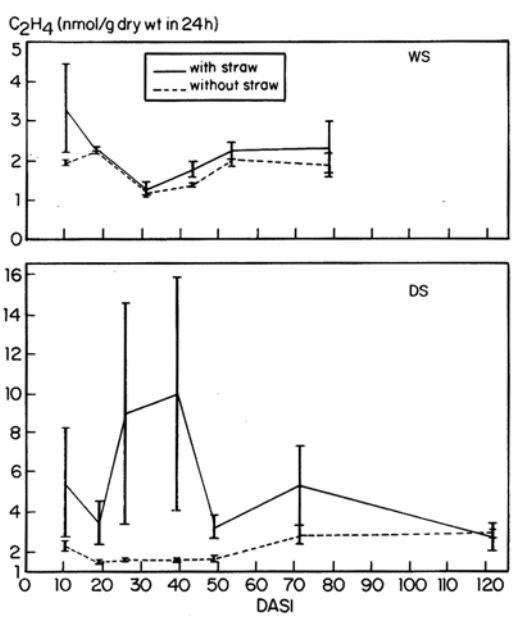
Table 4. Correlation between ARA and plant growth characters in 5 rice varieties at heading stage. IRRI, 1984 DS and WS.

	Constant factor	Correlation coefficient[a]	
		DS	WS
ARA vs root dry wt		0.752*	0.680*
	Shoot dry wt	0.687*	0.544^{ns}
ARA vs shoot dry wt		0.837**	0.515^{ns}
	Root dry wt	0.797**	0.197^{ns}
ARA vs total dry wt		0.885**	0.616^{ns}
ARA vs tiller no.		−0.116^{ns}	0.153^{ns}
	Total dry wt	0.347^{ns}	0.451^{ns}

[a] Correlation based on logarithms of ARA.

During DS, ARA at heading highly correlated ($r = 0.92$) with total dry matter (grains + straw) yield at maturity. However, the correlation between ARA and total grain yield was lower ($r = 0.74$). Varieties OS4 and Hua-chou-chi-mo-mor had lower yields but higher ARAs than IR58. Long-duration variety IR42 had the highest ARA and highest grain yield.

Effect of straw on ARA, bacterial enumeration, and plant growth. ARA of nonrhizospheric soil treated with straw peaked 10-40 d after straw incorporation (DASI) during DS (first crop). Results among replications varied highly because of uneven distribution of larger straw pieces (10-15 cm) in the soil. In WS, smaller straw pieces (5 cm) were incorporated, and variation was lower. The ARA of straw-treated soil was lower in WS than in DS (Fig. 3).



3. ARA of nonrhizospheric soil with and without straw amendment. IRRI, 1984 DS and WS.

Plant-associated ARA significantly differed among varieties (F value in Table 3). Straw treatment at vegetative stage corresponded to the time of ARA peak in the nonrhizosphere soil during DS. In WS, plant-associated ARA differed little with and without straw incorporation, although F values with straw treatment were higher than with control (Table 3).

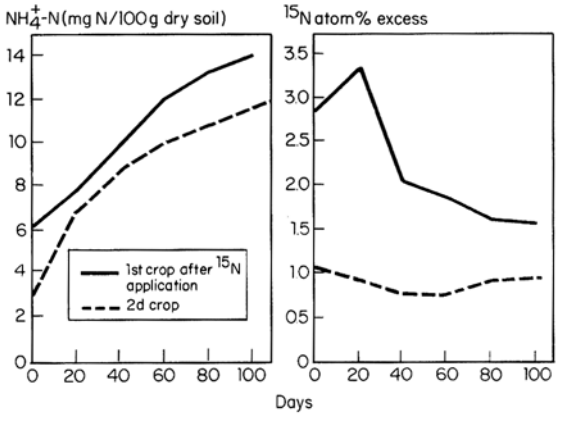
Straw incorporation did not significantly increase plant shoot, root weight at heading stage, and grain yield in either season. However, OS4 had significantly higher total dry matter (grain + straw) in first crop (DS), as did IR42, BPI 76, and Hua-chou-chi-mo-mor in the second crop (WS). This indicates varietal response to straw addition to soil.

Most probable number counts of aerobic N_2-fixing heterotrophs showed three- to nine-fold increase in soil at 35 and 58 DASI in DS. Phototrophic purple nonsulfur bacteria increased at 10 DASI in WS.

^{15}N dilution techniques. Contribution of biological N_2 fixation to plant N nutrition is estimated by ^{15}N level in plants. The ^{15}N abundance is determined either in natural level or by adding ^{15}N-labeled N source in soil. When ^{15}N-labeled ammonium salt is added to soil, ^{15}N abundance in available soil N fraction decreases sharply. After one crop of wet rice is grown, ^{15}N level in the available soil N fraction stabilizes. Under this condition, the ^{15}N dilution technique is safely used, because differences in growth pattern and growth duration affect ^{15}N abundance less than when ^{15}N abundance in available soil N fraction decreases sharply (Fig. 4). In the field, rice was grown continuously flooded in concrete pots of 1.5 × 1.5 m with 15 cm deep soil. After one or two crops of rice were grown, rice varieties of different growth durations were grown, with a reference rice variety for each group. Because all known rice varieties are N_2 fixing, relative N_2 fixation can be determined only by comparing a reference variety which may be lower in stimulating N_2 fixation (Nfs trait).

Four rice varieties were grown in each concrete pot and ^{15}N level in the grain was analyzed. Two series (A and B) of concrete pots were used.

In series A of 1983 DS, Pokkali's grain contained 0.62 atom % excess (AE %), equal to that of IR42 in the previous crop (0.63 AE %) (Table 5). This suggests low Nfs of Pokkali. In series B of 1984 DS, CR94-13, IR42, and Hua-chou-chi-mo-mor had



4. Changes in NH_4^+-N and its ^{15}N atom % excess in soils with ^{15}N-labeled substrate after 1 and 2 crops of wetland rice. IRRI, 1984.

significantly less ^{15}N AE % than did reference varieties. In the series of 1984 DS, Cina and C-22 had lower AE % than OS4. Pokkali and OS4 were known for low Nfs traits, determined by N balance, and IR42 and Hua-chou-chi-mo-mor are high in Nfs. Thus, ^{15}N dilution results coincided with N balance results.

We examined ^{15}N abundance of 2d (from the top) leaf blades of the same hills. CV was about 5%. Leaf blade analysis is appealing, because it is not destructive. Further screening is going on.

Preliminary analysis of ^{15}N natural abundance (δ ^{15}N-value) in rice grains grown in IRRI fields were 6.2 for IR42, 7.2 for OS4, 7.4 for IR26, 6.2 for Hua-chou-chi-mo-mor, and 5.9 for IR58. The lower the values, the more dependence on N_2 fixation, except in IR58. Delta ^{15}N values do not conflict with ^{15}N dilution data. Delta ^{15}N values are given as

$$\frac{^{15}\text{N AE \% of sample} - {}^{15}\text{N AE \% of air}}{^{15}\text{N AE \% of air}} \times 1000.$$

PHOTODEPENDENT NITROGEN FIXATION

Soil Microbiology Department

Standardization of ARA measurement. Trials to standardize measurement of photodependent ARA in submerged soils colonized by BGA have been conducted using soil samples from the field and from 1-m^2 microplots in a greenhouse, inoculated with various BGA strains. Laboratory cultures of the same strains were used for comparison.

In situ ARA of BGA exhibits a large variability because of a log-normal distribution of the organisms that leads to a CV of ARA measurements equal to 100%. By using composite samples of several core subsamples collected with glass tubes 2 cm in diameter and comprising the floodwater and the first 5 cm of soil, we have reduced the variability of the measurements in a plot. The CV calculated from 14 replicated measurements of 30 min in a 4- × 4-m plot, with composite samples of 13 cores each, was 21%.

Table 5. ^{15}N atom % excess (AE%) in the grains of various varieties grown in Maahas soils in concrete pots.[a] IRRI, 1983-84 DS and WS.

Variety	Growth duration (d)	^{15}N abundance (AE%)
Series A, 1983 DS, 4th crop		
Pokkali	91	0.62
Oking seroni	113	0.49
IR42	113	0.53
Raminad #3	120	0.50
SE		0.023
Series B, 1984 DS, 2d crop		
Group 1		
Tadukan	113	0.83
MGL2	108	0.81
TKM6	80	0.88
SE		0.064
Group 2		
IR58*	80	1.07
Hua-chou-chi-mo-mor	80	0.93 (13)
TN-1	97	0.97
Dee-geo-woo-gen	97	0.94
SE		0.039
Group 3		
OS4*	102	1.17
CR94-13	102	1.03 (12)
IR42	108	0.90 (25)
Peta	116	0.82
SE		0.046
Group 4		
Palawan	108	0.91
IR42	108	0.87
Cina	102	0.88
SE		0.022
Series A, 1984 WS, 2d crop		
OS4*	100	0.69
Kinandang Patong	100	0.66
Cina	103	0.63 (9)
C-22	103	0.62 (10)
SE		0.019
Series B, 1984 WS, 3d crop		
IR58	84	0.61
IR36	84	0.63
IR50	84	0.59
IR19728-9-3-2-33	84	0.59
SE		0.020

[a] Values in the parentheses are % of N derived from biological N_2 fixation, using reference variety with *.

Study of the optimal concentration of acetylene in incubation chamber atmosphere showed that the classical value of 10% is adequate for laboratory cultures but too low for soil samples covered with a thick mat of BGA. Under such conditions, ARA increased with acetylene concentration in the air up to 25%.

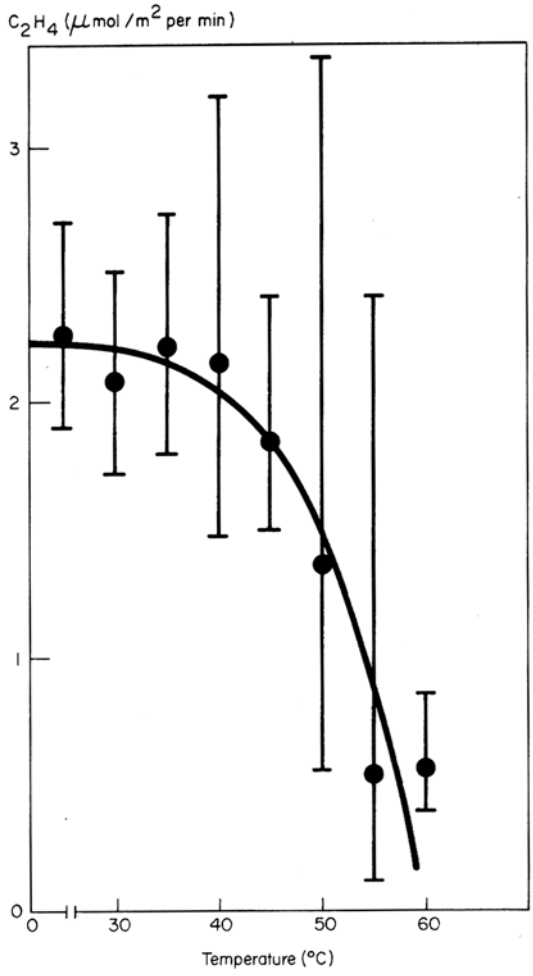
Temperature inside the enclosures placed in the field for ARA assays increased dramatically during exposure to light. Even during 2-h incubations on a cloudy day with moderate light intensities, the temperature inside the enclosure reached values higher than 40° C. Such temperatures inhibited ARA of BGA cultures and soil samples colonized by BGA. Figure 5 shows temperature effect on ARA of a soil inoculated with *Anabaena variabilis*. It demonstrates that field measurements of ARA of soil algae in nonthermostated enclosures may underestimate ARA. In Figure 6, confidence intervals of the means of six replications show variability of ARA measurement with soil samples.

Study of the effect of light intensity on ARA under controlled temperature (29° C) showed that 5 klux was enough to ensure maximum ARA of BGA cultures grown in liquid medium. Results with soil samples were variable and, depending on algae density at soil surface, ARA increased with light intensity till values of 20 to 40 klux.

Enhancement of ARA during incubation under acetylene, already reported by other authors for pure cultures, also occurred in soil samples, complicating the interpretation of ARA values.

Results indicate that ARA measurement of soil algae under constant light intensity and temperature may be more reliable than field measurement. More studies are needed to standardize the method as a reliable index of N_2-fixing activity.

N_2-fixing BGA in lowland rice soils. We surveyed BGA in the Philippines by collecting composite samples of surface soils from 61 wetland rice fields. The 2 most distant sites (Banaue terraces and South Cotabato) were about 1,300 km apart. Elevations ranged from 0 to 1,500 m, but most were low. About one-third of the sites were sampled when dry. The soils had these ranges of chemical property:



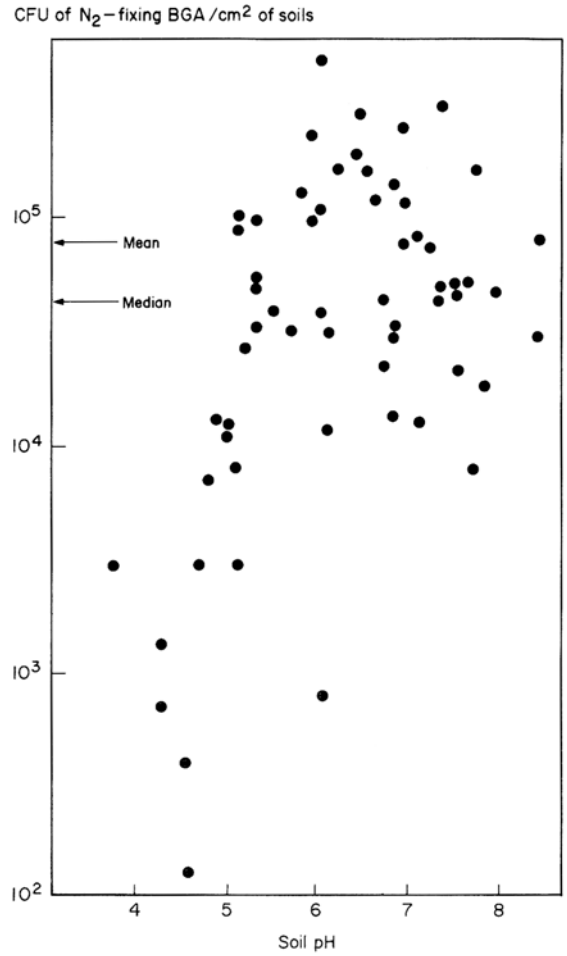
5. Effect of temperature on ARA measured on composite samples of 8 core subsamples, each from a soil inoculated with *Anabaena variabilis*. Each value is the average of 6 replications. Confidence intervals were calculated after logarithmic transformation of the data.

pH, 3.8 to 8.8; C, 1 to 28.8%; N, 0.08 to 2.6%; available P (Olsen), 0 to 64 ppm; CEC, 6 to 105 meq/100 g. Each soil sample comprised the top 0.5 cm of 10 core subsamples collected at, at least, 0.5-m intervals along a transect through the field.

To evaluate algal flora, soil suspension dilutions were plated on solid BG II media with and without mineral N. Petri dishes were incubated for 3 wk at laboratory temperature (22-30° C) and continuously under cold white fluorescent lamps. Counts were expressed as number of colony-forming units (CFU) per cm^2 of soil. N_2-fixing strains were classified into seven broad taxa (Table 6). Plate counts did not distinguish between vegetatively growing organisms and spores or propagules dormant in the soil. Strains present at a density lower than 1% of the total flora were most frequently not recorded. Therefore the method best inventories the major strains in a soil.

N_2-fixing strains were recorded in all samples. Their densities ranged from 10^2 to almost 10^6 CFU/cm^2, were higher than 10^4/cm^2 in more than 80% of the soils, and correlated highly significantly ($p<1\%$) with soil pH.

Among the taxa, *Nostoc*, a genus forming mucilaginous colonies, appeared in 98% of soils and dominated 62% of them (Table 6). *Anabaena* taxa were present in almost 80% of soils, but rarely



6. Density of colony-forming units (CFU) of N_2-fixing BGA in the surface (0-0.5 cm) soil of 61 Philippine rice fields, as a function of pH. 1984.

Table 6. Major taxa of N_2-fixing BGA in surface soil of 61 Philippine rice fields, 1984.

Taxon	Definition of the taxon	Samples (%) where the taxon was		
		Dominant	Second dominant	Recorded
Unicellular N_2-fixing	Unicellular strains growing on medium without N, form mucilaginous colonies	28	11	62
Anabaena	Filamentous, without branching, without polarity, do not form mucilaginous colonies of defined shape	7	21	78
Nostoc	Same as above but form mucilaginous colonies of defined shape	62	34	98
Scytonema group	Filamentous with false branching, without polarity, form velvet-like patches on agar medium	0	2	15
Calothrix group	Same as above but with polarity	4	26	55
Gloeotrichia group	Filamentous without branching, with polarity, form mucilaginous colonies of defined shape	0	0	13
Fischerella group	Strains with true branching, usually do not form mucilaginous colonies	0	6	44

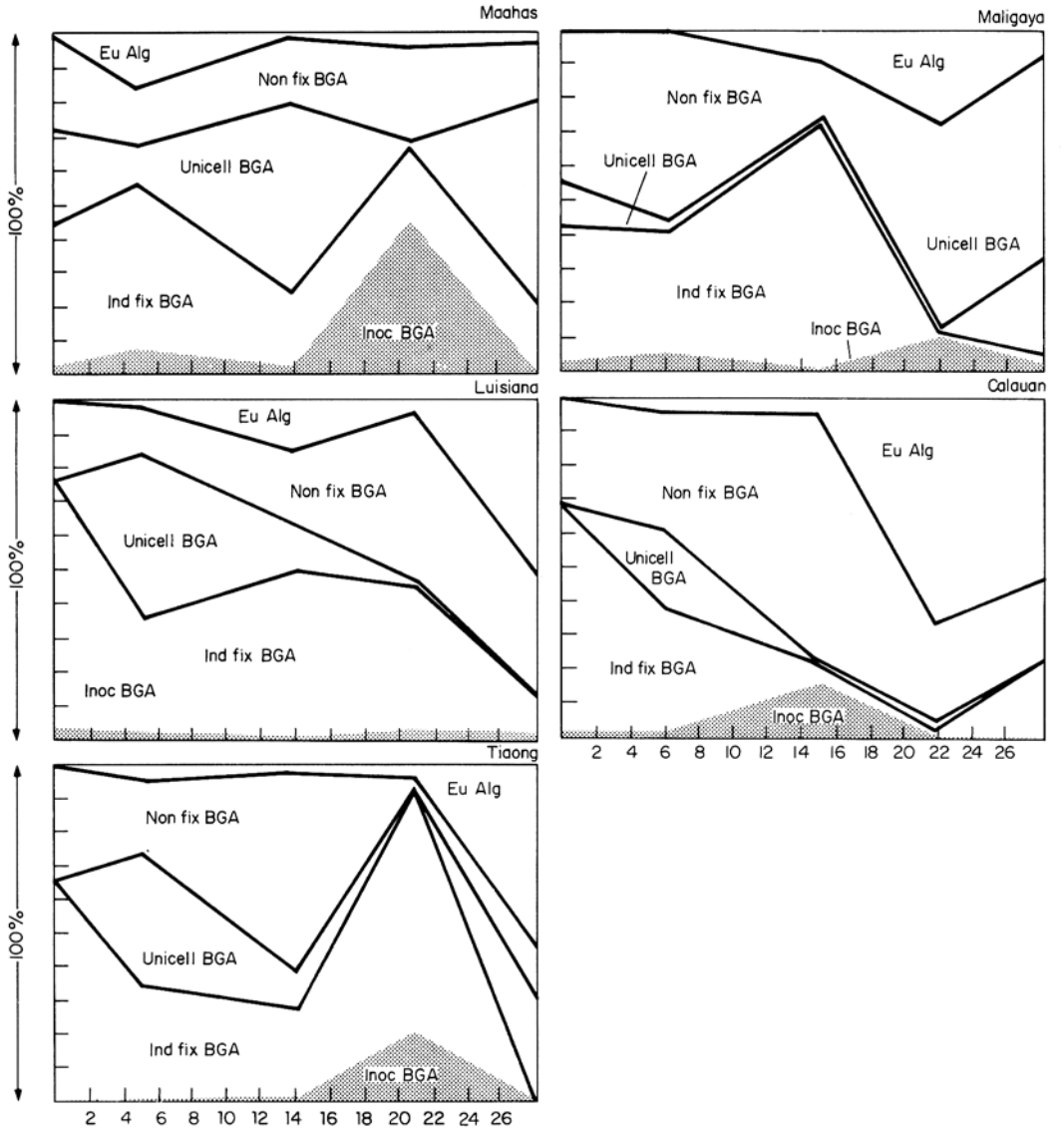
dominated. Similarly, nonmucilaginous strains with true or false ramifications showed in about half the soils but almost never dominated. Generally, mucilaginous strains are less efficient fixers and less susceptible to grazing than nonmucilaginous strains. The dominance of mucilaginous strains suggests grazing is a major barrier in developing blooms of nonmucilaginous, efficient, N_2-fixing strains in Philippine wetland soils.

Fate of inoculated BGA in different soils. The fate of a mixture of single-strain soil-based inocula (*Anabaena variabilis*, *Tolypothrix tenuis*, *Fischerella* sp., *Aulosira* sp.) was studied in 5 soils presenting a wide range of physicochemical properties (N: 0.09 to 2.6%, C: 1.06 to 19%, Olsen P: 4.6 to 18 ppm, CEC: 27 to 72 meq/100 g, pH: 5.3 to 7.7). Half of each soil was dry heated (1 h to 105° C) to reduce the level of indigenous strains and therefore favor the inoculated strains. The greenhouse experiment used 0.5-m^2 trays, with 4 replications per treatment. The soil layer was 4 cm thick; water was maintained at 4-cm depth. After soil submersion, inoculum, 5×10^6 CFU/g of dry material, was applied at a rate corresponding to 20 kg dry weight per hectare. Incident light intensity at floodwater surface, temperature, dissolved oxygen, and pH of the floodwater were measured daily. Algal populations and ARA were measured weekly. After 1 mo, soils were allowed to dry. Contents of C, N, and ash in the surface layer (0.5 cm) and the rest of the soil were determined. Then all soils of the same origin were mixed together, sieved, redistributed in the trays, and submerged. Half the trays received crushed neem seeds at 10 g/m^2 to control microcrustacean grazers. Algal growth and grazer populations were studied for another month.

Figure 7 shows the evolution of the relative composition of the algal flora in the five soils. In soils exposed to 150° C for 1 h, total algal flora averaged 10% of the initial level. Among algae, only BGA could survive heat treatment. Among these, N_2-fixing strains were most resistant, with survival from 0 to 45% (*Nostoc* sp.) and averaging 13%.

During the first 2 wk, blooms comprised mainly indigenous strains. Soon after BGA growth, grazer populations developed. Maximum N_2 fixation (ARA) occurred 15 d after submersion, mainly due to indigenous strains.

From wk 3 BGA blooms disappeared, gradually replaced by macroscopic eukaryotic algae. The CFU of N_2-fixing (ARA) algae recorded during the third and fourth weeks were mainly due to dormant propagules. Occasionally in all soils, CFU of inoculated BGA were significantly more numerous than the initial level, indicating some multiplication. N and C content significantly increased in the upper layer of soils except in peat.



7. Relative composition of algal flora in 5 soils inoculated with a mixture of dry soil-based inoculum of nonindigenous N_2-fixing BGA. IRRI, 1984. Eu Alg = eucaryotic algae, non fix BGA = non-N_2-fixing BGA, unicell BGA = unicellular N_2-fixing indigenous BGA; ind fix BGA = indigenous heterocystous N_2-fixing BGA, inoc BGA = inoculated N_2-fixing BGA.

During the second submersion, ostracod populations (grazers) were estimated. Without neem, ostracods rapidly increased soon after flooding, but neem-treated soils reduced ostracod until the ninth week. Neem also inhibited populations of grazing chironomid larvae for up to 4 wk. Dense blooms of N_2-fixing BGA developed in all neem-treated soils. In four soils, indigenous strains bloomed; in Tiaong soil an inoculated strain (*Aulosira* sp.) bloomed and developed the highest standing biomass, equivalent to 34 kg N/ha.

These experiments show that whereas inoculated strains persisted in soils at least 2 mo, their establishment as a bloom was infrequent, but possible when grazers were controlled.

Invertebrate fauna of lowland rice fields. Understanding aquatic community structure is essential to successfully manipulate rice field ecosystems to

encourage growth and biological N_2 fixation of indigenous or inoculated BGA. Twelve Philippine rainfed lowland rice fields were surveyed for fauna in 1984. Rice surveyed was at or near maximum tillering, in floodwater standing at least 1 wk.

From the 53 species recorded (Table 7), three major taxa are recognized: Ostracoda (12 spp.), Chironomidae (12 spp.), and Mollusca (6 spp.). These groups dominated the macroinvertebrate community at most sites. The most taxa recorded at one site were 26 (Ajuy), the least were 3 (Rosario).

For trophic grouping, the grazing component included opportunistic decomposers, which consume algae during the early stages of rice growth. On the average, 68% of taxa were grazers, mainly ostracods (30%), chironomids (18%), and molluscs (15%). Later in the rice crop, these groups still dominated the decomposers, but with reduced densities. The predatory Odonata, Coleoptera, and notonectid species comprised about 16% of all taxa.

Species diversity was calculated as the Shannon function $\bar{H}$, which combines species richness and equitability components. By hydrobiological standards, species diversity in the sites surveyed was low ($\bar{H} \cong 2$), indicating poor stability; but it agrees with the ecological principle that diversity is lower in stressed, young, or physicochemically limited systems. Population dominance was inversely proportional to diversity. In South Cotabato, a few species attained exceptionally high population densities: *Cyprinotus* (17,000/m^2), *Hemicypris* (2,550/m^2), *Macrothrix spinosa* (28,000/m^2), Tubificidae (18,500/m^2).

Negative correlations existed between the number of grazer taxa and both BGA spp. ($r = -0.79$) and their CFU/g dry soil ($r = -0.68$), implying that many species consume BGA, albeit selectively, in the relatively unspecified food chains of evolving ecosystems. Control of grazers will surely be necessary in developing BGA blooms in rice fields.

The rice field environment is one of extremes: soil perturbations by puddling, wetting, drying, agrochemicals, light extinction, etc. The fauna present are characteristic of a periodic environment; animals adapted to these extremes share dominance.

Control of grazing (use of pesticides) will enhance photosynthetic biomass in floodwater but delay the mineral recycling from organic matter. The implications of this for algal succession and soil fertility should be studied.

AZOLLA-ANABAENA SYMBIOSIS

Soil Microbiology Department

Azolla collection. Table 8 summarizes azolla collection showing accessions and sources. T. Lumpkin, Washington State University, USA, contributed his collections, mostly from Latin America.

Response of azolla to high temperature. Response of azolla, particularly new accessions, to various temperatures was examined in the phytotron. *A. microphylla* (Acc. #401, 417, 418) had higher relative growth rate and maximum biomass at 33° C (37° day/29° night, 12 h/12 h) than *A. pinnata* var. *pinnata* (Acc. #702 and 704) and *A. pinnata* (Acc. #2) (Table 9). This reaffirms *A. microphylla*'s greater tolerance for high temperature. *A. pinnata* Acc. #2 came from the Rice Research Station at Bumbong Lima, Malaysia, in 1976 and has been grown in the laboratory. In 1983, other populations were taken from various Malaysian sites and grown in the phytotron at 29 and 33° C. Acc. #2, 57, 58, 59 (from Bumbong Lima), 60 (from Kuala Kurau), and 61 (from Sebarang Perai) were used. Old and new populations did not differ significantly in their response to temperature.

Previous work showed *A. filiculoides* to be least tolerant of high temperature. To test this, we grew new accessions of *A. filiculoides* (#107 for Walka Lake, USA; #108 from Cranmore, USA; #109, Cali CA 007 Colombia; and #110, Lima, Peru) at 22°, 29°, and 33° C. *A. filiculoides* #101 and *A. microphylla* #417 were used as references. Azolla was grown in water solution with 20 g inoculum/m^2. At 8 d, a second inoculation was made, using biomass from the first growth. At 22° C, some strains (#101 and #417) showed better growth during the second growth. At 33° C, some strains (#107, 108, 110, 101) did not grow during the second growth. At three temperature levels, *A. microphylla* recorded the highest biomass production. At 33° C, Acc. #109 grew much better than reference Azolla #101. From these responses to temperature, the taxonomical position of #109 is doubtful.

Growth in the field. Azolla growth was studied in IRRI fields Oct 1983-May 1984. Various azolla species and strains (*A. pinnata* #5, 32, 40, 49;

Table 7. Macroinvertebrate fauna at 12 rainfed Philippine sites, 1984.[a]

	Panay			Leyte		Bohol			Cotabato			
	Ajuy	Barotac	San Dionisio	Hilongos	Tolosa	Balilihan	Loboc	Rosario	Surallah	Norala	Buayan	Magsaysay
Mollusca												
Brotia sp.	r	f										
Gyraulus sp.									r			
Indoplanorbis sp.	r	f										
Lymnaea viridis	r	f				r	r	r	a	r	r	r
Vivipara angularis		f							r		r	
Mixas cumingiana									f			
Oligochaeta												
Naididae	r	f	r			r			f		r	r
Tubificidae	r	r			r				f	r		
Hydracarina											r	
Cladocera												
Moina macrura	r											r
Macrothrix spinosa										f		
Ilyocryptus spinifer												
Copepoda												
Microcyclops varicans			r						r	r		
Mesocyclops leuckarti	r	r	r	r		r	r		a		r	r
Tropodiaptomus australis		r										
Ostracoda												
Cyprinotus sp.	a									a	a	
Hemicypris sp.				a			f		r	f	f	r
Cypretta sp.	r	r				r					r	f
Stenocypris sp.	r	r		a					r	r		r
Heterocypris sp.	a						f					
Strandesia sp. A.	r								r			
Strandesia sp. B.												
Chrissia sp.	r	r							r	r	r	
Eucypris sp.							f					
Cypris									r			
Candonopsis sp.	r											
Ilyocypris sp.												
Ephemeroptera												
Baetidae	r			r		a	a	r			r	
Odonata												
Agrionidae	r								f			
Libellulidae	r		r		a		r				r	
Hemiptera Unid.									f			
Anisops batillifrons	r	r	r	r	r	r	r			f	r	
Micronecta sp.	r	r		r	a						f	r
Diplonychus sp.		r							f	r	r	
Ranatra sp.							r					
Coleoptera												
Dytiscidae	r	r	r	r		r				r		
Laccophilus sp.												
Hydrophilidae unid.	r			r	r		f		r	a	r	r

| | | |

those values were 15, 2.4, and 1.4 times. *A. pinnata* #5 had the highest biomass of four species tested. Results indicate that growing azolla after 40 DT would not be practical.

Nutrient supply from soils to azolla. To know the nutrient supply of soils to azolla growth, 11 Philippine soils were placed in 10-cm-diam pots and flooded. Nutrient-depleted *A. pinnata* was inoculated with 5 treatments (no PKZn, no P, no K, no Zn, and with PKZn) and grown 3 wk. P, K, and Zn, particularly P, of floodwater decreased sharply up to 1 wk after application.

Biomass production was highly related to N and P contents of azolla plants and floodwater at 1 wk after application, even when P was added. Threshold values of P in azolla and floodwater seem to be

Table 9. Growth of azolla at 29° and 33°C.[a] IRRI, 1984.

Strains and acc. no.	Maximum growth rate per day		Maximum biomass fresh weight (g/10 cm^2)	
	29°	33°	29°	33°
A. pinnata #2	.268	.229 (85)	4.8	1.1 (23)
A. microphylla #401	.344	.294 (85)	5.2	1.9 (37)
#417	.398	.282 (71)	4.5	1.7 (38)
#418	.331	.304 (92)	3.5	1.9 (54)
A. pinnata var. *pinnata* #702	.237	.190 (80)	4.5	1.3 (29)
#704	.253	.180 (71)	4.2	1.4 (33)

[a] Values in parentheses are value relative to 29°.

Table 10. Azolla growth from October 1983 to May 1984, IRRI.

Azolla species	Acc.	Source	From Oct 83 to Jan 84		From Feb to May 1984	
			Harvests[a] (no.)	Accumulated[b] biomass (kg fresh wt/m^2)	Harvests[a] (no.)	Accumulated[b] biomass (kg fresh wt/m^2)
A. pinnata	#5	Bangkok, Thailand	3 1/3	4.0	1 1/3	1.4
	#32	Jianci, China	1 1/3	2.2	1 1/3	1.8
	#40	Garut, Indonesia	0	1.0	No growth	
	#9	Fuchou, China	3	3.7	1 1/3	1.3
A. pinnata var. *pinnata*	#701	Kakadu, Australia	4 2/3	4.0	2 1/3	3.7
A. caroliniana	#301	Ohio, USA	3 2/3	3.7	2 2/3	3.1
	#302	Madison, USA	3 1/3	3.1	2 2/3	4.0
A. microphylla	#407	Paraguay	0	1.0	No growth	
	#417	Paraguay	0	2.5	No growth	
	#418	Paraguay	3 2/3	3.2	3 1/3	4.1

[a] Av of 3 replications. [b] Accumulation of harvest biomass + standing biomass.

Table 11. Dual culture of rice and azolla at IRRI, 1983 WS and 1984 DS.

Trials sequence	Crop duration and rice variety	Chemical N applied (kg/ha)	Split ratio	Azolla incorporation		Rice grain yield (t/ha)		
				No N	N content (kg/ha)	No N	Chemical	Azolla
9th	May-Aug 1983 IR56	100	2:1:1	5	55	3.1	3.8	3.8
10th	Aug-Nov 1983 IR56	60	1:1:1	4	67	3.1	3.9	3.8
11th	Nov 1983-Mar 1983 IR56	100	3:1:1:1	4	90	2.6	4.1	3.8

0.10% and about 0.1 mg P/litre. In two soils with slight P deficiency, adding K increased azolla yield and its K content. Threshold value of K seems to be 1.5% in plants and 4 mg/litre in floodwater.

P in azolla was more correlated with floodwater P after 1 wk flooding than with Olsen P measured in the dried soils.

Culture of rice and azolla in wide-narrow row spacing. Wide rows were alternated with narrow rows to allow more space for azolla grown at 25 hills/m^2. The experimental design resembled previous ones except the mixture of *A. pinnata*, *A. microphylla*, and *A. caroliniana* was inoculated. Table 11 shows results.

As previously, azolla application equivalent to 90 kg N produced yields as well as did equal chemical N (urea). IR56 yielded less than IR42 up to the 5th trial.

AZOLLA ADAPTIVE RESEARCH TRIAL

Training and Technology Transfer and Soil Microbiology Departments

An azolla adaptive research trial used three inoculation rates and two levels of P and N to verify azolla adaptability and biomass production in a farmer's field in Baybay, Leyte, Philippines, Jul-Oct 1984.

Azolla biomass was measured 10 and 35 d before it was incorporated and rice transplanted. Azolla at 80 kg/ha with 4.4 kg P/ha gave significantly higher azolla biomass than rates of 40 and 0 kg (Table 12).

The highest rate also produced the highest IR60 yields. IR60 responded best to added P at 80 kg azolla/ha. On the other hand, adding N increased yield significantly only at 0 and 40 kg azolla/ha (Table 13).

Table 14 shows that P increased yields significantly when no N was added. Similarly, N increased yields without P addition. However, adding both N and P did not increase yield significantly more than adding either.

AZOLLA INSECT PESTS

Entomology Department

Confirmed azolla insect pests. Of the seven azolla insect pests described below, the last four can seriously damage azolla. Figure 8 shows the adult female of these pests. Figures 9 and 10 show confirmed locations of these pests in the Philippines.

1. *Chironomus kiiensis* Tokunaga (Diptera, Chironomidae)

Table 12. Azolla biomass production with P application in Baybay, Leyte, Philippines, 1984.

Azolla inoculation rate (kg/ha)	Biomass production[a]		
	No P	4.4 kg P/ha	Difference
0	0.0	0.2	0.2^{ns}
40	0.3	1.0	0.7*
80	0.8	2.0	1.2*

[a]Av of 6 replications and 2 N levels, using International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) scoring system 0-10.

Table 14. Effect of P and N on mean grain yield of IR60 at Baybay, Leyte, Philippines, 1984.

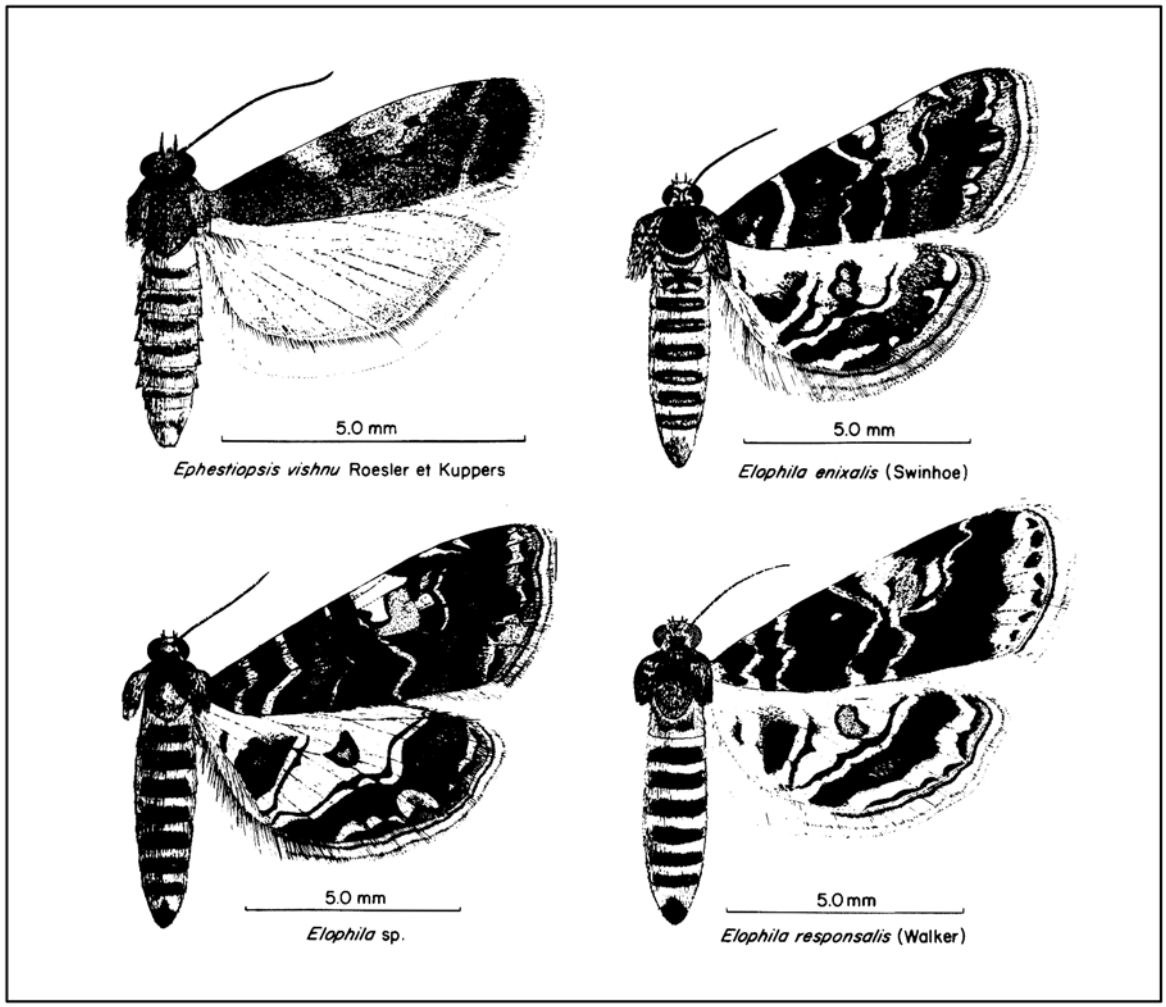
N (kg/ha)	Yield[a] (t/ha)		
	No P	4.4 kg P/ha	Difference
0	3.8	4.0	.2*
20	4.1	4.2	.1^{ns}
Difference	.3*	.2^{ns}	

[a]Av of 6 replications and 3 azolla levels. CV = 9.2%.

Table 13. Effect of azolla, N, and P on mean grain yield of IR60 in Baybay, Leyte, Philippines, 1984.

Azolla inoculation rate (kg/ha)	Yield[a] (t/ha)					
	P			N		
	0	4.4 kg/ha	Difference	0	20 kg/ha	Difference
0	4.0	4.1	.08^{ns}	3.9	4.3	.45*
40	3.8	3.9	.07^{ns}	3.7	4.0	.29*
80	3.9	4.3	.34*	4.1	4.2	.08^{ns}

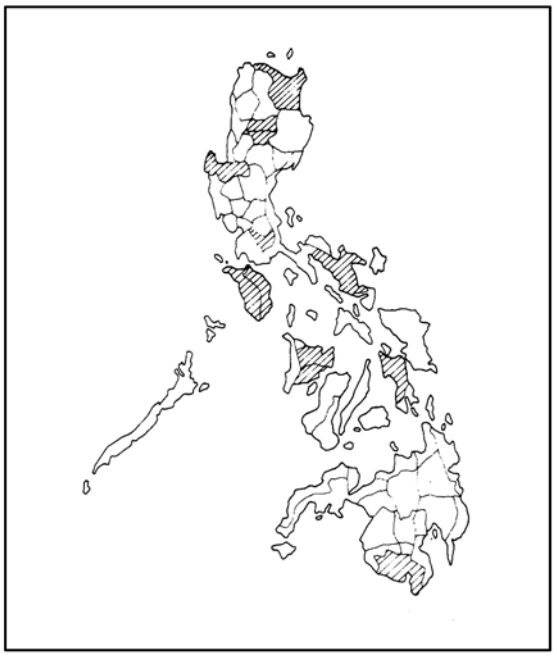
[a]Av of 6 replications.



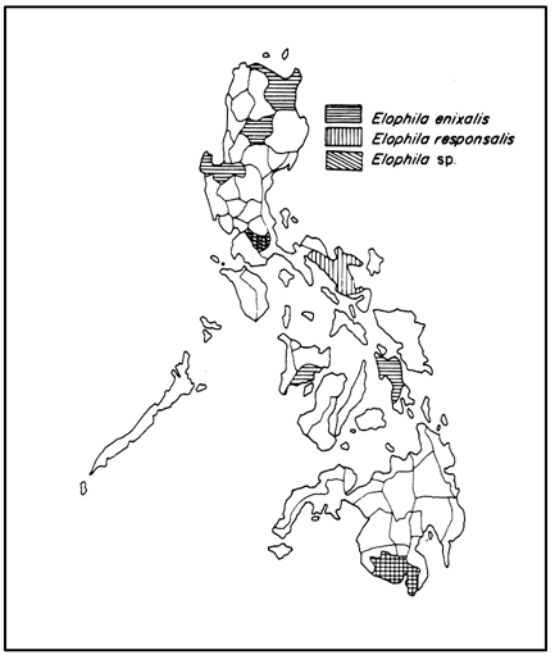
8. Adult females of pyralid pests on azolla, IRRI, 1984.

Specimens collected in: Philippines (Luzon, Leyte, Mindanao)
Damage to azolla: negligible

2. *Polypedilum anticum* Johannsen (Diptera, Chironomidae)
   Specimens collected in: Philippines (Luzon, Leyte)
   Damage to azolla: negligible
3. *Polypedium suturalis* Johannsen (Diptera, Chironomidae)
   Specimens collected in: Philippines (Luzon)
   Damage to azolla: negligible
4. *Ephestiopsis vishnu* Roesler et Küppers [spinning worm] (Lepidoptera, Pyralidae)
   = *Cryptoblabes* sp.?
   Specimens collected in: Philippines (Luzon, Panay, Leyte, Mindanao) (Fig. 9), Indonesia (West Java, N. and S. Sulawesi, Dec 1984), Thailand (Bangkhen, Dec 1984)
   Damage to azolla: very serious
   Natural enemies confirmed: A braconid, *Apanteles* sp., parasitizes the larvae and pupae of the host and parasitism was 1.5% at IRRI from 1983 to 1984.
5. *Elophila enixalis* (Swinhoe) [caseworm] (old name *Nymphula enixalis*) (Lepidoptera, Pyralidae)
   Specimens collected in: Philippines (Luzon, Leyte, Panay, Mindanao) (Fig. 10), Thailand (Bangkhen, Dec 1984)



9. Distribution of the spinning worm *E. vishnu* on azolla in the Philippines. IRRI, 1984.



10. Distribution of 3 caseworm *Elophila* spp. on azolla in the Philippines. IRRI, 1984.

Hosts other than azolla: *Vallisneria*, *Synnema*, *Echinodorus*, *Potamogeton*, etc.
Damage to azolla: serious
Natural enemies: *Amauromorpha accepta metathoracica* Ashmead (Hymenoptera, Ichneumonidae), a parasitoid on larvae of *E. enixalis* and *E.* sp. Parasitism was less than 1% at IRRI 1984.
Diplonychus rusticus (Fabricius) (Heteroptera, Belostomidae), a predator of host larvae at IRRI.

6. *Elophila responsalis* (Walker) [caseworm] (Lepidoptera, Pyralidae)
Specimens collected in: Philippines (Luzon, Mindanao) (Fig. 10)
Host other than azolla: *Pistia* sp.
Damage to azolla: serious
Natural enemies: see *E. enixalis*

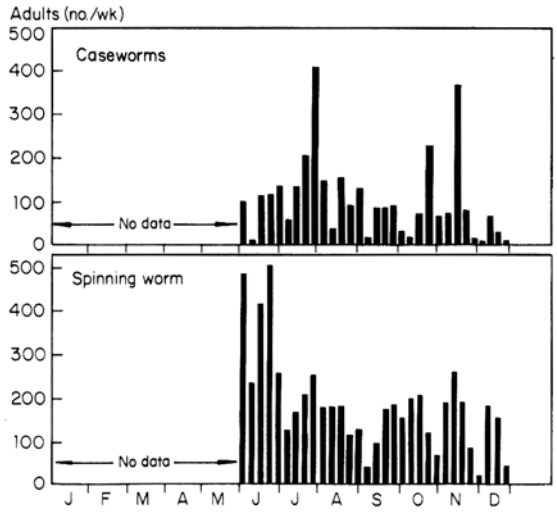
7. *Elophila* sp. [caseworm] (Lepidoptera, Pyralidae)
Specimens collected in: Philippines (Luzon) (Fig. 10), Indonesia (West Java, South Sulawesi, Dec 1984)
Damage to azolla: serious
Natural enemies: see *E. enixalis*

Insect prevalence and effect on azolla. Seasonal prevalence of four major insect pests, azolla biomass production, and azolla yield loss caused by insect pests at IRRI are described below.

Light trap catches. A light trap with a 10-watt blue-black fluorescent tube and an electric fan was established in azolla (mainly *A. microphylla* and *A. pinnata*) fields at IRRI on 1 Jun 1984. Daily adult catches were recorded through December. Adult populations of caseworms were highest in July; those of the spinning worm were highest in June (Fig. 11).

Larval and pupal populations. Larval (second- to final-instars) and pupal populations of the caseworms and the spinning worm were measured on *A. microphylla* (IRRI Acc. No. 418) and *A. pinnata* (No. 5).

A. microphylla was inoculated in 8 plots (plot size, 2.5 × 3.5 m) at IRRI farm at the rate of 0.5 kg (fresh weight)/m^2 on 16 Oct 1983. All plots were cleaned 30 Mar to 15 Apr, but inoculated again 16 Apr. Four plots were treated with monocrotophos 30% EC at 0.75 kg ai/ha every 2 wk, and 4 others not treated for control. Whenever azolla covered more than 3/4 of water surface, enough azolla was



11. Light trap catches of caseworms *Elophila enixalis, E. responsalis,* and *Elophila* sp. and the spinning worm at IRRI, 1 Jun-31 Dec 1984.

removed to keep at least 1/4 water surface open.

Neither larva nor pupa was found in treated plots. Although caseworm populations in untreated plots fluctuated considerably (Fig. 12), they averaged 56.8/ m^2 throughout the experimental period. The caseworm complex populations were lower May to June, but higher November to December.

The larval and pupal populations of the spinning worm in untreated plots also varied over time (Fig. 12), but averaged 146.0/ m^2, with peaks in January to February and June to August.

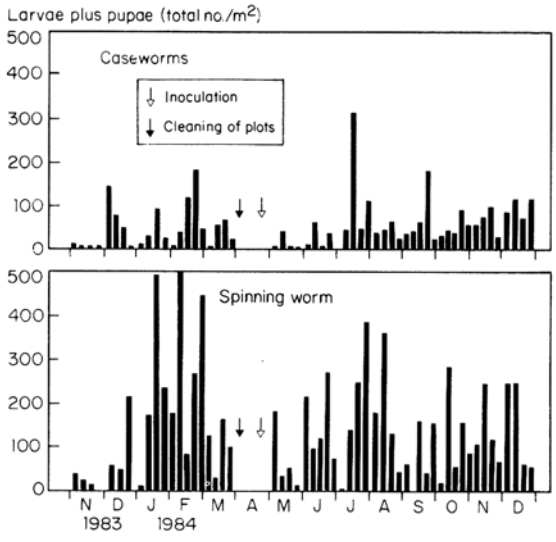
A. pinnata was inoculated as *A. microphylla* was. Populations of the three caseworms and the spinning worm are shown in Figure 13.

Comparing Figure 12 with Figure 13 clearly shows both caseworm and spinning worm populations were higher on *A. microphylla* than on *A. pinnata*. Further, population density was greater for spinning worm than caseworms. Finally, the peak periods on *A. microphylla* approximately corresponded to those on *A. pinnata*, except for caseworms during January to March.

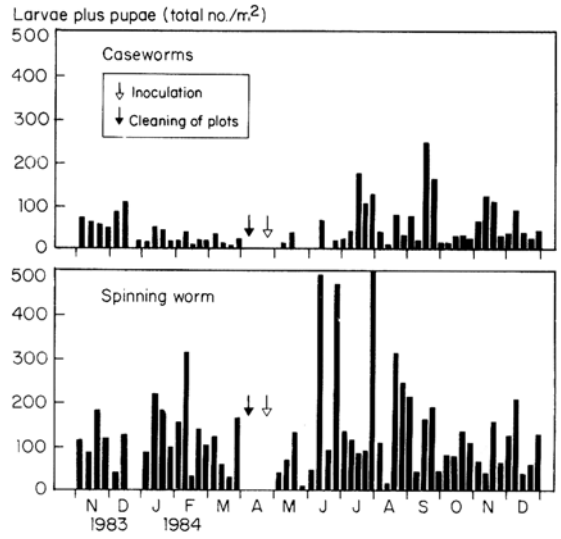
Standing biomass and yield loss. Standing biomass in insecticide-treated and untreated plots of *A. microphylla* is illustrated in Figure 14. The amount fluctuated considerably, but averaged 1.030 kg/ m^2 in treated plots and 0.671 kg/ m^2 in untreated plots. Yield losses from insect pests were estimated by the following formula:

$$\text{Yield loss (\%)} = (1.00 - \text{the standing biomass values in untreated plots divided by those in treated plots}) \times 100.$$

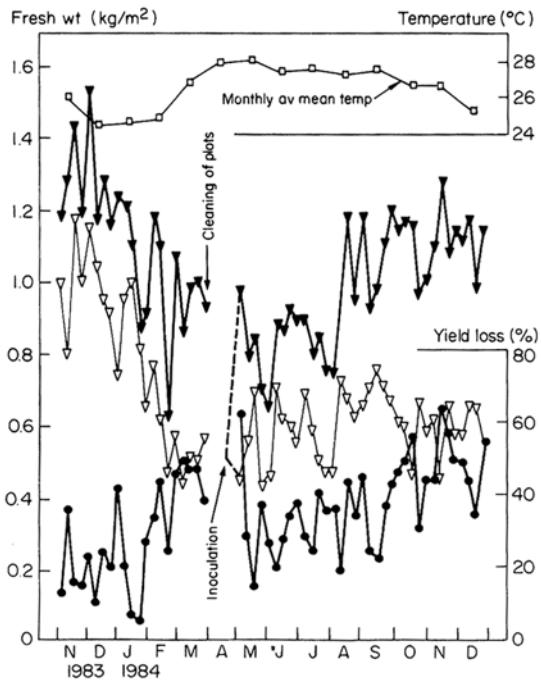
The estimated yield losses, averaging 35%, appear in Figure 14. They increased gradually from Nov



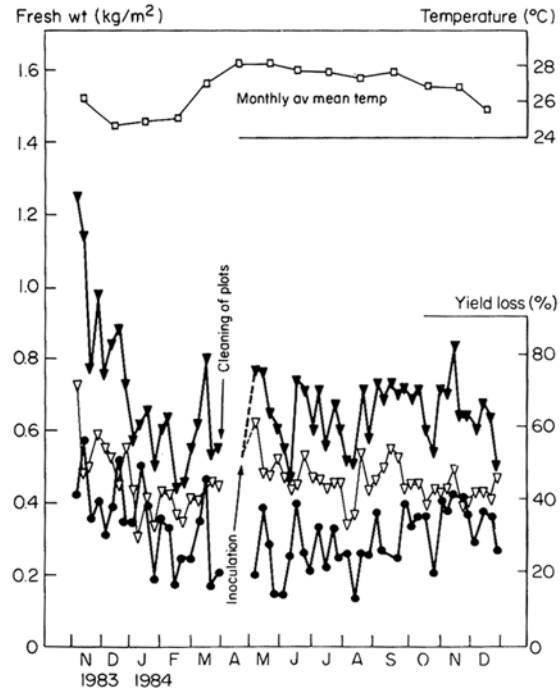
12. Weekly larval and pupal samples of caseworms and the spinning worm on *A. microphylla* in untreated plots at IRRI, Nov-Dec 1984.



13. Weekly larval and pupal samples of caseworms and the spinning worm on *A. pinnata* in untreated plots at IRRI, Nov 1983-Dec 1984.



14. *Azolla microphylla* standing biomass in insecticide-treated (▼) and untreated plots (▽) and yield loss (●) at IRRI farm, Nov 1983-Dec 1984.



15. *Azolla pinnata* standing biomass in insecticide-treated (▼) and untreated plots (▽) and yield loss (●) at IRRI farm, Nov 1983-Dec 1984.

1983 to Dec 1984. With *A. pinnata*, standing biomass averaged 0.666 kg/m^2 in treated plots and 0.449 kg/m^2 in untreated ones (Fig. 15). Yield loss averaged 31%.

During months with higher temperatures, standing biomass in treated plots was smaller in *A. microphylla* (Fig. 14) but did not fluctuate considerably in *A. pinnata* throughout the year since Jan 1984 (Fig. 15).

Table 15 summarizes the interactions among azolla biomass, pest populations, and yield loss (%) caused by pests. Though yield loss was 35% on *A. microphylla* and 31% on *A. pinnata*, *A. microphylla* produced at least 0.364 kg/m^2 more in treated plots and 0.222 kg/m^2 more in untreated plots than *A. pinnata*.

Screening insecticides for spinning worm and caseworm. Nine insecticides were tested in liquid

Table 15. Standing biomass of 2 Azolla spp., larval and pupal populations of the spinning worm and 3 caseworms, and yield loss at IRRI farm, Nov 1983-Dec 1984.

Insecticide treatment	Standing biomass (kg fresh wt/m^2)		Larvae + pupae (no./m^2)				Yield loss estimate (%)	
			Spinning worm		Caseworm			
	Av	Range	Av	Range	Av	Range	Av	Range
A. microphylla								
Treated	1.030	0.615-1.530	0.0	–	0.0	–	34.6	5.8-64.2
Untreated	0.671	0.430-1.185	146.0	0.0-522.3	56.8	2.5-315.5		
A. pinnata								
Treated	0.666	0.441-1.244	0.0	–	0.0	–	31.2	13.1-57.4
Untreated	0.449	0.304-0.720	134.8	5.8-621.5	48.0	0.0-246.5		

formulations against 4th-instar larvae of the spinning worm and caseworms. Against spinning worms, methomyl was best, but monocrotophos and diazinon showed promise. Against caseworms (mainly *E. enixalis*), methomyl was best, but triazophos, diazinon, carbofuran, monocrotophos, and carbosulfan were promising.

Of 10 granular insecticides, phenthoate + MIPC, propaphos, cartap, ethoprop, carbofuran, diazinon, and benfuracarb showed more than 85% mortality against the spinning worm.

Soil and crop management

Management of other nutrients

Agronomy and Soil Chemistry/ Physics Departments

LONG-TERM FERTILITY EXPERIMENTS **294**
IRRI **294**
BPI stations **294**
Farmers' fields **294**
POTASSIUM AND ZINC INTERACTIONS IN LOWLAND RICE **295**
SULFUR STATUS OF SOME PHILIPPINE SOILS **297**
Survey **297**
SULFUR FRACTIONS AND CARBON, NITROGEN, AND SULFUR RELATIONSHIPS **298**
Yield response to sulfur **299**
SULFUR MANAGEMENT FOR IRRIGATED RICE **300**
INFLUENCE OF WATER MANAGEMENT ON SULFUR RESPONSE **301**
LONG-TERM SULFUR FERTILITY EXPERIMENT **301**
STRAW AMENDMENTS AND SOIL CARBON IN LOWLAND SOILS **302**
DEEP WATER RICE RESPONSE TO NUTRIENTS IN FARMERS' FIELDS **303**

LONG-TERM FERTILITY EXPERIMENTS

Agronomy Department

In 1984, fertility research continued in the 40th (dry season [DS]) and the 41st (wet season [WS]) consecutive crops at IRRI and the 17th year at 3 experiment stations of the Philippine Bureau of Plant Industry (BPI). Soils at these sites vary in physical and chemical characteristics (Table 1).

IRRI. During DS, IR8 damage by tungro (RTV) and brown planthopper was so severe that IR8 was removed before harvest. IR36 and IR29723-143-3-2-1 responded similarly to combinations of N, P, and K fertilizers (Table 2). N fertilizer alone gave yields comparable to those of N combined with P or K or both. With P or K alone, yields were not better than in the control. WS results were similar.

In both seasons, applying part of the N as compost at the rate of 24 kg N/ha produced yields comparable to those when all N applied was inorganic (Table 2).

BPI stations. In Maligaya silty clay loam, the highest rate of K, plus N and P, produced the highest yield of 8.0 t/ha in IR29723-143-3-2-1 during DS (Table 3). Yields, however, were not significantly higher than with the single application of K, plus N and P. IR29723-143-3-2-1 yielded higher than IR36 in all NPK treatments. They responded differently, however, to different combinations of NPK.

During WS, both rices yielded best when all three elements N, P, and K were applied (Table 3).

Irrespective of season, N, P, and K were all deficient in Maligaya soil, as indicated by soil analyses (Table 1). Comparison with earlier years shows that although originally marginally deficient in major elements, this soil has become highly responsive to those elements under continuous rice cropping.

In DS at Bicol, IR29723-143-3-2-1 yielded significantly better than IR36 in all fertilizer treatments (Table 4), but both rices responded similarly. Applying N and K, or N alone, did not produce significantly higher yields than no application. With N and P, however, yields were comparable to those with N, P, and K. Results were similar during WS. Soil test data showed that Pili clay soil is deficient in P (Table 1), but also responds to N and K.

In Visayas, IR29723-143-3-2-1 yielded higher than IR36 and IR8 at all fertilizer treatments during DS. IR36 had intermediate yields (Table 5).

In previous years, applying N and P to Santa Rita clay soil sustained reasonable yields; applying either N with K, or N alone, did not increase yields significantly over no fertilizer. In 1984 DS and WS, however, N alone significantly increased yields. Table 1 shows Santa Rita clay lacks N; hence, N response was expected. Soil P is relatively sufficient. However, high Ca in soil may hinder P availability; thus, response to N plus P is spectacular.

Farmers' fields. The 16th and 17th crops in Luisiana, Laguna, and the 14th and 15th in Tanay, Rizal, were grown in 1984. On Tanay soil, WS yields were higher than DS due to drought. Rice responded to N alone or with P and K in both soils (Table 6, 7). Single applications of P or K gave yield increase over the control with P increases usually significantly better. In both soils, NP usually

Table 1. Some chemical properties of soils in long-term fertility trials at IRRI and 3 BPI experiment stations (Maligaya, Bicol, and Visayas),[a] 1984 DS.

Character[b]	Location[c]			
	IRRI	Maligaya	Bicol	Visayas
pH (1:1 wt/vol H_2O)	5.8 (5.6-6.1)	5.9 (5.8-6.3)	5.0 (4.8-5.2)	7.0 (7.0-7.1)
Organic C (%)	2.29 (2.14-2.42)	1.18 (1.04-1.26)	2.26 (2.10-2.38)	1.41 (1.37-1.47)
Total N (%)	0.20 (0.19-0.22)	0.11 (0.09-0.16)	0.22 (0.18-0.33)	0.11 (0.10-0.11)
Available P Bray 2 (ppm)	21 (13-31)	13 (11-16)	17 (9-25)	27 (19-35)
Exchangeable K (meq/100 g ads)	1.66 (1.42-1.98)	0.15 (0.12-0.18)	0.32 (0.25-0.43)	0.59 (0.51-0.66)
Exchangeable Ca (meq/100 g ads)	17 (16-18)	18 (17-18)	14 (13-15)	34 (34-34)
Exchangeable Mg (meq/100 g ads)	11 (10-11)	8 (8-9)	7 (7-7)	16 (15-16)
Soil series	Maahas clay	Maligaya silty clay loam	Pili clay	Santa Rita clay
Soil order	Mollisol	Inceptisol	Vertisol	Vertisol

[a]Mean of 8 NPK treatments at IRRI and 6 at BPI stations. [b]ads = air dry soil. [c]Soil test values in parentheses are ranges.

produced yields comparable to NPK.

Results suggest P is much more needed with N than K. Likewise, with continuous cropping, the low yields indicate the need for higher rates of N and P, and possibly K.

Table 2. Effect of NPK fertilizers on yield of test rices in the 40th (DS) and 41st (WS) consecutive crops in the long-term fertility trial. IRRI, 1984.

Fertilizer (kg/ha)			Yield[b] (t/ha)		
N[a]	P	K	IR8	IR36	IR29723-143-3-2-1
			DS		
0	0	0	–	3.8 b	4.3 b
140	0	0	–	6.6 a	6.8 a
0	13	0	–	4.1 b	3.7 b
0	0	25	–	3.9 b	4.3 b
140	13	0	–	6.5 a	6.7 a
140	0	25	–	6.4 a	6.9 a
140	13	25	–	6.9 a	6.7 a
140[c]	13	25	–	6.1 a	6.1 a
			WS		
0	0	0	3.0 b	3.7 b	3.3 c
60	0	0	3.8 a	4.9 a	5.4 ab
0	13	0	3.1 b	3.8 b	3.5 c
0	0	25	3.0 b	3.6 b	3.5 c
60	13	0	3.9 a	4.5 a	5.8 a
60	0	25	3.9 a	4.6 a	5.5 ab
60	13	25	4.2 a	5.0 a	5.4 ab
60[c]	13	25	4.1 a	4.6 a	5.1 b

[a]Includes 40 kg N/ha during DS and 20 kg N/ha topdressed 5-7 d before panicle initiation (DBPI) during WS. [b]Av of 4 replications. [c]24 kg N/ha from compost.

POTASSIUM AND ZINC INTERACTIONS IN LOWLAND RICE

Agronomy Department

In 1984 WS, trials were begun to evaluate yield responses of IR36 to K and Zn with emphasis on Ca to Mg and Ca to K ratios. Before trials began, soils were analyzed on three sites (two irrigated and one

Table 4. Effect of NPK fertilizers on yields of IR36 and IR29723-143-3-2-1 in the long-term fertility trial. Bicol Experiment Station, Pili, Camarines Sur, Philippines, 1984 DS and WS.

Fertilizer (kg/ha)			Yield[b] (t/ha)		
N[a]	P	K	IR36	IR29723-143-3-2-1	Mean
			DS		
0	0	0	3.2 cd	3.6 bc	3.4 bc
140	0	0	2.6 d	3.7 bc	3.2 c
140	26	0	4.1 abc	5.8 a	5.0 a
140	0	50	3.3 cd	4.6 b	4.0 b
140	26	50	5.0 a	6.1 a	5.6 a
140	26	50 + 25	4.9 a	6.2 a	5.6 a
			WS		
0	0	0	3.1 a	3.7 bc	0.6 ns
70	0	0	4.1 a	3.1 c	1.0 *
70	26	0	3.6 a	5.6 a	2.0 **
70	0	50	3.1 a	4.2 b	1.1 *
70	26	50	4.1 a	5.7 a	1.6 **
70	26	50 + 25	4.0 a	5.5 a	1.5 **

[a]Includes 40 kg N/ha during DS and 30 kg N/ha topdressed 5-7 DBPI during WS. [b]Av of 3 replications. IR8 was excluded because of RTV damage.

Table 3. Effect of NPK fertilizers on IR36 and IR29723-143-3-2-1 yields in the long-term fertility trial. Maligaya Rice Research and Training Center, Munoz, Nueva Ecija, Philippines, 1984 DS and WS.

Fertilizer (kg/ha)			Yield[b] (t/ha)		
N[a]	P	K	IR36	IR29723-143-3-2-1	Difference
			DS		
0	0	0	2.2 bc	2.5 d	0.3 ns
140	0	0	2.7 b	3.7 c	1.0 **
140	26	0	5.8 a	6.0 b	0.2 ns
140	0	50	1.8 c	3.2 cd	1.4 **
140	26	50	6.1 a	7.5 a	1.4 **
140	26	50 + 25	6.2 a	8.0 a	1.8 **
			WS		Mean
0	0	0	2.2 de	1.0 de	2.1 c
70	0	0	1.6 e	3.1 bc	2.4 c
70	26	0	3.5 abc	3.3 abc	3.4 b
70	0	50	2.2 de	2.6 cd	2.4 c
70	26	50	4.1 a	4.1 a	4.1 a
70	26	50 + 25	4.0 ab	4.0 ab	4.0 a

[a]Includes 40 kg N/ha during DS and 30 kg N/ha during WS topdressed 5-7 DBPI. IR8 was excluded because of RTV damage. [b]Av of 3 replications.

Table 5. Effect of NPK fertilizers on grain yield of test rices in the long-term fertility trial. Visayas Experiment Station, Hamungaya, Jaro, Iloilo, Philippines, 1984 DS and WS.

Fertilizer (kg/ha)			Yield[b] (t/ha)			
N[a]	P	K	IR8	IR36	IR29723-143-3-2-1	Mean
			DS			
0	0	0	2.0 d	2.4 d	2.9 c	2.4 d
140	0	0	3.2 c	4.0 b	4.3 b	3.8 b
140	26	0	4.5 ab	5.3 a	6.4 a	5.4 a
140	0	50	2.2 d	3.4 bc	4.1 b	3.2 c
140	26	50	4.8 ab	5.4 a	6.4 a	5.5 a
140	26	50 + 25	5.0 a	5.4 a	6.2 a	5.5 a
			WS			
0	0	0	–	2.7 d	3.1 e	2.9 c
70	0	0	–	3.1 d	4.1 c	3.6 b
70	26	0	–	4.3 a	4.6 abc	4.5 a
70	0	50	–	3.2 cd	3.9 cd	3.6 b
70	26	50	–	4.0 ab	5.1 a	4.6 a
70	26	50 + 25	–	4.0 ab	5.0 ab	4.5 a

[a]Includes 40 kg N/ha during DS and 30 kg N/ha topdressed 5-7 DBPI during WS. [b]Av of 3 replications. RTV damaged IR8 during WS.

Table 6. Effect of NPK on yield of IR36 and IR29723-143-3-2-1 in the 16th (DS) and 17th (WS) consecutive crops. Luisiana, Laguna, Philippines, 1984.

Fertilizer treatment[a]	Yield (t/ha)			
	DS		WS	
	IR36	IR29723-143-3-2-1	IR36	IR29723-143-3-2-1
Control	2.3 e	2.7 d	2.6 e	2.5 d
N	3.8 b	3.8 b	3.5 bc	3.5 bc
P	3.3 bc	3.4 bc	3.3 cd	3.0 cd
K	2.9 cd	2.8 cd	2.9 de	2.5 d
NP	4.6 a	4.6 a	4.1 a	3.9 ab
PK	2.5 de	2.7 d	3.2 cd	3.0 cd
NK	3.7 b	3.5 b	3.2 cd	3.5 bc
NPK	4.6 a	4.9 a	3.9 ab	4.1 a

[a]120 kg N/ha for DS and 60 kg N/ha for WS; 17.5 kg P/ha and 33 kg K/ha in both seasons. CV = 11.1% for DS and 10.4% for WS.

Table 7. Effect of NPK on yield of IR36 and IR29723-143-3-2-1 in the 14th (DS) and 15th (WS) consecutive crops. Tanay, Rizal, Philippines, 1984.

Fertilizer treatment[a]	Yield (t/ha)			
	DS		WS	
	IR36	IR29723-143-3-2-1	IR36	IR29723-143-3-2-1
Control	2.1 d	2.1 d	2.9 e	3.2 c
N	3.7 b	3.8 b	4.2 c	4.2 b
P	2.7 c	2.3 d	3.2 de	3.6 c
K	2.6 cd	2.5 d	3.2 de	3.3 c
NP	4.2 a	4.0 ab	5.0 a	4.4 b
PK	2.2 d	2.4 d	3.5 d	3.6 c
NK	3.3 d	3.2 c	4.4 bc	4.2 b
NPK	4.4 a	4.3 a	4.8 ab	5.0 a

[a]120 kg N/ha for DS and 60 kg N/ha for WS; 17.5 kg P/ha and 33 kg K/ha in both seasons. CV = 10.4% for DS and 8.0% for WS.

Table 8. Characteristics of soils for trials on K-Zn interaction in lowland rice. Bugallon and Mangatarem, Pangasinan, Philippines, 1984 WS.

Criterion	Bugallon		Mangatarem			
	Topsoil	Subsoil	Irrigated		Rainfed	
			Topsoil	Subsoil	Topsoil	Subsoil
pH (1:1)	5.0	4.9	6.8	6.9	6.8	6.8
OM (%)	3.3	3.5	2.3	2.1	1.7	1.1
Total N (%)	0.16	0.16	0.11	0.09	0.08	0.05
Available P (ppm, Olsen)	0.85	0.68	1.22	1.05	2.50	1.30
Exchangeable cations (meq/100 g)						
Na	0.24	0.20	0.22	0.22	0.11	0.12
K	0.03	0.01	0.09	0.13	0.25	0.12
Mg	11	12	27	28	20	22
Ca	11	12	16	17	8	9
Ca + Mg/K	750	2410	475	353	114	252
CEC (meq/100 g)	26	30	46	49	29	31
Fe (ppm, perchloric acid)	4.2	4.4	6.0	5.9	4.8	3.9
Available Zn (ppm, K & P)	0.28	0.24	0.05	0.04	0.10	0.05
Particle size (%)						
Sand	17	12	3	4	32	33
Silt	57	53	48	44	39	36
Clay	26	35	49	52	29	31
Texture	Silty loam	Silty clay loam	Silty clay	Silty clay	Clay loam	Clay loam

rainfed) in Pangasinan Province (Table 8). Soils of the irrigated sites have high Ca and Mg but low available K and Zn.

At the rainfed site in Mangatarem, IR36 yielded similarly in all treatments (Table 9). However, it responded to K at both irrigated sites and to Zn in Bugallon.

At Mangatarem, 100-20 kg K-Zn gave highest yield, whereas at Bugallon, 200-60 kg K-Zn produced highest yield (Fig. 1). Increasing Zn without K decreased yields on Mangatarem soil but increased yields on Bugallon soil (Fig. 2). Therefore, the soils need K much more than Zn. Bugallon soil, coarser (loamy) with higher Ca:Mg or Ca:K values than Mangatarem soil (clay), responded better to Zn and K. Therefore Ca:K or Ca:Mg may serve as useful criteria for rice yield response to K and Zn.

Table 9. Effect of different rates of K and Zn on grain yield of lowland rice IR36. Pangasinan, Philippines, 1984 WS.

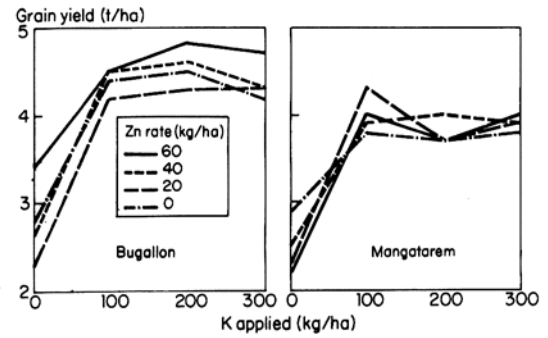
Treatment[a] N-P-K + Zn (kg/ha)	Grain yield (t/ha)		
	Bugallon, irrigated	Mangatarem	
		Irrigated	Rainfed
0-0-0	2.2 f	1.8 e	1.9 c
N-P-0	2.8 e	2.9 c	3.9 ab
N-P-100	4.4 abc	3.8 ab	3.6 ab
N-P-200	4.5 abc	3.7 b	3.7 ab
N-P-300	4.2 c	4.0 ab	3.7 ab
N-P-0 + 20	2.3 f	2.3 de	3.8 ab
N-P-0 + 40	2.6 ef	2.5 cd	4.0 a
N-P-0 + 60	3.4 d	2.2 de	3.7 ab
N-P-100 + 20	4.2 c	4.3 a	3.8 ab
N-P-200 + 20	4.3 bc	3.7 b	3.5 b
N-P-300 + 20	4.3 bc	3.9 ab	3.7 ab
N-P-100 + 40	4.5 abc	3.9 ab	3.7 ab
N-P-200 + 40	4.6 abc	4.9 ab	4.1 a
N-P-300 + 40	4.3 bc	3.9 ab	3.8 ab
N-P-100 + 60	4.5 abc	4.0 ab	3.9 ab
N-P-200 + 60	4.8 a	3.7 b	4.1 a
N-P-300 + 60	4.7 ab	3.8 ab	3.9 ab
N-O-300 + 60	3.3 d	3.0 c	3.7 ab

[a]Urea and P at 26 kg P/ha and 40 kg N/ha were broadcast and incorporated at planting time. N at 100 kg N/ha was applied at 3 stages: basal, active tillering, and at 5-7 DBPI.

SULFUR STATUS OF SOME PHILIPPINE SOILS

Agronomy Department

Survey. Analysis continued for total S, SO_4^{-2}-S, and other soil properties of 167 soil profile samples from 19 Luzon provinces and 2 in Visayas (Annual report for 1983).

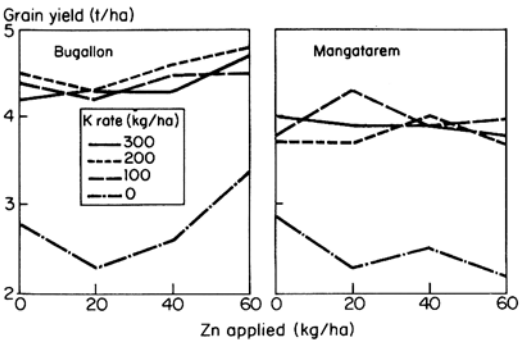


1. Grain yield of irrigated IR36 as influenced by Zn and K. Bugallon and Mangatarem, Pangasinan, Philippines, 1984 WS.

Total S content ranged from 21 to 1,274 ppm in surface soils (0-20 cm) and 8 to 1,872 ppm in subsurface horizons (21-100 cm). Phosphate extractable sulfate varied from 0 to 705 ppm in surface soils and from 0 to 100 ppm in subsurface horizons.

In 99 sites analyzed, 26 surface soils contained less than the critical limit of 9 ppm SO_4^{-2}-S set by Islam and Ponnamperuma (1982). These soils, mostly from Cagayan, Isabela, Tarlac, and Batangas, are low in organic C (<1%), slightly acidic, and silty clay to silty clay loam in texture.

Total S and organic C were significantly correlated in the first 4 depths (0-80 cm) but not at 80-100 cm, indicating most S is organically combined. Sulfate-S correlated significantly with pH only down to the soil depth of 60 cm. Clay content was correlated with total S in surface soils and with sulfate-S in subsurface samples (Table 10). Other soil properties did not correlate with total S and SO_4^{-2}-S contents.



2. Grain yield of irrigated IR36 as influenced by Zn and K. Bugallon and Mangatarem, Pangasinan, Philippines, 1984 WS.

Sulfate-S content was lower at greater soil depth in 61 sites, as was total S in 51 sites. However, two soils from Isabela and Pampanga had more S and SO_4^{-2}-S with increasing depth.

SULFUR FRACTIONS AND CARBON, NITROGEN, AND SULFUR RELATIONSHIPS

Agronomy Department

In the study to determine S fractions and C-N-S relationships of 25 Luzon rice soils, soil pH was 6.0-7.6; organic C, 0.6-3.9%; total N, 0.06-0.32%; CEC, 4-49 meq/100 g; and soil texture, sandy loam to clay (Table 11).

Total S, ranging from 76 to 1,051 ppm, significantly correlated with organic C (0.71**) and total N ($r = 0.72$**). Phosphate-extractable sulfate varied from 0 to 89 ppm and accounted for about 0-15% of total S in surface soils. Organic S (total S minus sulfate-S) accounted for 85 to 100% of total S in the soil.

The percentages of S-forms in the soils are shown in Table 12. An average of 19% of S was converted to H_2S by reducing the mixture containing hydroiodic acid (HI). This reducible S included phosphate-extractable S and ester sulfate S which accounted for about 14% of total S. Soils also contained significant amounts of C-bonded S (total S minus HI reducible S).

Organic S fractions in the soils correlated significantly with total S, total N, and organic C (Table 13). Ester sulfate S, however, was not significantly correlated with organic C.

Table 10. Correlation coefficients (r) between total S and SO_4-S, and organic C, pH, and clay content, 1984.

S form	Soil depth (cm)	Correlation coefficient (r)		
		pH	Organic C	% clay
Total S	0-20	0.26**	0.41**	0.20**
	20-40	0.13^{ns}	0.41**	0.16^{ns}
	40-60	0.07^{ns}	0.22**	0.17^{ns}
	60-80	0.02^{ns}	0.26**	0.19^{ns}
	80-100	0.01^{ns}	0.15^{ns}	0.20^{ns}
SO_4-S	0-20	0.32**	0.13^{ns}	0.30^{ns}
	20-40	0.20*	0.31**	0.21
	40-60	0.23*	0.08^{ns}	0.25
	60-80	0.16^{ns}	0.02^{ns}	0.21
	80-100	0.07^{ns}	0.11^{ns}	0.27

Table 11. Some chemical characteristics and texture of the soils studied in the greenhouse. IRRI, 1984.

Site no.	Province, town	pH (1:1)	Organic C (%)	Total N (%)	Olsen P (ppm)	CEC (meq/100 g)	Available Zn (ppm)	Available S (ppm)	Total S (ppm)	Soil texture
	Batangas									
1	San Jose	7.4	1.1	0.10	1.2	19	1.0	15	117	Loam
2	San Juan	7.4	1.2	0.10	11.4	18	0.6	70	264	Clay
	Cagayan									
3	Amulug	7.2	1.6	0.15	5.5	31	0.1	8	246	Silty clay loam
4	Gattaran	7.6	3.9	0.32	14.1	44	nil	89	1051	Clay
5	Lal-lo	6.2	0.8	0.08	1.7	17	0.4	10	91	Silt loam
6	Tuguegarao	7.0	1.7	0.14	7.5	32	0.2	13	246	Clay
	Cavite									
7	Carmona	6.4	0.7	0.06	1.0	10	0.6	nil	76	Clay loam
	Isabela									
8	Cabagan	6.8	0.6	0.06	1.0	4	1.5	3	11	Silty clay loam
9	Ilagan	7.1	1.0	0.09	38.9	17	1.8	6	17	Silty clay
	Laguna									
10	Bay	6.3	1.9	0.16	9.1	49	0.4	13	343	Clay
11	Los Baños	6.6	2.1	0.20	21.4	34	1.2	27	504	Silty clay loam
	La Union									
12	Bacnotan	7.2	1.3	0.12	8.2	32	0.1	16	219	Sandy loam
	Nueva Ecija									
13	Bongabon	7.4	0.7	0.07	2.9	12	0.6	11	92	Loam
14	Cabanatuan	6.6	1.0	0.07	11.4	4	0.7	4	139	Silty clay
	Nueva Vizcaya									
15	Aritao	6.4	0.8	0.08	1.4	18	0.5	3	130	Silty clay loam
	Pampanga									
16	Arayat	7.2	1.4	0.14	10.0	28	0.2	10	224	Loam sand
	Pangasinan									
17	Aguilar	6.2	1.0	0.09	1.2	16	0.8	nil	134	Sandy loam
18	Santa Maria	6.2	1.1	0.10	2.4	14	1.9	12	240	Sandy loam
	Tarlac									
19	Bamban	6.4	0.9	0.09	9.1	25	1.0	7	416	Loam
20	Capas	6.2	1.4	0.13	17.7	35	1.2	20	133	Sandy loam
21	Gerona	7.0	1.5	0.15	36.6	37	0.2	nil	321	Silt loam
22	Moncada	7.4	0.7	0.07	3.1	15	0.9	6	101	Silty clay loam
23	San Manuel	6.5	0.9	0.09	22.8	19	2.1	10	805	Silt loam
24	Tarlac	6.0	1.6	0.15	3.1	23	1.6	9	181	Clay loam
	Zambales									
25	Botolan	6.4	1.9	0.16	5.0	23	0.8	28	269	Loam

Among the 25 surface soils, the C:N averaged 11.1 and the N:S 6:1. The C:N:S ratio varied from 11:1:1 to 142:13:1.

Yield response to sulfur. Soils were tested for S response in the greenhouse, using ammonium sulfate at 30 ppm S. Response was highest in Gattaran (49 g/pot) and lowest in Amulug (0.2 g/pot). Seven of the 25 soils had low SO_4^{-2}-S and total S but did not respond significantly to applied S (Fig. 3).

In 18 soils, yields responded significantly to residual S. Of soils which had not responded to applied S, Carmona responded best at 45 g/pot. Some soils not responding significantly to applied S responded significantly to residual S. Twelve soils significantly responded to both applied and residual S.

S fractions in the 25 soils studied were correlated with grain yield, straw yield, and relative total yield of the untreated (without S) pots. Limitation of a single S form was not important in producing high yields.

Table 12. Total S and percentage distribution of various forms in some rice soils in Luzon, Philippines, 1984.

Site no.[a]	Total S (ppm)	S form as % of total S				
		Sulfate S	Hydroiodic acid-reducible S	Ester sulfate S	C-bonded S	Total organic S
1	117	13	22	9	78	87
2	264	11	22	8	78	89
3	246	3	23	20	77	97
4	1051	8	18	10	82	92
5	91	11	41	30	59	89
6	246	5	20	15	80	95
7	76	0	16	16	84	100
8	112	3	13	11	87	97
9	175	3	24	21	76	97
10	343	4	18	15	82	96
11	504	5	14	8	86	95
12	219	7	52	45	48	93
13	92	12	20	8	80	88
14	139	3	21	18	79	97
15	130	2	23	21	77	98
16	224	4	14	10	86	96
17	134	0	8	8	92	100
18	240	5	7	2	93	95
19	416	2	10	8	90	98
20	133	15	17	2	83	85
21	321	0	16	16	84	100
22	101	6	9	3	91	94
23	805	1	20	18	80	99
24	181	5	17	12	83	95
25	269	10	19	8	81	90

[a] See Table 11 for site identification.

SULFUR MANAGEMENT FOR IRRIGATED RICE

Agronomy Department

The effectiveness of five S fertilizers, namely, urea S (US), S bentonite (SB), calcium sulfate (CS), elemental S (ES), and ammonium sulfate (AS) were compared in five apparently S-deficient soils.

Table 13. Correlation coefficients (*r*) between organic S fractions and total S, total N, and organic C, 1984.

Relationship	*r*
Organic S vs	
Total S	0.99**
Total N	0.69**
Organic C	0.68**
Ester sulfate S vs	
Total S	0.78**
Total N	0.41*
Organic C	0.39^{ns}
C-bonded S vs	
Total S	0.99**
Total N	0.71**
Organic C	0.71**

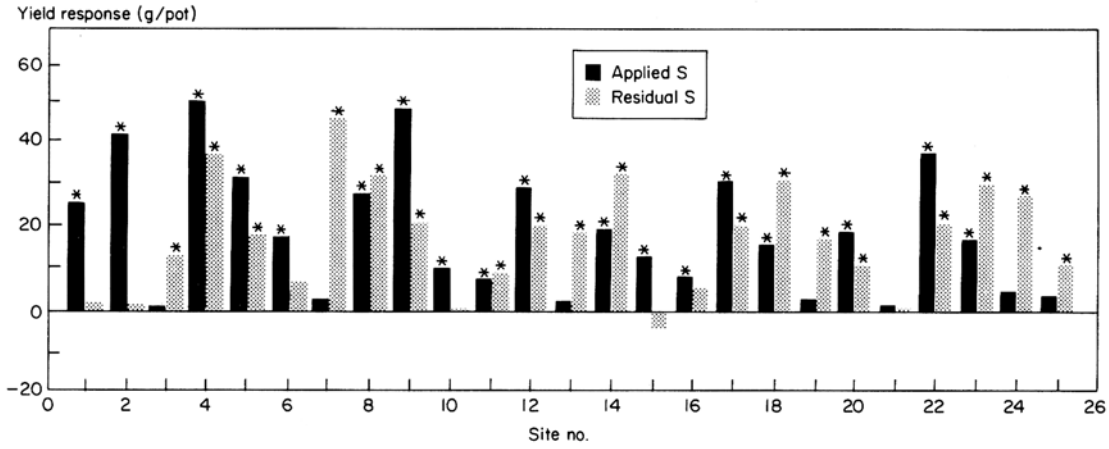
Except in Aguilar, the five S sources significantly increased yields over the control (Fig. 4). US (21% S) was as effective as other sources in Bacnotan and Santa Maria, and better in San Juan. In Moncada, it was as effective as ES, inferior to AS, and better than SB.

CS (16% S) was significantly better than SB and as effective as AS in San Juan. In Aguilar, it gave a significant yield increase over AS. It was superior to SB, but inferior to US, ES, and AS in Moncada.

ES (70% S) gave significant yield advantage over SB in San Juan and over SB and CS in Moncada, and was as good as other S fertilizers at other locations.

AS (24% S) significantly outyielded SB and ES in San Juan, but was outyielded markedly by US and CS in Aguilar. In Moncada, it was superior to other sources.

US appears to be the most promising S fertilizer for rice; high S-containing SB (90% S) appears least effective. Except in Bacnotan, SB gave no significant yield increases over the control.



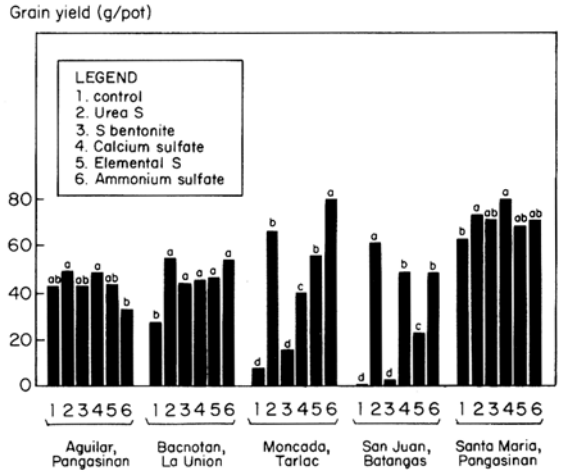
3. Yield response of IR58 to applied and residual S. IRRI greenhouse, 1984.

INFLUENCE OF WATER MANAGEMENT ON SULFUR RESPONSE

Agronomy Department

To test effects of water management on S availability and S response, a greenhouse study used three S-deficient soils under three water regimes. AS was added at 0 and 30 ppm S.

No responses were significant in Botolan. In Bacnotan and Aguilar soils, yields responded to S and also differed with water management. Allowing the soil to dry before prolonged submergence or intermittent flooding produced significantly higher yields than a soil never allowed to dry (Table 14).



4. Yield response of IR36 to different S fertilizers. IRRI, 1984.

LONG-TERM SULFUR FERTILITY EXPERIMENT

Agronomy Department

Studies on effects of continuous application of high analysis fertilizers (urea and triple superphosphate) continued at IRRI during 1984 DS and WS (fourth and fifth crop) using IR56.

Table 14. Effect of water management on yield of IR36 grown in 3 Luzon soils. IRRI, 1984.

Soil	Water regime[a]	S (ppm)	Grain yield (g/pot)
Botolan, Zambales	M_1	0	50 def
		30	50 def
	M_2	0	46 efgh
		30	56 cde
	M_3	0	42 fghi
		30	35 i
Bacnotan, La Union	M_1	0	48 efg
		30	75 a
	M_2	0	37 hi
		30	71 ab
	M_3	0	38 ghi
		30	50 def
Aguilar, Pangasinan	M_1	0	40 fghi
		30	62 bc
	M_2	0	13 j
		30	59 bc
	M_3	0	46 efgh
		30	54 cde

[a] M_1 = soil dried before transplanting, and submerged after transplanting until 1 wk before harvest; M_2 = soil never allowed to dry up; M_3 = soil kept under water until 1 wk before transplanting, and irrigated everytime it dried.

During the fourth crop, inorganic N alone or with P or K, or with P, K, and S gave significant yield increases over the control (Table 15). Use of organic (azolla and straw) and inorganic (urea) N sources gave similar yield increases. P and K were not effective applied singly but together significantly improved yield by 0.8 t/ha. No significant response to S and Zn was observed.

Except for S, no elements produced significant responses during the fifth crop (Table 15). P and K applied individually or combined, and Zn yielded significantly less than the control. N response was high during DS but absent during WS. A typhoon 3 wk before harvest caused heavy lodging.

STRAW AMENDMENTS AND SOIL CARBON IN LOWLAND SOILS

Soil Chemistry/Physics Department

Previous research showed that rice straw initially decomposes in puddled tropical wetland soils similarly as in upland soils. The decrease over time of C from added rice straw is given in Table 16. Turnover times T (in years) of remaining C compounds at time t (in months) are increasing by:

$$T = 0.202 \times e^{0.1282\,t} \quad (r^2 = 0.9904) \qquad (1)$$

A decay series can be used to calculate the remaining C derived from straw amendments. C gain from seasonal additions can be calculated:

$$C_g = C_a \times [p_1 + (p_1 \times p_2) + (p_1 \times p_2 \times p_3) + \ldots . (p_1 \times p_2 \ldots . p_i)] \qquad (2)$$

C_g = gain of C (kg/ha)
C_a = C added each season (kg/ha)
$p_1, p_2 \ldots . p_i$ = proportion of C remaining after each season following the sequence 0.300, 0.599, 0.902, 0.976, 0.988, etc. derived from Table 1.

The rate will likely become constant at the decay level of the stabilized (autochthonous) organic matter. The decay rate of autochthonous organic matter, unlike that of fresh plant residues, depends highly on the water regime. In a dry fallow rice - rice cropping system, this rate in an Andaqueptic Haplaquoll was 0.4%/season. Permanent submergence reduces this decay, enhancing accumulation of soil C. Changes in soil C in the dry fallow rice - rice cropping system are computed by the following equation:

$$C_s = C_o - (C_l - C_b) + C_g \qquad (3)$$

C_s = current amount of soil C (kg/ha),
C_o = initial amount of soil C (kg/ha),
C_l = loss of stabilized soil C (kg/ha),
C_b = additional loss of soil C derived from former inputs (estimated to be constantly 300 kg/ha during initial seasons), and
C_g = gain of seasonal C addition (kg/ha) derived from 2.

The relation between organic C addition and the soil organic C content at steady state is shown in Figure 5. The computed changes fit quite well with data from long-term experiments at IRRI (Fig. 6).

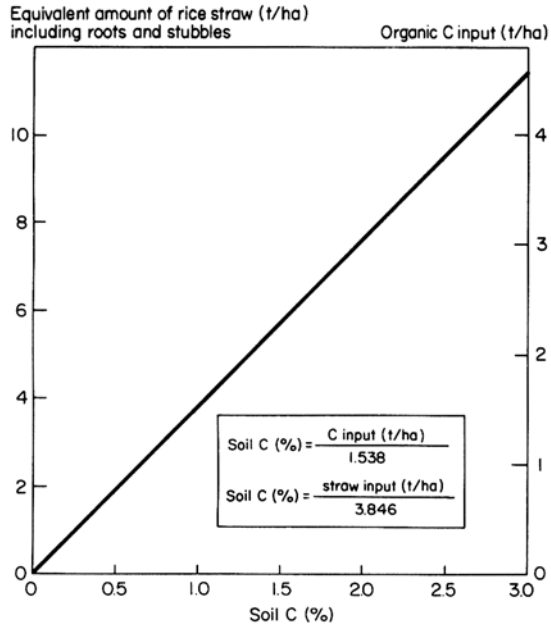
Table 15. Yield of 14 treatments in the long-term fertility trial with irrigated IR56 rice. IRRI, 1984 cropping seasons.

Treatment[a]	Yield (t/ha)	
	Dry season	Wet season
Control	3.1 c	3.5 cd
Zn alone	2.5 c	3.1 fg
N + Zn	4.6 a	3.4 de
P + Zn	3.0 c	2.5 h
K + Zn	2.8 c	3.2 ef
NP + Zn	4.7 a	3.6 cd
NK + Zn	4.4 a	4.0 ab
PK + Zn	3.8 b	2.8 g
NPK + Zn	5.0 a	3.7 bcd
NPK only	5.0 a	3.9 ab
NPK + S	4.4 a	3.7 bcd
NPK + Zn + S	4.9 a	4.1 a
NPK + Azolla + Zn	5.1 a	3.6 cd
NPK + Straw + Zn	4.5 a	3.8 abc
CV (%)	10.2	5.9

[a] Zn as root dip in 4% ZnO solution. S as AS at 40 kg S/ha.

Table 16. Remaining C of incorporated rice straw over time. IRRI, 1984.

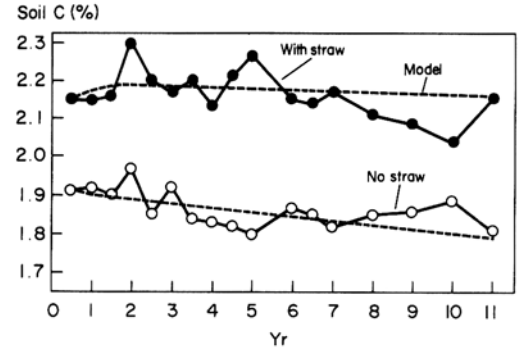
Time after incorporation (mo)	Remaining C (%)
0	100.0
6	30.0
12	18.0
18	14.4
24	13.0
30	12.4
36	12.1



5. Relation of seasonal straw amendments to soil C content in tropical lowland soils (2 rice crops a year, dry fallow). IRRI, 1984.

Soil organic C levels evidently change very slowly and to reach a new steady state might take hundreds of years.

We can deduce that newly added or generated organic substrates like manures, rice straw, and soil biomass are the main sources of soil N in tropical wetland soils. In general, soil biomass contains 2-3% of the organic C in soil.



6. Change of soil C content due to seasonal straw amendments (5 t/ha) at IRRI. Field data are adjusted to uniform sampling time and a bulk density of 1 Mg/m^3.

DEEP WATER RICE RESPONSE TO NUTRIENTS IN FARMERS' FIELDS

Agronomy Department

Yields and fertilizer responsiveness of advanced breeding lines of deep water rice were tested in three farmers' fields in Prachinburi Province, Thailand. Fertilizer was applied 3 wk after seedling emergence to give 37 kg N and 16 kg P/ha. The trials were sown in June and harvested December-January.

At Bang Puang, all varieties were affected by rapid water rise in August (100 cm in 18 d). Water reached 120 cm 10 Oct. Yields were low, and fertilizer did not improve production. The best entry was HTA7205-11 (Table 17).

Fertilizer markedly improved yields at Amphoe Muang. Without fertilizer, the flood (120 cm)

Table 17. Yield of deep water rices without and with fertilizer (37 kg N and 16 kg P) on acid sulfate soils with rapid water rise. Prachinburi Province, Thailand, 1983 WS.

Entry	Yield (t/ha)							
	Bang Puang		Amphoe Muang		Prajuntakarm		Mean	
	No fertilizer	NP	No fertilizer	NP	No fertilizer	NP	No fertilizer	NP
HTA7421-8-1-0	0.8	0.9	1.1	1.4	1.5	1.6	1.1	1.3
SPR7270-18	0.3	0.6	0.10	0.9	0.4	0.3	.3	.6
HTA7205-11	1.1	1.2	0.10	1.8	1.6	1.3	.9	1.1
SPR7297-343	0.3	0.3	0	0.8	0	0	.3	.5
SPR7299-2	0.5	0.7	0	0.9	0.1	0.3	.3	.6
RD19	0.8	0.7	0.1	1.7	0.5	0.9	.4	1.1
Mean	0.6	0.7	0.4	1.3	0.7	0.7		
LSD (0.05)	0.32[a]		0.34[b]	0.36[c]	0.31[a]			

[a]LSD for varieties. [b]LSD for fertilizer same variety. [c]LSD for varieties at same fertilizer level. Fertilizer differences not significant at Bang Puang and Prajuntakarm sites.

destroyed all plots of SPR7297-343 and SPR7299-2, and 3 of 4 plots of SPR7270-18 and RD19. With fertilizer, all varieties survived and yielded 0.9 to 1.8 t/ha. The best entries were HTA7205-11 and HTA7421-8-1-0. Fertilizer improved average yield by 0.9 t/ha.

At Prajuntakarm, floodwater reached 200 cm and SPR7297-343 failed to survive. SPR7299-2 lost three of four plots with zero fertilizer and two of four with fertilizer. Best entries were HTA7421-8-1-0 and HTA7205-11. Fertilizer did not increase yields.

Soil and crop management

International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)

Agronomy Department

NITROGEN FERTILIZER EFFICIENCY FIELD TRIALS **306**
- Irrigated rice **306**
  - IRRI farm **306**
  - Farmers' fields **306**
- Medium deep water rice **307**
- Deep water rice **307**

INTERNATIONAL TRIALS **309**
- Fifth international trial on nitrogen fertilizer efficiency in irrigated rice (13 treatments) **309**
- Fifth international trial on nitrogen fertilizer efficiency in irrigated rice (17 treatments) **309**
- Third international trial on nitrogen fertilizer efficiency in rainfed lowland rice **311**
- Sources of phosphorus in flooded rice **311**
- Long-term fertility trial **311**

INSFFER TRAINING COURSE **312**

SITE CHARACTERIZATION **313**

NITROGEN FERTILIZER EFFICIENCY FIELD TRIALS

Irrigated rice. *IRRI farm.* The 5th (dry season [DS]) and 6th (wet season [WS]) trials of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) in irrigated rice were conducted at IRRI in 1984. N response was significant with all N sources at all N levels in both seasons (Table 1, 2). In DS within N rates, grain yields with different N sources were comparable. Although the highest yield of 7.3 t/ha was obtained at 174 kg N/ha as sulfur-coated urea (SCU), 87 kg N/ha was most efficient.

At all N levels during WS, urea supergranules (USG) produced yields comparable with those of SCU. At 58 kg N/ha, prilled urea (PU) either as standard best split (BS) or locally selected BS was generally inferior to USG and SCU.

Farmers' fields. N fertilizer efficiency trials continued in 1984 on farmers' irrigated fields.

Soils were analyzed before trial installation (Table 3). In both seasons, IR36 responded significantly to all N sources and to all N rates (Table 4, 5). DS yields generally increased as the N rate increased, more so on Calauan than on Famy soil.

Table 1. Effect of sources, rates, and methods of urea application on grain yield of IR58. Fifth trial of INSFFER (irrigated). IRRI, 1984 DS.

Treatment[a]	Yield (t/ha)
No fertilizer N	4.6 e
58 kg N/ha	
PU BS	6.4 bcd
SCU	6.3 cd
USG	6.1 d
87 kg N/ha	
PU BS	6.6 abcd
SCU	7.1 ab
USG	6.4 bcd
116 kg N/ha	
PU BS	7.0 abc
SCU	7.1 ab
USG	7.0 abc
174 kg N/ha	
PU BS	6.8 abcd
SCU	7.3 a
USG	7.1 ab

[a]For split application, 2/3 broadcast and incorporated (B&I) without water during the last harrowing and 1/3 topdressed 5-7 d before panicle initiation (DBPI). PU = prilled urea, SCU = sulfur-coated urea, USG = urea supergranules, BS = best split.

Table 2. Effect of sources, rates, and methods of urea application on grain yield of IR58. Sixth trial of INSFFER (irrigated). IRRI, 1984 WS.

Treatment[a]	Yield (t/ha)
No fertilizer N	1.8 e
29 kg N/ha	
PU locally selected BS	2.7 d
PU standard BS	2.7 d
SCU	3.6 abc
USG	3.1 cd
58 kg N/ha	
PU locally selected BS	3.1 cd
PU standard BS	3.2 cd
SCU	3.8 ab
USG	3.7 ab
87 kg N/ha	
PU locally selected BS	3.4 bc
PU standard BS	3.8 ab
SCU	4.0 a
USG	3.7 ab

[a]For locally selected BS application, 1/2 topdressed at 10 d after transplanting (DT) and 1/2 topdressed 10 d after panicle initiation (DAPI). For standard BS application 2/3 B&I without water during the last harrowing and 1/3 topdressed 5-7 DBPI.

Although significant differences among N sources were noted at 174 kg N/ha, 87 kg N/ha was most efficient in DS and 58 kg N/ha in WS. In DS on Calauan soil (0.22% total N), only at highest N rate did yields differ significantly among N sources (lower with SCU). On Famy soil (0.13% total N), differences among N sources were noted even at lowest N. SCU at 58 and 116 kg N/ha was superior to PU.

Table 3. Characteristics of soils for INSFFER trials in farmers' fields in Calauan and Famy, Laguna, Philippines, 1984.

Soil property	Calauan		Famy
	DS	WS	
pH (1:1)	6.0	6.1	5.1
Total N (%)	0.22	0.17	0.13
OM (%)	3.9	2.9	2.2
Available P (ppm)	12	10	5
Exchangeable K (meq/100 g)	0.84	0.82	0.04
Exchangeable Ca (meq/100 g)	20	18	9
CEC (meq/100 g)	39	38	23
Available Zn (ppm, K & P)	0.60	0.26	4
Texture	Silty clay	Silty clay	Silty clay

In WS at Calauan (0.17% total N), PU standard BS and PU as locally selected BS gave comparable grain yields at the same N level. USG at 29 and 87 kg N/ha gave higher yields than other N sources.

Medium deep water rice. N efficiency trials in medium deep water (50 cm water depth) continued at IRRI. Three sources of N (PU, SCU, and USG) at 3 rates (29, 58, and 116 kg N/ha) were applied in three ways: broadcast and incorporated (B&I), B&I followed by (fb) foliar spray of urea solution, and deep placement (DP). Water depth was increased 5 cm/d starting at 30 d after transplanting (DT) and maintained at 50 cm until harvest.

Two rices were used: photoperiod-insensitive IR21071-53-2-3-2E-P_2 in DS and photoperiod-sensitive IR11288-B-B-69-1 in WS.

The yield of IR21071-53-2-3-2E-P_2 at 29 kg N/ha increased by more than 1.1 t/ha over the control. Increasing N from 29 kg N/ha to 58 and 116 kg N/ha did not increase grain yield.

Among N sources, SCU B&I at 58 kg N/ha yielded highest (6.7 t/ha) but not significantly more than with PU and USG at the same rate. Foliar spraying of urea solution following B&I gave no advantage over full dose B&I and deep-placed USG.

Table 4. Effects of sources, rates, and methods of N fertilizer application on yield of IR36 on Calumpang silty clay in Calauan, Laguna, and on Maligaya silty clay in Famy, Laguna. INSFFER (irrigated), 1984 DS.

Treatment[a]	Yield (t/ha)	
	Calauan	Famy
No fertilizer N	2.5 d	2.5 f
	58 kg N/ha	
PU BS	4.9 c	3.5 e
SCU	5.1 c	4.3 cd
USG	4.9 c	4.6 bcd
	87 kg N/ha	
PU BS	5.4 bc	4.4 cd
SCU	5.5 bc	4.8 abcd
USG	6.1 ab	4.4 cd
	116 kg N/ha	
PU BS	5.7 bc	4.3 d
SCU	6.1 ab	5.3 a
USG	6.2 ab	4.9 abcd
	174 kg N/ha	
PU BS	6.7 a	4.8 abcd
SCU	5.4 bc	5.0 abc
USG	6.6 a	5.2 ab

[a] For split application, 2/3 urea was B&I at last harrowing before planting, and 1/3 topdressed 5-7 DBPI.

Table 5. Effects of sources, rates, and methods of N fertilizer application on yield of IR36 on Calumpang silty clay in Calauan, Laguna. INSFFER (irrigated), 1984 WS.

Treatment[a]	Yield (t/ha)
No fertilizer N	3.9 f
29 kg N/ha	
PU locally selected BS	4.2 de
PU standard BS	4.1 e
SCU	4.5 cde
USG	4.7 bcd
58 kg N/ha	
PU locally selected BS	5.0 abc
PU standard BS	5.1 ab
SCU	4.6 bcd
USG	4.8 bcd
87 kg N/ha	
PU locally selected BS	4.0 abc
PU standard BS	4.9 bc
SCU	4.8 bc
USG	5.5 a

[a] PU, locally selected BS: 1/2 at 4-5 DT and 1/2 at 30 DT. PU, standard BS: 2/3 urea B&I at last harrowing before planting, and 1/3 topdressed 5-7 DBPI.

USG DP recorded the most tillers, panicles, and spikelet production per unit area, but early lodging wiped out potential yield increase.

In WS, photoperiod-sensitive IR11288-B-B-69-1 yielded significantly higher with higher N rates (Table 6). PU B&I at 116 kg N/ha yielded highest at 4.6 t/ha, but without fertilizer it yielded 3.4 t/ha.

Among N sources and methods of application, PU B&I at increasing N rates increased yield. No significant differences were observed among SCU B&I, USG DP, and PU B&I followed by foliar spray of urea solution 5-7 d before panicle initiation (DBPI).

Among plant characters recorded, tiller number at 30 DT and tiller and panicle numbers/m^2 at harvest were reduced without N.

Deep water rice. In the second deep water rice trial in deep water (max 100 cm) ponds at IRRI, photoperiod-insensitive IR21037-21-2E-P_2 was tested in DS and photoperiod-sensitive IR11288-B-B-69-1 in WS. Three N sources (PU, SCU, and USG) at 3 rates (29, 58, and 116 kg N/ha) were applied in 3 ways (B&I, B&I fb foliar spray of urea solution 5-7 DBPI, and DP of USG). Water depth was increased 5 cm/d starting at 30 DT and maintained at 100 cm until harvest.

Grain yield response to added N was significant in IR21037-21-2E-P_2 for all sources, rates, and

Table 6. Effects of sources, rates, and methods of N application on yield and some agronomic characteristics of IR11288-B-B-69-1 at 50 cm water depth. IRRI, 1984 WS.

Treatment	Grain yield (t/ha)	Tillers 30 DT (no./m²)	Tillers at harvest (no./m²)	Panicles at harvest (no./m²)	Panicle length (cm)	Unfilled spikelet (%)
No fertilizer N	3.4 e	113 e	128 b	116 d	25.9 abc	14.1 a
			29 kg N/ha			
PU B&I	3.4 e	142 cde	174 a	168 a	26.0 abc	11.4 ab
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	4.1 abc	161 abcd	151 ab	146 abcd	24.5 c	9.4 bc
SCU B&I	3.9 bcde	154 bcd	133 b	128 cd	25.1 bc	10.0 bc
USG 10-12 cm DP	3.8 bcde	196 a	156 ab	142 abcd	25.4 bc	9.4 bc
			58 kg N/ha			
PU B&I	4.0 bcd	138 cde	144 ab	138 abcd	26.1 abc	10.5 bc
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	4.2 ab	171 abcd	134 b	131 bcd	25.7 bc	9.9 bc
SCU B&I	3.6 de	171 abcd	146 ab	136 abcd	26.7 ab	12.6 ab
USG 10-12 cm DP	3.7 cde	134 de	156 ab	156 abc	27.6 a	7.3 c
			116 kg N/ha			
PU B&I	4.6 a	184 ab	174 a	167 ab	26.7 ab	9.5 bc
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	4.2 abc	154 bcd	130 b	124 cd	25.9 abc	12.0 ab
SCU B&I	3.4 e	155 bcd	140 ab	130 cd	26.4 ab	10.4 bc
USG 10-12 cm DP	4.2 ab	175 abc	157 ab	146 abcd	26.9 ab	10.2 bc

methods of N application except with 116 kg N/ha from PU applied full dose as B&I (Table 7). The yield increment due to N ranged from 0.7 to 1.9 t/ha. USG at 58 kg N/ha yielded highest, 4.2 t/ha. SCU B&I and USG DP yielded significantly more with a 29 kg N increment from 29 to 58 kg N/ha. Increased N application using PU B&I and PU B&I fb foliar spray of urea solution 5-7 DBPI did not increase yields.

SCU B&I yielded higher at 116 kg N/ha than at

Table 7. Effects of sources, rates, and methods of N application on yield and some agronomic characteristics of deep water rice IR21037-21-2E-P$_2$. IRRI, 1984 DS.

Treatment	Grain yield (t/ha)	Tillers at harvest (no./m²)	Panicles at harvest (no./m²)	100-grain wt (g)	Spikelets (no./m²)	Unfilled spikelet (%)
No fertilizer N	2.3 e	179 ef	167 d	1.99 a	27,069 c	11.9 ab
			29 kg N/ha			
PU B&I	3.0 d	229 cdef	213 bcd	2.03 a	36,015 bc	14.9 a
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	3.0 d	170 f	164 d	2.04 a	25,829 c	13.1 ab
SCU B&I	3.0 d	190 ef	184 cd	2.05 f	28,597 c	10.7 ab
USG 10-12 cm DP	3.6 c	224 cdef	214 bcd	2.05 a	35,650 bc	10.8 ab
			58 kg N/ha			
PU B&I	3.8 abc	240 bcde	234 abc	2.04 a	35,507 bc	10.1 ab
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	3.0 d	208 def	210 bcd	2.09 a	27,235 c	12.4 ab
SCU B&I	3.5 c	218 cdef	205 cd	2.09 a	34,033 bc	8.7 b
USG 10-12 cm DP	4.2 a	281 abc	269 ab	1.95 a	43,487 ab	8.3 b
			116 kg N/ha			
PU B&I	2.6 de	258 abcd	247 abc	2.00 a	37,201 bc	10.8 ab
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	3.7 bc	236 bcdef	226 abcd	2.13 a	30,052 c	12.4 ab
SCU B&I	4.1 ab	295 ab	281 a	2.05 a	48,707 a	9.2 b
USG 10-12 cm DP	3.8 abc	305 a	286 a	1.99 a	49,498 a	10.0 ab

Table 8. Effects of sources, rates, and methods of N application on yield and agronomic characteristics of IR11288-B-B69-1 at 100 cm water depth. IRRI, 1984 WS.

Treatment	Yield (t/ha)	Tillers 30 DT (no./m²)	Tillers at harvest (no./m²)	Panicles at harvest (no./m²)	Panicle length (cm)	Unfilled spikelet (%)
No fertilizer N	2.3 f	128 c	126 bc	121 b	23.1 a	10.0 a
			29 kg N/ha			
PU B&I	3.0 abcd	133 bc	146 bc	140 ab	23.6 a	15.2 a
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	2.3 def	152 bc	124 c	121 ab	23.2 a	13.3 a
SCU B&I	3.0 abcde	171 abc	157 abc	160 ab	22.4 a	10.9 a
USG 10-12 cm DP	2.0 bcdef	140 bc	140 bc	137 ab	23.6 a	12.7 a
			58 kg N/ha			
PU B&I	3.2 ab	166 abc	161 abc	162 ab	3.8 a	12.9 a
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	2.4 cdef	121 c	119 c	111 b	23.5 a	11.0 a
SCU B&I	3.0 abc	149 bc	131 bc	124 b	23.7 a	10.5 a
USG 10-12 cm DP	2.3 ef	171 abc	185 abc	175 ab	22.1 a	15.4 a
			116 kg N/ha			
PU B&I	2.6 bcdef	138 bc	159 abc	158 ab	23.1 a	10.6 a
2/3 PU B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	2.8 abcdef	172 abc	156 abc	145 ab	22.9 a	9.0 a
SCU B&I	2.7 abcdef	213 a	194 ab	175 ab	23.1 a	13.7 a
USG 10-12 cm DP	3.3 a	193 ab	216 a	197 a	22.8 a	13.2 a

58 kg N/ha. USG at 116 kg N/ha produced the most tillers, panicles, and spikelets, but lodging eliminated potential yield increase.

In WS, IR11288-B-B-69-1 yielded 2.3 t/ha without N. When N was applied, USG deep placement at 116 kg N/ha yielded highest (3.3 t/ha) (Table 8). Foliar spraying of urea following basal N gave no advantage over broadcast and incorporation at planting time.

Fertilizer did not affect panicle length and unfilled spikelets, but did increase tiller and panicle production per unit area. Tillers and panicles increased with some fertilizer treatment at crop maturity because of the line's nodal tillering ability.

INTERNATIONAL TRIALS

In 1984, 75 scientists from 20 national programs conducted 12 collaborative research trials. Four new trials began: N fertilizer efficiency in upland conditions, comparison of hand- and machine-applied N fertilizers in irrigated rice, integrated use of inorganic and organic fertilizers for lowland rice, and soil fertility management of acid upland rice soils. INSFFER received results of 93 trials from 5 collaborative trials at 76 sites in 11 countries.

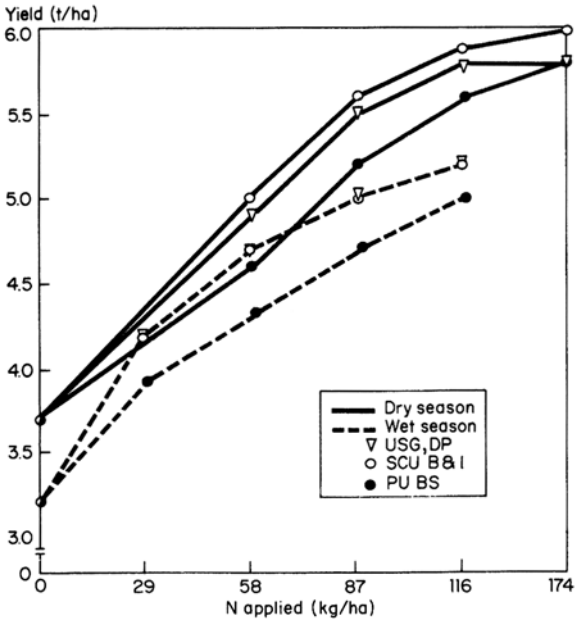
Fifth international trial on nitrogen fertilizer efficiency in irrigated rice (13 treatments). With 40 new N efficiency trials in 1984, 109 have been conducted at 67 irrigated sites in 10 countries. Average N responses of rice to SCU B&I and USG DP were similar but higher than to PU best split (BS), especially at low N in both seasons (Fig. 1). SCU and USG increased yield 35% more than PU at 58 kg N/ha during DS and 46% more than PU at 29 kg N/ha during WS. SCU and USG were more advantageous at lower N.

Regression analysis via multifertilizer response model (MRM) and fertilizer test model (FTM) showed 95 of 109 trials responded positively to N. SCU and USG were superior to PU in 36% and 40% of the trials.

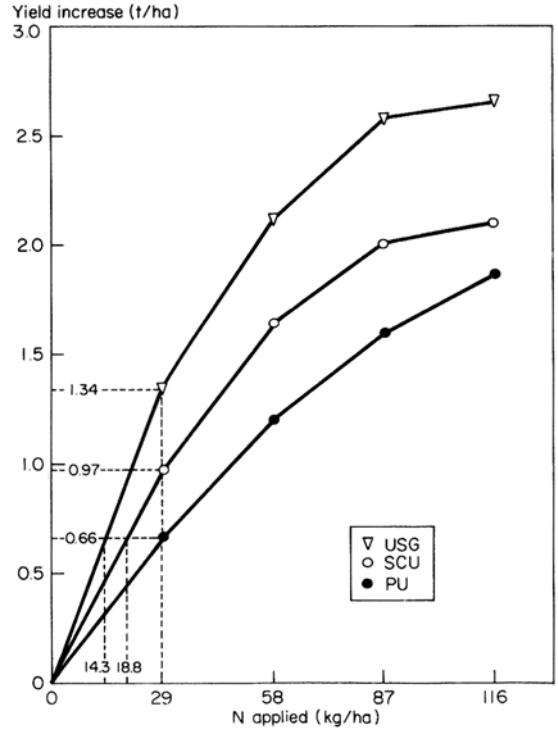
Figure 2 shows estimated yield response of rice to different urea forms and application rates in a Coimbatore trial. At 29 kg N/ha, SCU was 35% and USG 51% more input efficient than PU.

Other trials showed that at 29 kg N/ha, SCU was 18 to 89% and USG was 22 to 88% more input efficient than PU.

Fifth international trial on nitrogen fertilizer efficiency in irrigated rice (17 treatments). Trials were conducted in 1982-83 DS at 16 sites in 7 countries. Yield responses to SCU B&I, USG DP, and USG + PU DP and topdressed at 5-7 DBPI were comparable. Each was superior to PU BS (Fig. 3). Average yield increase at 58 kg N/ha was



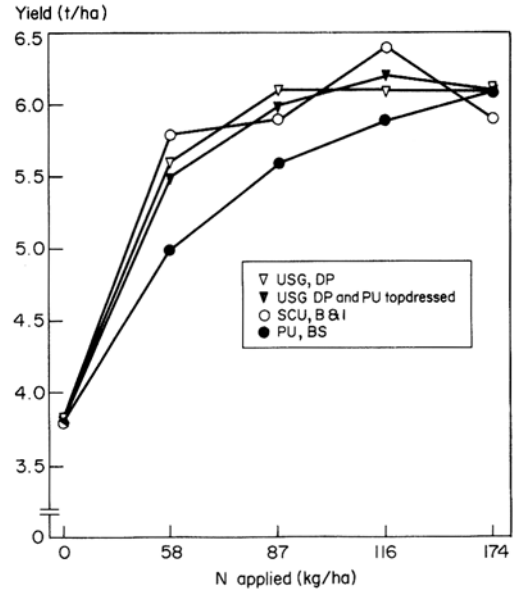
1. Av yields with urea forms and application rates. Av of 16 DS and 93 WS trials. Fifth international trial on N fertilizer efficiency in irrigated rice, INSFFER, 1984.



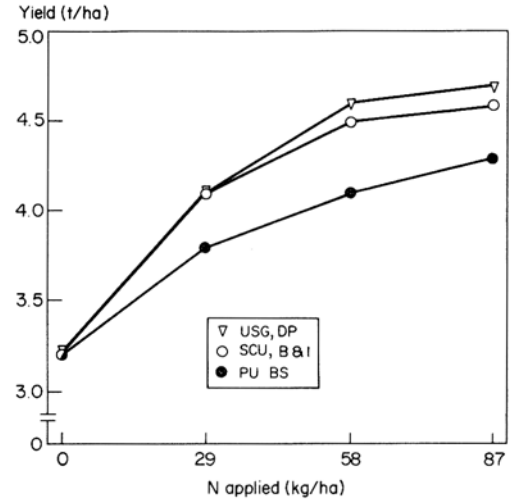
2. Estimated yield of irrigated rice with USG, SCU, and PU, using data from a trial in Coimbatore, India, 1981 WS. Fifth international trial on N fertilizer efficiency in irrigated rice, INSFFER, 1984.

32 kg rice/kg N for SCU, USG and USG + PU, 53% greater than the 21 kg rice/kg N for PU.

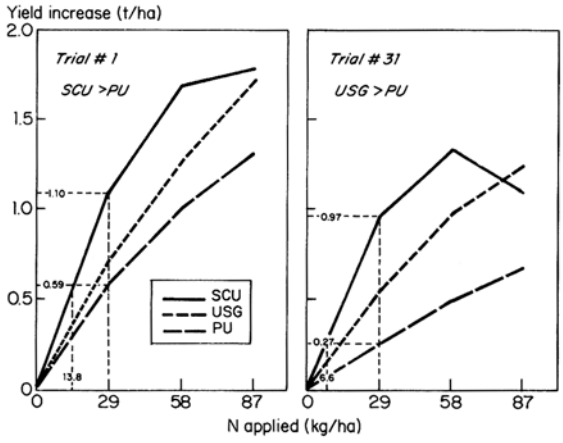
Rice responded to N in 15 of 16 trials. Compared to yields from PU, yields were 1.2-1.8 times higher from SCU, 1.2 to 1.7 from USG, and 1.3-1.8 from USG + PU, at 58 kg N/ha.



3. Av yields with urea forms and application rates in 16 DS trials. Fifth international trial on N fertilizer efficiency in irrigated rice, INSFFER, 1984.



4. Av yields with urea forms and application rates in 35 trials. Third international trial on N fertilizer efficiency in rainfed lowland rice, INSFFER, 1984.



5. Estimated yields of rainfed lowland rice with PU, SCU, and USG in Chandana, Bangladesh (trial #1), and Teresa, Philippines (trial #31). Third international trial on N fertilizer efficiency in rainfed lowland rice, INSFFER, 1984.

Third international trial on nitrogen fertilizer efficiency in rainfed lowland rice. Yields from SCU and USG in 35 trials at 21 sites in 7 countries since 1981 were similar and superior to PU (Fig. 4). At the rate of 29 kg N/ha, SCU and USG produced 31 kg rice/kg N, about 50% more than PU gave.

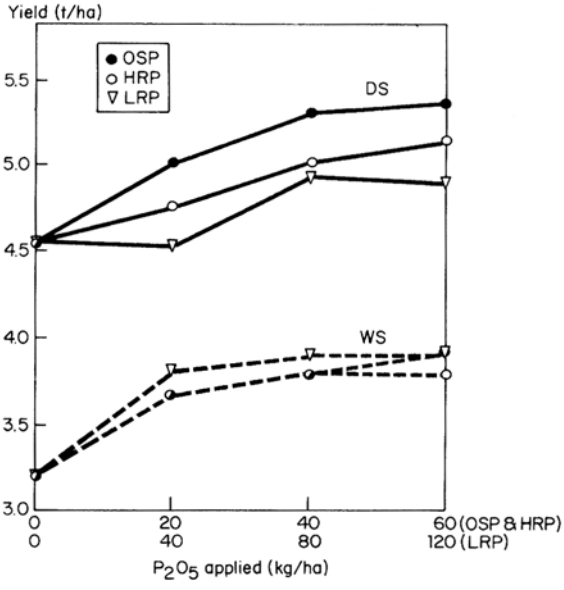
Rice responded to applied N in 33 of 35 trials. Compared to PU, output efficiencies at 29 kg N/ha were 1.1 to 2.6 times higher with SCU, and 1.2 to 3.7 times higher with USG. To generate the same yield that PU gave at 29 kg N/ha, SCU required 52% less N (trial #1) and USG 77% less (trial #31) (Fig. 5).

Sources of phosphorus in flooded rice. In the past 6 yr, 99 trials on P sources were conducted at 26 sites in 12 countries. Flooded rice response to P source was tested in 80 trials; residual effects of P after 5 seasons of application at 4 sites in 2 countries were evaluated in 19 trials.

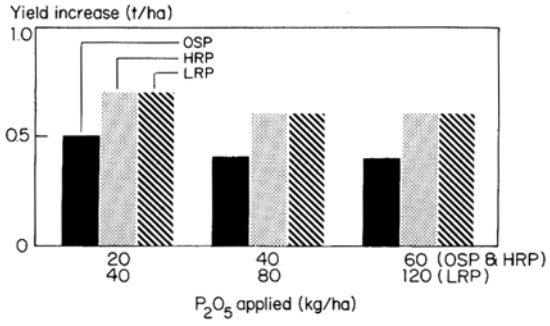
Ordinary superphosphate (OSP) elicited higher yields during DS, and similar yields in WS, compared to highly soluble rock phosphate (HRP) and less soluble rock phosphate (LRP) (Fig. 6). P produced more than 0.5 t yield increase/ha over all sources and seasons (Fig. 7). P response was higher during DS than during WS.

Yield increases from residual P were comparable to or better than those from applied P (Table 9). Residual LRP was markedly better than OSP and HRP in both seasons. LRP residual yield increases were 1.8 for DS and 0.7 t/ha for WS. Values for residual OSP were 1.5 (DS) and 0.6 t/ha (WS), while those for HRP were 1.2 (DS) and 0.6 t/ha (WS) (Table 9).

Long-term fertility trial. Responses to continuous application of N, P, and K averaged higher in DS than in WS (Fig. 8). In 72 of 100 trials since 1976, N alone produced an average yield increase of 1.4 t/ha over control in DS and 1.2 t/ha in WS (Table 10). P applied alone increased yields significantly (0.9 t/ha) in 24% of the trials, and K alone increased yields by 0.8 t/ha in 13%. Average yield increases from NPK + Zn treatment in suspected



6. Yields with P sources and application rates. Av of 28 DS and 52 WS trials. International trial on P sources in flooded rice, INSFFER, 1984.



7. Av yields with P sources and application rates in 80 trials. International trial on P sources in flooded rice, INSFFER, 1984.

Table 9. Mean yield increase over control due to applied and residual P at 2 Philippine and 2 Thailand sites. International trial on sources of P in flooded rice, INSFFER, 1984.

	Mean yield increase (t/ha)		
	OSP	HRP	LRP
Philippines			
Lucban			
P applied	0.9	0.6	.9
Residual	1.2	0.9	1.2
Teresa			
P applied	1.7	1.2	1.2
Residual	1.1	0.8	1.6
Thailand			
Klong Luang			
P applied	1.1	1.0	0.9
Residual	1.0	1.0	1.1
Rangsit			
P applied	0.8	1.0	0.9
Residual	0.7	1.0	1.3
All sites			
DS			
P applied	1.7	1.4	1.4
Residual	1.5	1.2	1.8
WS			
P applied	0.7	0.7	0.7
Residual	0.6	0.6	0.7

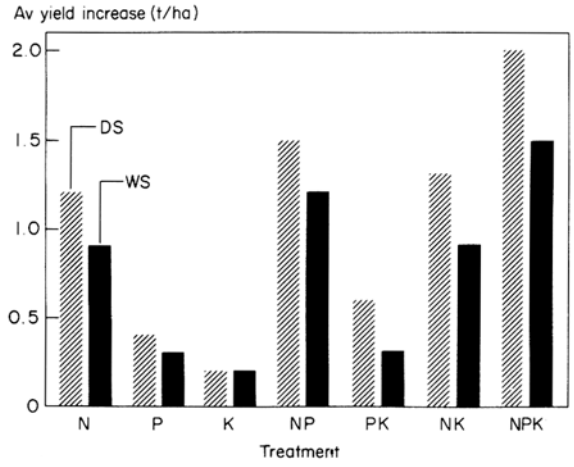
Zn-deficient sites in both seasons were lower than those from NPK alone.

In Indonesia, addition of Zn to NPK tended to depress yield during DS (Table 11). N alone remained limiting after eight croppings in Maros and five in Sukamandi.

Yield response to N was significant in 15 consecutive croppings in Luisiana, Philippines. Response to P, however, was significant only after 12 continuous croppings. Of 17 trials in Tanay, 15 gave significant yield response to N alone and 7 to P alone. NP produced higher yields than N alone in both sites (Table 12).

INSFFER TRAINING COURSE

Twenty-six participants representing 12 countries (Bangladesh, Burma, China, India, Indonesia, Malaysia, Nepal, Nigeria, Philippines, Sri Lanka, Thailand, and Vietnam) attended the sixth INSFFER course, 6 Feb to 25 May 1984. Since 1979, 132 participants from 15 countries have taken the 4-mo training.



8. Av yield increase with N, P, and K treatment in 44 DS and 56 WS trials. International long-term fertility trial, INSFFER, 1984.

Trainees carried out the following fertilizer trials at IRRI during 1984 DS:

- The fifth international trial on N fertilizer efficiency in irrigated lowland rice. Differences in IR60 grain yield were not significant among PU BS, SCU B&I, and USG DP at the same N rate, except at 58 kg N/ha where PU produced significantly higher yield (5.7 t/ha) than SCU (4.9 t/ha) and at 116 kg N/ha where SCU yielded nearly 1.0 t/ha higher than PU BS.

Table 10. Significant yield responses to N, P, and K applied individually or in combinations, averaged over number of responsive trials.[a] International long-term fertility trial, INSFFER, 1984.

Treatment	WS		DS	
	Trials (no.) responsive to the treatment	Av yield response (t/ha)	Trials (no.) responsive to the treatment	Av yield response (t/ha)
N	39 (56)	1.2	33 (44)	1.4
P	15 (55)	0.8	9 (44)	1.0
K	9 (55)	0.8	4 (44)	0.8
NP	17 (45)	1.4	36 (44)	1.8
PK	18 (54)	0.9	19 (44)	0.9
NK	40 (55)	1.2	33 (44)	1.6
NPK	48 (55)	1.6	41 (44)	2.0
NPK + Zn[b]	9 (15)	1.4	5 (12)	1.9

[a] Numbers in parentheses represent the total trials in each treatment. [b] Additional treatment tested in suspected Zn-deficient sites.

- Comparison of hand- and machine-applied PU and USG in lowland rice IR60 under good water control. At 58 kg N/ha, PU applied by machine and USG deep placed by hand produced significantly higher yields (6.5 t/ha) than the farmers' method (1/2 N at 15 DT + 1/2 N at 5-7 d after panicle initiation) and researchers' split application (2/3 basal + 1/3 at 5-7 DBPI) of PU. At 87 kg N/ha, yield differences were not significant among the methods of applying PU and USG; however, machine-applied PU produced significantly higher yield (6.8 t/ha) than the farmers' method (6.1 t/ha).
- The first international trial on integrated use of inorganic and organic N fertilizers in lowland rice under good water control. Averaged over 2 N rates (58 and 87 kg/ha), PU plus fresh azolla or rice straw (basal incorporated, equivalent to 29 kg N/ha) produced yields comparable to those with PU BS (5.2 t/ha). PU plus azolla produced significantly higher yield (5.4 t/ha) than PU plus straw (4.8 t/ha). On the other hand, USG plus azolla produced yield comparable to that of USG alone (5.6 t/ha). USG plus straw gave significantly lower yield (5.0 t/ha) than USG alone.
- Azolla INSFFER trial. Plots treated with azolla (applied either as the only source of N or in combination with 30 kg N/ha as urea) produced yields comparable to the 4.5 t/ha of plots with 60 kg N/ha as urea.

Table 11. Mean yield responses to N, P, and K individually or in combinations, by site and season in Indonesia. International long-term fertility trial in rice, INSFFER, 1984.

Treatment	Mean yield response[a] (t/ha)					
	Lanrang		Maros		Sukamandi	
	DS (5)	WS (5)	DS (5)	WS (3)	DS (3)	WS (2)
N	0.8	0.4	1.8	0.9	1.3	1.0
P	1.0	0.1	0.6	0.2	0.3	0.3
K	0.3	0.3	0.3	0.0	0.0	−0.3
NP	1.3	1.0	1.9	0.7	1.9	1.6
PK	0.3	0.1	0.3	0.0	0.4	0.1
NK	0.8	0.3	2.0	0.9	1.8	1.7
NPK	1.5	1.1	1.9	1.2	2.2	2.7
NPK + Zn	−0.1[b]	1.1[b]	1.9	1.0	–	–

[a] Figures in parentheses denote number of trials. [b] Av of 3 trials only.

Table 12. Mean yield response to N, P, and K individually or in combinations, by site and season in the Philippines. International long-term fertility trial in rice, INSFFER, 1984.

Treatment	Mean yield response[a] (t/ha)			
	Luisiana		Tanay	
	DS (9)	WS (10)	DS (7)	WS (10)
N	1.3	1.0	1.5	1.1
P	0.3	0.2	0.2	0.5
K	0.1	0.0	−0.2	0.1
NP	2.2	1.2	1.8	1.5
PK	0.5	0.2	0.2	0.4
NK	1.5	0.7	1.7	1.1
NPK	2.9	1.6	2.2	1.6

[a] Figures in parentheses denote number of trials.

SITE CHARACTERIZATION

The sixth INSFFER site visit was held in the Philippines jointly with the Soil Management Support Services (SMSS) and the Bureau of Soils of the Ministry of Agriculture and Food of the Philippines. Eighty-three participants representing 21 countries joined the tour and workshop. The group consisted of pedologists, soil chemists, soil fertility specialists, and agronomists.

Sixteen INSFFER sites in seven provinces were characterized by the group according to various classification systems. According to Soil Taxonomy, the soils in these sites represented the orders Vertisol, Mollisol, Inceptisol, and Entisol.

The group agreed that the most appropriate system to relate fertilizer results to site characterization was the Fertility Capability Classification (FCC).

Soil and crop management

Rice crop cultural practices

Agronomy and Plant Physiology Departments

CONTINUOUS CROPPING **316**
1, 2, 3 CROPS PER YEAR EXPERIMENT **316**
PLANT GROWTH REGULATOR STUDIES **316**
Effect of plant growth stimulants **316**
Effect of a plant growth retardant **317**
Seedling age **317**
Cultivar **318**
SPACING AND SEEDLING RATE WITHOUT N **318**

CONTINUOUS CROPPING

Agronomy Department

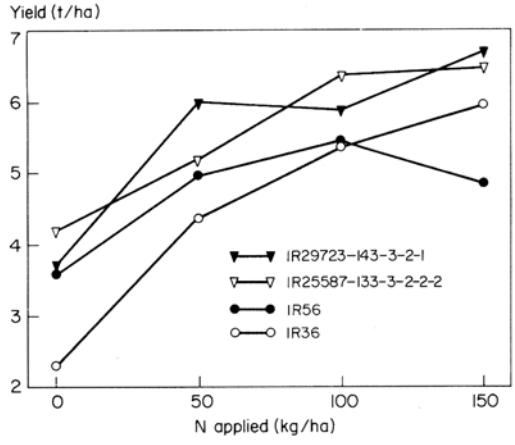
The continuous cropping experiment continued to compare transplant and broadcast crop establishment of six rices at four N rates. In both dry (DS) and wet (WS) seasons, IR8 was destroyed by tungro (RTV) and hopperburn. Rats damaged early maturing IR58.

In DS, transplanted rice (TPR) yielded higher than broadcast rice (BR). In WS, yield differences between the two were slight (Table 1). Without added N, a promising genetic line, IR29723-143-3-2-1, gave 3.7 t/ha. The same line yielded 6.7 t/ha at high N rate in DS (Fig. 1), and 4.9 t/ha in WS (Fig. 2). Without N application, IR25587-133-3-2-2-2 and IR29723-143-3-2-1 yielded 3.7 t/ha in WS (Fig. 2).

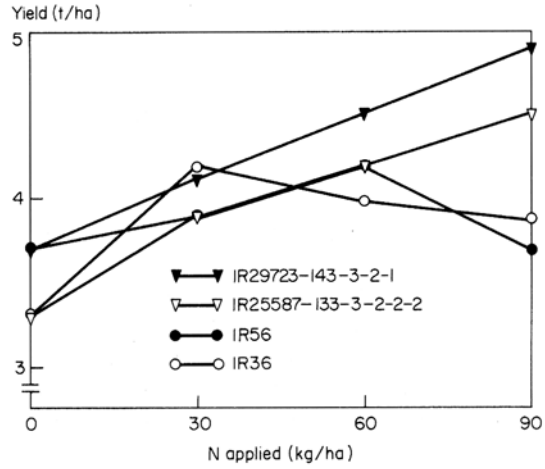
Table 1. Av yields of TPR and BR at 4 N rates. Continuous cropping experiment, IRRI, 1984.

Fertilizer rate[a] (kg N/ha)		Yield[b] (t/ha)			
		DS (crop 64)		WS (crop 65)	
DS	WS	TPR	BR	TPR	BR
0	0	3.4	2.9	3.5	3.2
50	30	5.1	4.2	4.0	3.7
100	60	5.9	5.1	4.2	4.0
150	90	6.0	5.2	4.2	4.0

[a] All treatments except 0 kg N/ha included application of 2/3 N basal incorporated and 1/3 N topdressed 5-7 d before panicle initiation (DBPI). 50 kg K and 26 kg P were applied basally and incorporated. [b] Yields of IR8 and TPR IR58 were not included.



1. Av yields of TPR at 4 N rates. Continuous cropping experiment, IRRI, 1984 DS.



2. Av yields of TPR at 4 N rates. Continuous cropping experiment, IRRI, 1984 WS.

1,2,3 CROPS PER YEAR EXPERIMENT

Agronomy Department

The experiment to test long-term effects of cropping frequency continued, using traditional variety Binato and three modern rices.

Over 15 yr, TPR averaged 4.2 t/ha and BR, 3.8. Yields of TPR Binato averaged less than those of modern rices (Table 2), mainly because of lodging.

Total yield of a cropping pattern of 3 crops/yr was 14.4 t/ha (Table 2). High yields were recorded during DS. Yields of the early and late WS plantings were similar (Fig. 3).

PLANT GROWTH REGULATOR STUDIES

Agronomy Department

Experiments during 1984 DS and WS studied the effects of synthetic plant growth regulators on grain yield and yield components of TPR.

Effect of plant growth stimulants. Seeds of IR42, IR58, and IR29723-143-3-2-1 were soaked for 48 h separately in 50 ppm solutions of benzyl adenine (BA), gibberellic acid (GA_3), kinetin, and distilled water (as check). Then they were germinated, raised in wetbeds, and transplanted as 20-d-old seedlings.

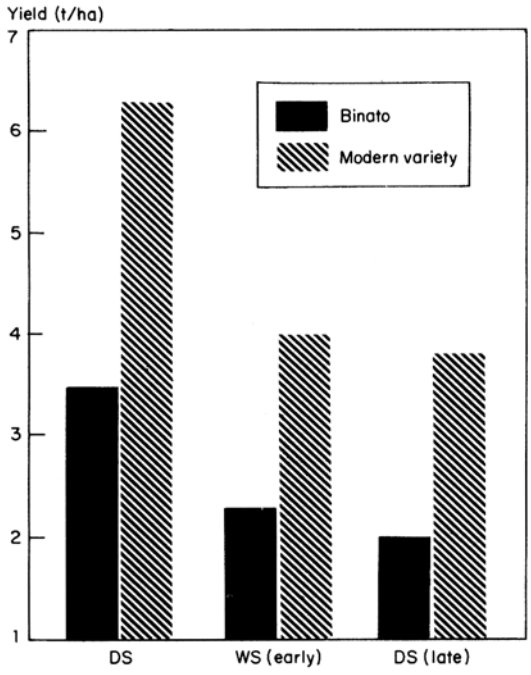
In DS, grain yield and most yield components of all cultivars did not respond to the treatments. Only

Table 2. Yield per year of transplanted traditional variety Binato and modern rices. 1, 2, 3 crops per year experiment, IRRI, 1970-84.

Crops (no./yr)	Yield (t/ha)	
	Binato	Modern
1	2.1	3.8
2	5.6	10.8
3	7.9	14.4

the BA treatment resulted in a significant increase in IR58 tiller number over other treatments and markedly longer panicles and higher grain-straw ratio than the GA_3 and check treatments.

In WS, RTV eliminated IR42 from the experiment. Growth regulators greatly affected some yield components of IR58 and IR29723-143-3-2-1, but not their grain yields. Grain-straw ratio of IR58 was significantly higher in the BA than in the GA_3 treatments. GA_3 significantly increased spikelet number of IR29723-143-3-2-1, but spikelet sterility was high. Plants treated with BA had significantly more sterile spikelets than did untreated plants.



3. Av yield of traditional variety Binato and modern rices (av of 3 rices). 1,2,3 crops per year experiment, IRRI, 1970-84.

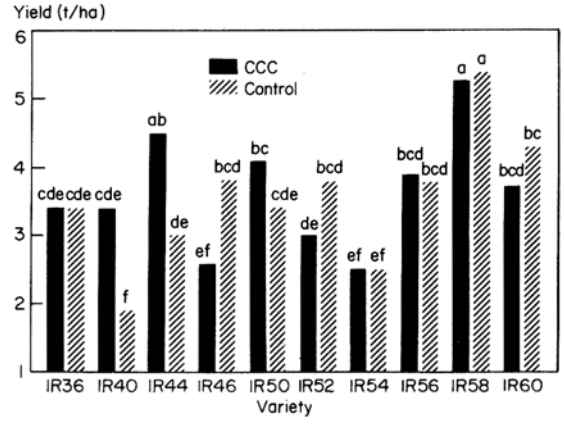
Effect of a plant growth retardant. The effect of the growth retardant CCC (2-chloro-ethyl-trimethyl ammonium chloride) on grain yield was examined in three experiments.

Seedling age. IR42, IR58, and IR29723-143-3-2-1 were raised in a wetbed nursery and transplanted at 20, 30, 40, and 50 d old. CCC was applied on seedlings 5-7 d after seeding (DAS) at 1.5 kg ai/ha in DS and 3.0 kg ai/ha in WS. In WS, IR42 was not planted because of RTV.

In DS, the CCC treatment did not affect yield and yield components of any cultivars regardless of seedling age; however, it affected the grain-straw ratio of IR42, panicle number of IR58, and 100-grain weight of IR29723-143-3-2-1 all in the 50-d-old planting. With CCC treatment, the grain-straw ratio of IR42 and the panicle number of IR58 were significantly higher than the untreated. However, the CCC-treated IR29723-143-3-2-1 gave significantly lighter grains than the untreated.

In WS, the grain yield and yield components of IR58 were affected only by seedling age, but not by CCC treatment.

Yields of IR29723-143-3-2-1 in WS were greatly affected by CCC treatment and seedling age. The untreated 30- and 50-d-old plants yielded significantly more than treated counterparts. Yields of the treated plants also decreased markedly when planted beyond 20 d. On the other hand, untreated plants yielded markedly less only when planted at 50 d. Generally, yield components of IR29723-143-3-2-1 were not affected by CCC or by seedling age.



4. Yields of IR varieties with plant growth retardant CCC sprayed to seedlings at 2-to 3-leaf stage. IRRI, 1984 late DS.

Cultivar. Ten cultivars were tested for response to CCC when transplanted 30 DAS.

In DS, CCC significantly increased grain yields of IR40 and IR44, but markedly decreased IR46 yield (Fig. 4). Other cultivars did not respond to CCC application.

In WS, CCC did not affect yields.

SPACING AND SEEDLING RATE WITHOUT N

Plant Physiology Department

When no or little fertilizer is available, cultural practices may be altered to maximize yields. Yields will be low but still may be economical.

Ways to increase yields include straw incorporation, keeping the field flooded before transplanting to improve nutrient status, deep plowing, use of green manure, and use of longer-growth-duration varieties.

This research studied seedling number and spacing to use when no N is added on a high yielding, long-duration modern variety. During DS, the highest yield of IR42 at no N added was 3.82 t/ha when planted close (20 × 15 cm) and at 8 seedlings/hill.

Both close spacing and more seedlings per hill improved grain yields by increasing leaf area index at flowering and panicle number per square meter.

Soil and crop management

Tillage and management of soil physical conditions

Agronomy, Soil Chemistry/ Physics, and Agricultural Engineering Departments

CORE SAMPLER FOR PUDDLED SOILS **320**
PERCOLATION RATES IN LOWLAND RICE **320**
Greenhouse experiment **320**
Field experiment **320**
MAIZE AND MUNGBEAN RESPONSE TO TILLAGE AFTER LOWLAND RICE WITH SHALLOW WATER TABLE **322**
TEMPERATURE PROFILE OF A LOWLAND RICE SOIL **323**
RESTRUCTURING OF PUDDLED SOIL FOR RAINFED MUNGBEAN **323**

CORE SAMPLER FOR PUDDLED SOILS

Agronomy Department

A core sampler was designed to collect undisturbed samples of known volume from 0- to 10-cm depth in soft, puddled rice soils under a maximum floodwater depth of 8 cm (Fig. 1). The instrument is simple, inexpensive, and easy to use. It operates in <2 min/sample.



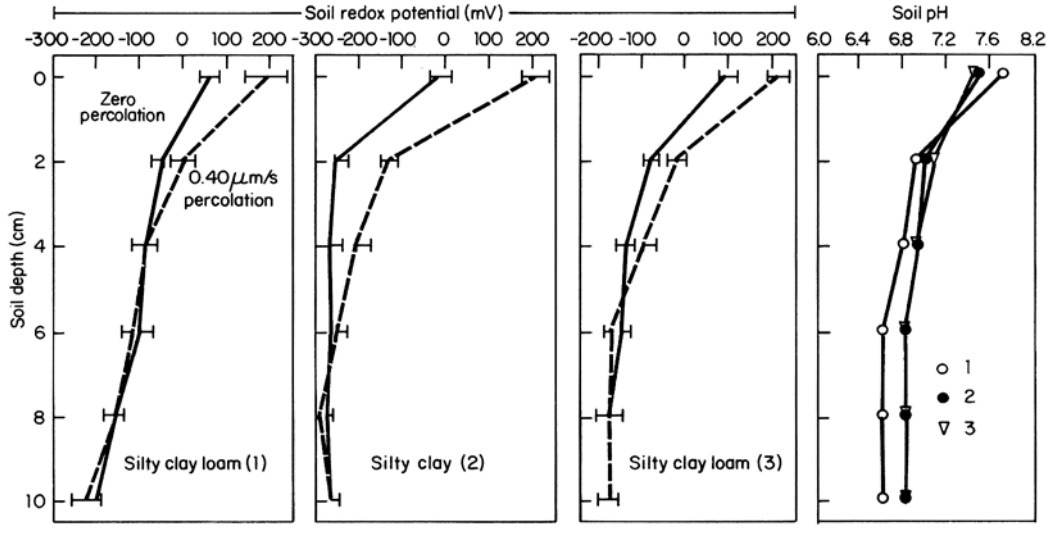
1. Core-sampler for puddled soil. IRRI, 1984.

PERCOLATION RATES IN LOWLAND RICE

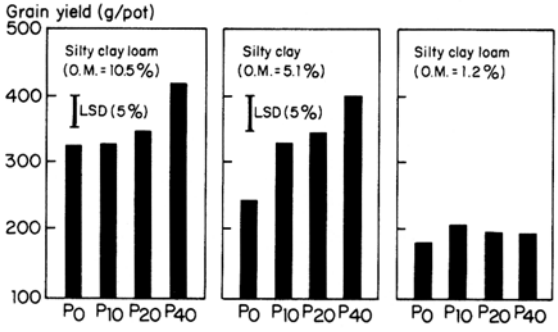
Agronomy Department

Greenhouse experiment. Two silty clay loams and one silty clay were used in a greenhouse experiment on percolation rates (PR). PR 0, 10, 20, 40 mm/d were regulated with hosecock clamps and hypodermic needles. Highest PR (40 mm/d) increased soil redox potential in the top 2-cm depth, but did not affect soil pH (Fig. 2). Soil redox potential and pH decreased with soil depth. Average soil temperature at 1430 h at 10-cm depth of silty clay soil for the whole crop season was 27.5 ± 1.4 and 28.0 ± 1.4° C in 40 mm/d in percolated and nonpercolated soil, against 30.0 ± 2.8° C air temperature. Grain yields with all PR were similar in silty clay loam soil having 1.2% organic matter (O.M.), but increased significantly with increasing PR in 2 other soils having 5.1 and 10.5% O.M. (Fig. 3). The higher grain yields were attributed to higher tillering, more number of panicles/hill, panicle length, and panicle weight in soils with higher PR.

Field experiment. In the field study in a clay loam soil at IRRI, PR were modified either by placing polyethylene sheets at 40-cm depth or by puddling.



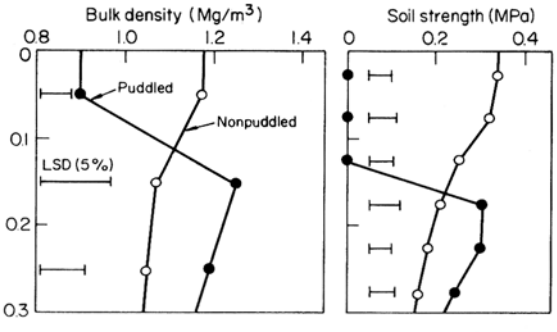
2. Effect of percolation on soil redox potential and soil pH. IRRI, 1983.



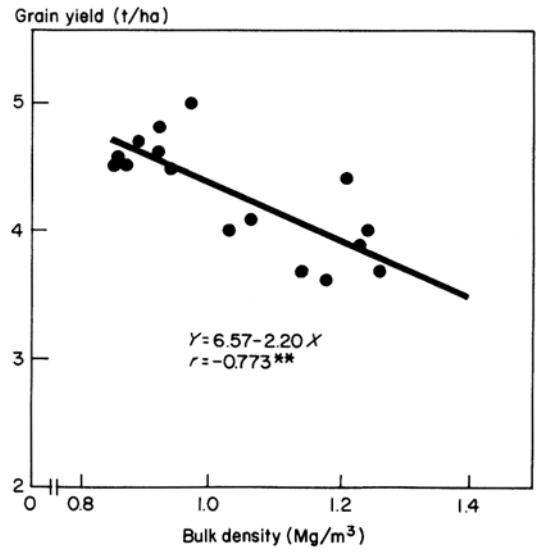
3. Effect of different PR on IR36 yield in soils varying in O.M. content. P_0 = no percolation, P_{10} = 10 mm percolation/d, P_{20} = 20 mm/d, and P_{40} = 40 mm/d.

Two 18-d-old seedlings/hill were transplanted. Effects on soil physical properties, grain yield, and yield components were recorded.

Bulk density of puddled soil in the top 10-cm layer was 23% lower than that of nonpuddled soil (Fig. 4). But at 10-20 cm and 20-30 cm, bulk density of puddled soil was significantly higher than that of



4. Effect of puddling on bulk density and penetration resistance of a clay loam soil. IRRI, 1984 WS.



5. Relationship between grain yield of IR36 and bulk density of 0-10 cm clay loam soil. IRRI, 1984 WS.

nonpuddled soil by 17% and 13%, respectively. Soil resistance to mechanical penetration in the top 15-cm depth was zero in puddled plots and 0.35 MPa in nonpuddled (Fig. 4). But below 15 cm, soil strength in puddled plots was significantly higher than in nonpuddled plots. Average PR for different treatments are shown in Table 1.

The crop stand in nonpuddled soil was poor because of higher soil bulk density and higher soil strength at transplanting time. This significantly reduced plant height and grain yield (Table 1). The relationship between grain yield and bulk density of 0-10 cm soil is shown in Figure 5. Grain yield was significantly higher in puddled than in nonpuddled soil because of more panicles/m^2 and higher panicle weight. In nonpuddled soil, crop maturity was

Table 1. Effect of puddling and PR on grain yield and yield components of IR36. IRRI, 1984.

Treatment[a]	PR (mm/d)	Grain yield (t/ha)	Plant ht (cm)	Panicles (no./m^2)	Panicle wt (g)	100-grain wt (g)
T1	1903	3.7	70	360	1.5	2.15
T2	627	4.0	74	343	1.6	2.34
T3	1.9	4.8	86	425	1.9	2.31
T4	1.2	4.6	80	450	2.1	2.27
LSD (5%)	474	0.5	7	63	0.3	0.05

[a]T1 = nonpuddled without polyethylene sheet at 40 cm depth, T2 = nonpuddled with polyethylene sheet at 40 cm depth, T3 = puddled without polyethylene sheet at 40 cm depth, and T4 = puddled with polyethylene sheet at 40 cm depth.

delayed by 8 d. Higher PR increased water losses and significantly decreased 100-grain weight and grain yields.

MAIZE AND MUNGBEAN RESPONSE TO TILLAGE AFTER LOWLAND RICE WITH SHALLOW WATER TABLE

Agronomy Department

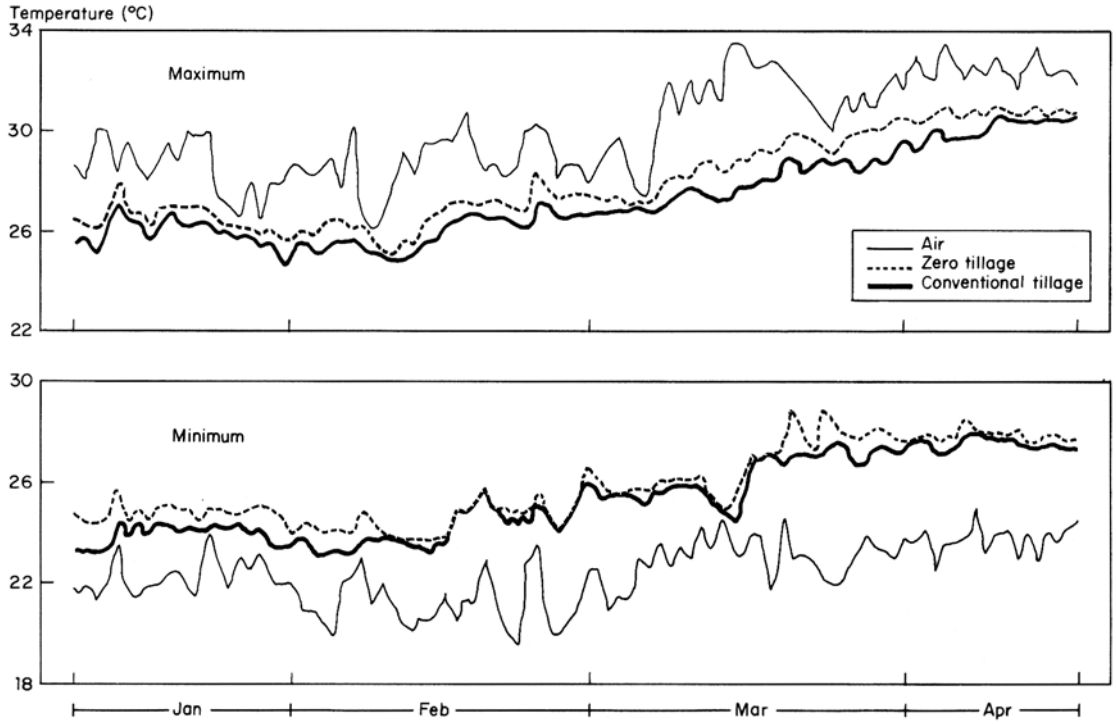
After lowland rice in 1983 wet season (WS), maize and mungbean were planted in 1984 dry season (DS) at IRRI to investigate reduction of turnaround time. Minimum tillage (two 7- to 10-cm-deep rototillings) was evaluated against zero tillage and conventional tillage (one 13- to 15-cm-deep moldboard plowing followed by two 7- to 10-cm-deep rototillings) in a Tropaquept soil with a water table fluctuating between 9 and 30 cm depth throughout the crop season. Soil physical properties, and their effects on root and shoot-growth and grain yields of maize and mungbean were studied.

Table 2. Tillage effects on bulk density and aeration porosity at field moisture content of 0-10 cm soil 4 wk after planting. IRRI, 1984.

Treatment	Maize		Mungbean	
	Bulk density (t/m^3)	Aeration porosity (%)	Bulk density (t/m^3)	Aeration porosity (%)
Zero tillage	1.01	6.0	1.00	8.0
Minimum tillage	0.92	17.2	0.91	20.7
Conventional tillage	0.91	18.3	0.90	19.0
LSD (5%)	0.03	6.6	0.06	7.2

Turnaround time was 2 d with minimum tillage, 1 d with zero tillage, and 4 d with conventional tillage. Moisture content at sowing time was 0.56 kg/kg in zero tillage plots, 0.51 kg/kg in minimum tillage, and 0.50 kg/kg in conventionally tilled.

Due to poor seed-soil contact in tilled plots, seedling emergence of maize was significantly lower in minimum tilled (76%) and conventionally tilled plots (74%) than in zero tilled plots (90%). Tilled plots were reseeded to maintain similar plant



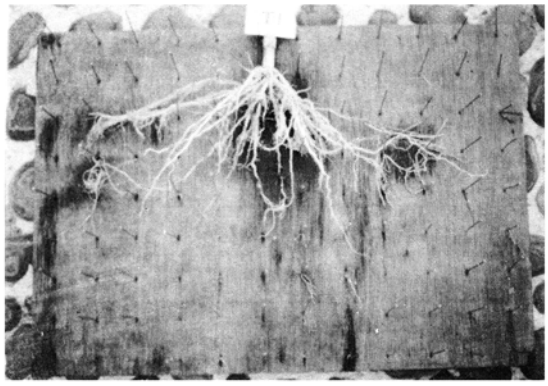
6. Daily maximum and minimum temperatures in air and in soil at 10-cm depth under zero and conventional tillage treatments. IRRI, 1984 DS.

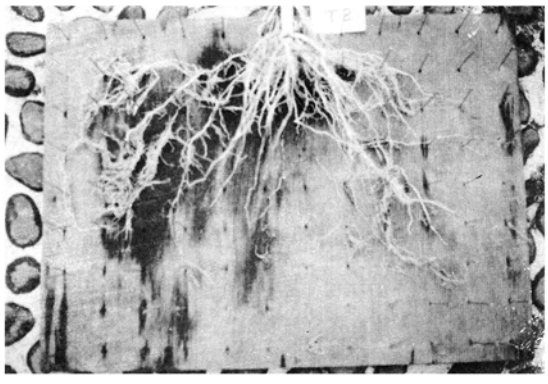
populations in all treatments. Mungbean emergence was >90% in all tillage treatments.

Tillage did not affect soil strength and water potential at 15-cm depth. Soil strength increased progressively with depth from 0.2 MPa at surface to 4.0 MPa at 60 cm. Water potential at 15-cm depth was always below −70 mbar. Reduction in bulk density, increase in aeration porosity (Table 2),

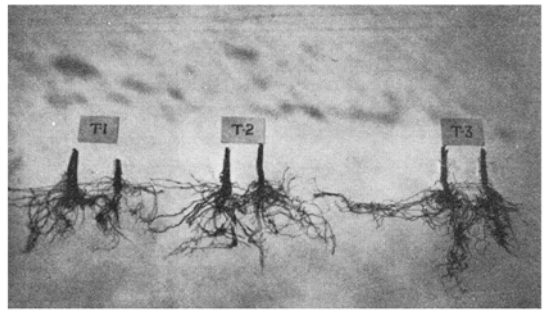
Table 3. Tillage effects on weed growth in maize and mungbean. IRRI, 1984.

Treatment	Weed growth (t/ha) in	
	Maize	Mungbean
Zero tillage	2.6	2.2
Minimum tillage	0.2	0.2
Conventional tillage	0.3	0.3
LSD (1%)	0.7	0.7





7. Root distribution of maize grown after lowland rice with zero (T1) and minimum tillage (T2) under shallow water table (13-27 cm) condition. IRRI, 1984 DS.



8. Root distribution of mungbean grown after lowland rice with zero (T1), minimum (T2), and conventional tillage (T3) under shallow water table (13-27 cm) condition. IRRI, 1984 DS.

reduction in maximum soil temperature at 10-cm depth (Fig. 6), and reduction in weed growth (Table 3) due to tillage favored root growth (Fig. 7, 8), shoot growth and grain yields of maize and mungbean (Table 4). However, harvest index (Table 4) and NPK concentrations of grains and straw of both crops remained unaffected by tillage method (Table 5, 6). Nevertheless, due to higher dry matter production, nutrient uptake per hectare was significantly higher in tilled plots.

TEMPERATURE PROFILE OF A LOWLAND RICE SOIL

Agronomy Department

Puddling decreased thermal conductivity of an IRRI clay loam soil from 2.45×10^{-3} to 2.12×10^{-3} Cal/cm per s °C, increased volumetric heat capacity from 0.78 to 0.83 Cal/cm^3 °C, and decreased thermal diffusivity from 3.14 to 2.56 cm^2/s. Consequently, damping depth decreased from 9.3 to 8.4 cm, and maximum soil temperature and diurnal temperature amplitude to 15-cm depth (Fig. 9). The time-lag between maximum temperature at surface and at depths of 5, 10, 15, 20, 25, and 30 cm was 4, 6, 7, 10, 10, and 11 h, respectively.

RESTRUCTURING OF PUDDLED SOIL FOR RAINFED MUNGBEAN

Soil Chemistry/ Physics and Agricultural Engineering Departments

The Annual Report for 1983 showed how disruption of the compacted layer by strip tillage helped maize roots grow deeper and more profusely in a

Table 4. Effect of tillage on grain yield and yield components of maize and mungbean. IRRI, 1984.

Treatment	Maize					Mungbean			
	Grain yield (t/ha)	Stalk yield (t/ha)	Ears (thousand/ha)	Plant ht (cm)	Harvest index	Grain yield (t/ha)	Straw yield (t/ha)	Plant ht (cm)	Harvest index
Zero tillage	0.6	0.8	38	132	0.29	0.4	0.5	43	0.47
Minimum tillage	2.0	3.3	52	185	0.30	0.7	1.0	53	0.41
Conventional tillage	2.1	3.3	53	189	0.31	0.8	1.0	56	0.44
LSD (1%)	0.8	1.1	14	25	ns	0.2	0.4	0.10	ns

ns = nonsignificant.

Table 5. Effect of tillage on the nutrient uptake of maize. IRRI, 1984.

Treatment[a]	Grain						Stalk					
	N		P		K		N		P		K	
	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha
Z	1.5	9	0.36	2	0.40	2	0.49	4	0.33	3	1.8	14
M	1.5	30	0.35	6	0.36	7	0.53	18	0.28	9	1.6	52
C	1.4	30	0.34	7	0.36	8	0.59	20	0.35	12	1.7	54
LSD	ns	11**	ns	3**	ns	3**	ns	12**	ns	6	ns	23**

[a]Z = zero tillage, M = minimum tillage, C = conventional tillage.

Table 6. Effect of tillage on the nutrient uptake of mungbean. IRRI, 1984.

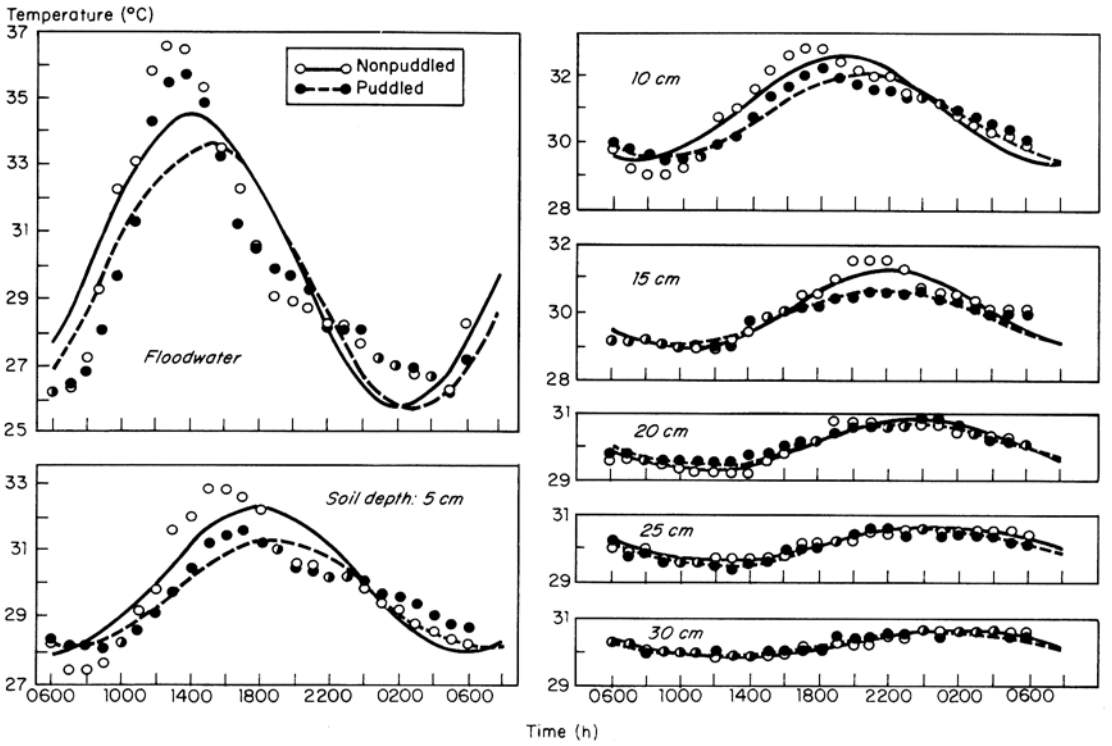
Treatment[a]	Grain						Stalk					
	N		P		K		N		P		K	
	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha
Z	4.5	18	0.52	2	1.4	5	2.3	11	0.31	1	2.9	13
M	4.3	29	0.52	4	1.4	10	2.3	24	0.31	3	3.0	29
C	4.4	34	0.53	4	1.4	11	2.6	26	0.32	3	3.0	30
LSD (1%)	ns	10	ns	1	ns	4	ns	12	ns	1	ns	13

[a]Z = zero tillage, M = minimum tillage, C = conventional tillage.

previously puddled lowland rice soil. However, the strip tillage tine produced a cloddy tilth that reduced plant emergence. Rolling the tilled strips alleviated this problem. Also reported were problems of shallow water tables from working alongside a flooded field.

In 1984 DS, with mungbean as test crop, two forms of strip tillage were evaluated on a site adjacent to the 1983 maize experiment. The water table was maintained below 1.4-m depth by drains of 25-cm diameter installed at 2-m depth between the experiment's dry plot and the adjacent irrigated plot. As in 1983, the soil was Typic Tropaquept, but layers below 20 cm had less organic C and were somewhat less dense (Table 7), with less clay below 30 cm and correspondingly more sand.

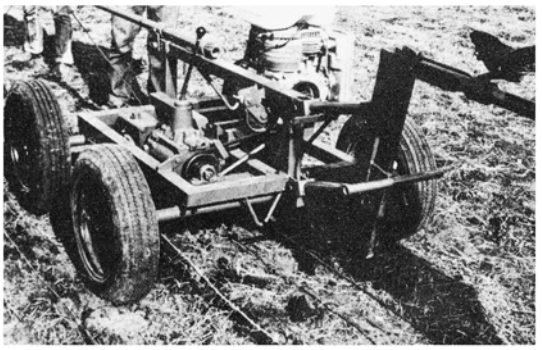
One strip tillage system comprised a prototype winch/cable system, powered by a 6 kW (8 hp) engine, pulling a single narrow tine (Fig. 10). This system achieved adequate traction at high topsoil moisture; it exerted a draft force of 6 kN on the tine, and strip cultivated to 35-cm depth, though slowly.



9. Effect of puddling on temperature profile of a clay loam soil. IRRI, 1984 WS.

Table 7. Soil physical properties on Field F13 at IRRI, 1984 DS.

Depth (cm)	Organic C (%)	Bulk density (t/m^3)	Clay (%)	Silt (%)	Sand (%)	Texture
0-10	1.38	0.95	38	42	20	Silty clay loam
10-20	0.93	1.00	37	37	26	Clay loam
20-30	0.58	0.91	38	33	29	Clay loam
30-40	0.49	0.86	35	30	35	Clay loam
40-50	0.41	0.85	33	29	38	Clay loam



10. Winch/cable device with narrow tine for strip tillage. IRRI, 1984.

The other equipment — a 4-wheel-drive 22 kW (30 hp) tractor with a wider, thicker tine — disturbed the soil as deeply, but produced cloddier tilth. These systems were compared to each other and to conventional tillage (moldboard plowing to 9-cm depth followed by 2 harrowings) in terms of soil physical and plant variables.

The effects of the cultivations on dry bulk density and on total porosity are shown in Table 8. Each of the strip tillage procedures decreased bulk density by an average of 0.07 ± 0.04 t/m^3 over the 0-30 cm layer; for total porosity, which even in undisturbed soil attained the high value of 0.61, there were

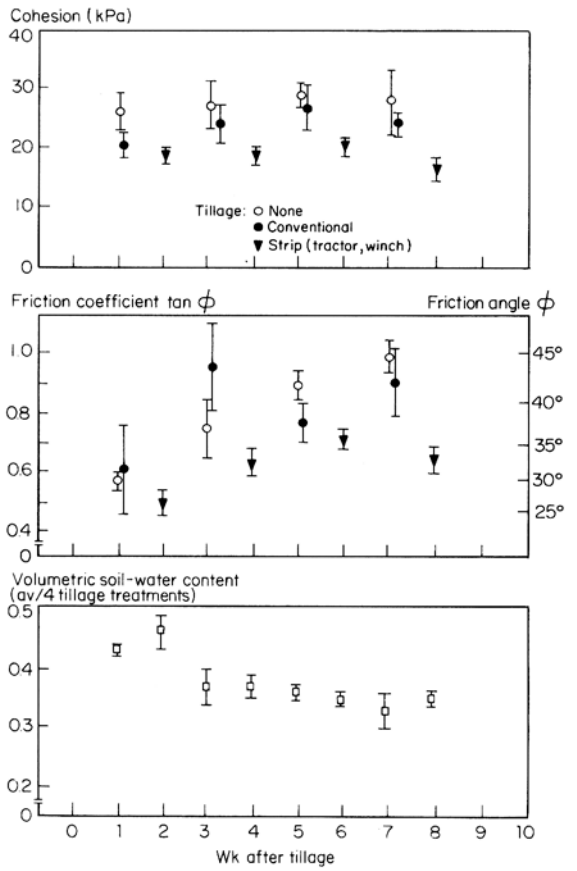
Table 8. Effect of cultivation method on dry bulk density ρ/t per m^3 and on fractional total porosity ϵ at various depths in a clay loam soil at IRRI, 1984 DS.[a]

Depth (cm)	Uncultivated soil		Plowed and harrowed		Strip-tilled by four-wheel-drive tractor		Strip-tilled by cable/winch	
	ρ	ϵ	ρ	ϵ	ρ	ϵ	ρ	ϵ
0-10	0.95	0.61	0.94	0.62	0.88	0.64	0.90	0.63
10-20	1.00	0.59	0.96	0.61	0.92	0.63	0.92	0.63
20-30	0.91	0.63	0.91	0.63	0.86	0.65	0.83	0.66
30-40	0.86	0.65	0.84	0.66	0.83	0.66	0.83	0.66
40-50	0.85	0.65	0.82	0.67	0.83	0.66	0.83	0.66

[a]Means of 4 replications at each of 4 sampling dates, and assuming 2.45 t/m^3 particle density.

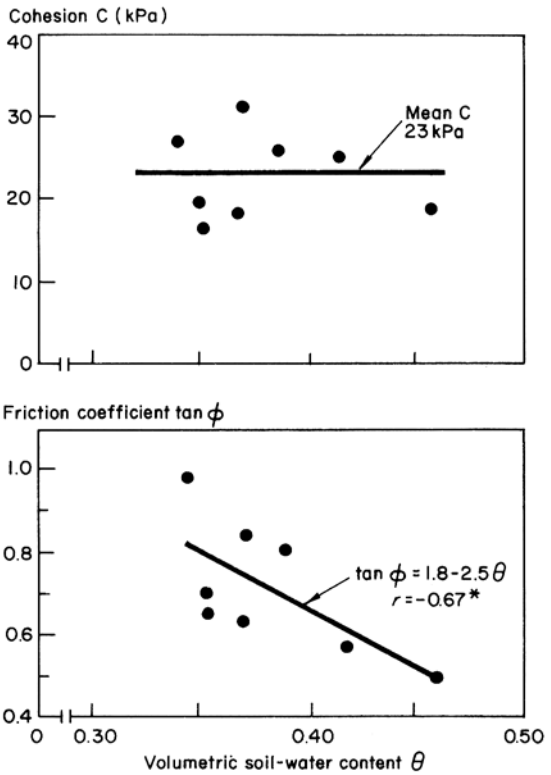
corresponding increases of 0.03 ± 0.02. Conventional tillage had less effects, probably because the harrowing repacked surface soil that plowing loosened.

Soil shear strength and frictional properties also were changed by soil disturbance and restructuring.



11. Cohesion, friction coefficient, and volumetric soil-water content for the 0-20 cm layer in field F13, IRRI, 1984 DS. (For unconfined soil and normal stresses of 0-50 kPa)

Figure 11 shows for the 0-20 cm layer the Mohr-Coulomb parameters of cohesion and internal friction angle, and the volumetric soil-water content, plotted against weeks since tillage. Compared to untilled soil, conventional tillage and both kinds of strip tillage reduced cohesion and friction coefficient — a consequence of the physical separation of the soil aggregates. The influence of water



12. Relation of cohesion and of friction coefficient to volumetric soil-water content for the 0-20 cm layer in Field F13, IRRI, 1984 DS. Av over 4 tillage treatments for unconfined soil and normal stresses of 0-50 kPa.

content on cohesion and friction coefficient is seen in Figure 12. Over the sampled moisture range, and within the precision of the measurements, cohesion was essentially constant, at 23 kPa. Friction coefficient was high, implying a complex soil geometry, and declined as water content increased — as would occur if the water acted as a lubricant between the soil aggregates.

For both strip tillage treatments, spacing between tilled strips, and hence between rows of plants, was 0.4 m, as it was also between rows on the conventionally tilled plots. Seeds were precision-planted by hand at 25/m of row. Plot size was 11.0 × 5.6 m. The six replications for each treatment were arranged as two Latin squares. Turnaround time (time interval between field-draining and seed-planting) ranged from 3 to 7 d, and increased regularly along the field, averaging 4 d for the first Latin square and 6 d for the second. The field had only one access, and cultivation and manual seeding could progress only toward that access point without damaging soil structures. This progression in turnaround time caused problems in interpreting results.

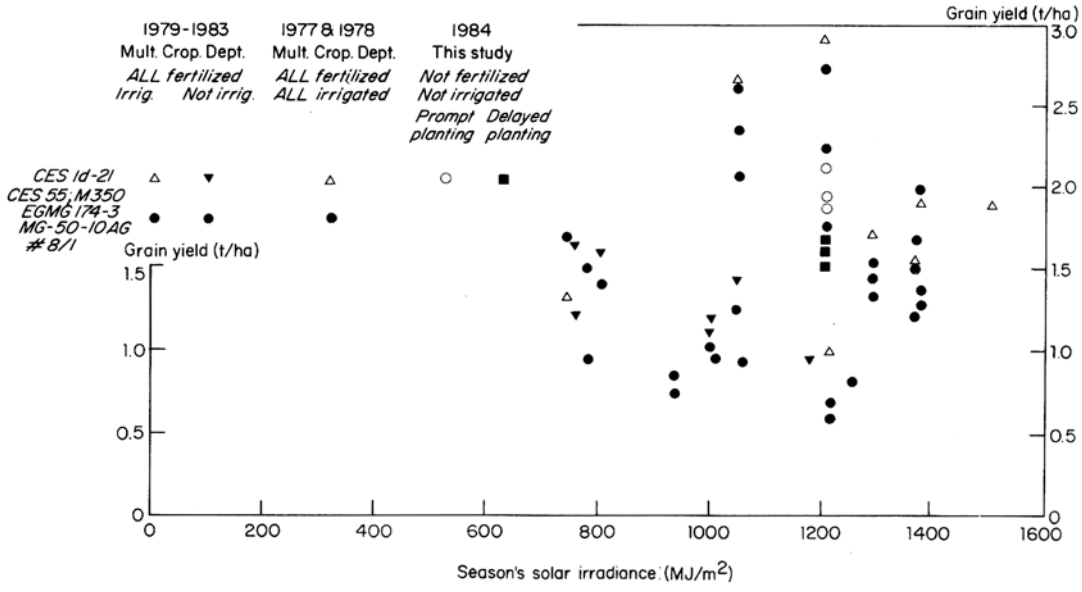
Table 9. Effect of tillage and delay (4 and 6 d) between field draining and seed planting, on grain yield (from 2 primings) and fresh fodder yield of mungbean. Field F13, IRRI, 1984 DS.

Tillage	Yields (t/ha)			
	Grain		Fodder	
	4 d	6 d	4 d	6 d
Conventional	1.93	1.60	10.7	11.0
Strip by tractor	1.86	1.65	9.0	10.9
Strip by winch	2.10	1.53	9.9	10.2
Standard error	0.06	0.06	0.7	0.7

The grain yields of mungbean are summarized in Table 9, by Latin square and tillage. For the first Latin square, with 4 d turnaround delay, yields were about 2 t/ha; at 6 d delay, yields were about 0.4 t/ha less. On strips created by the winched tine, prompt planting yielded more than 2 t/ha — without fertilizer, without irrigation, and with only 33 mm of rainfall to supplement the water stored in the soil profile. The Philippine average mungbean yield is about 0.6 t/ha.

The fresh fodder yields (Table 9) of about 10 t/ha were slightly lower with prompt planting.

Thorough weed and pest control and use of high-yielding CES 1d-21 contributed to high yields. Figure 13 shows yields of various cultivars in

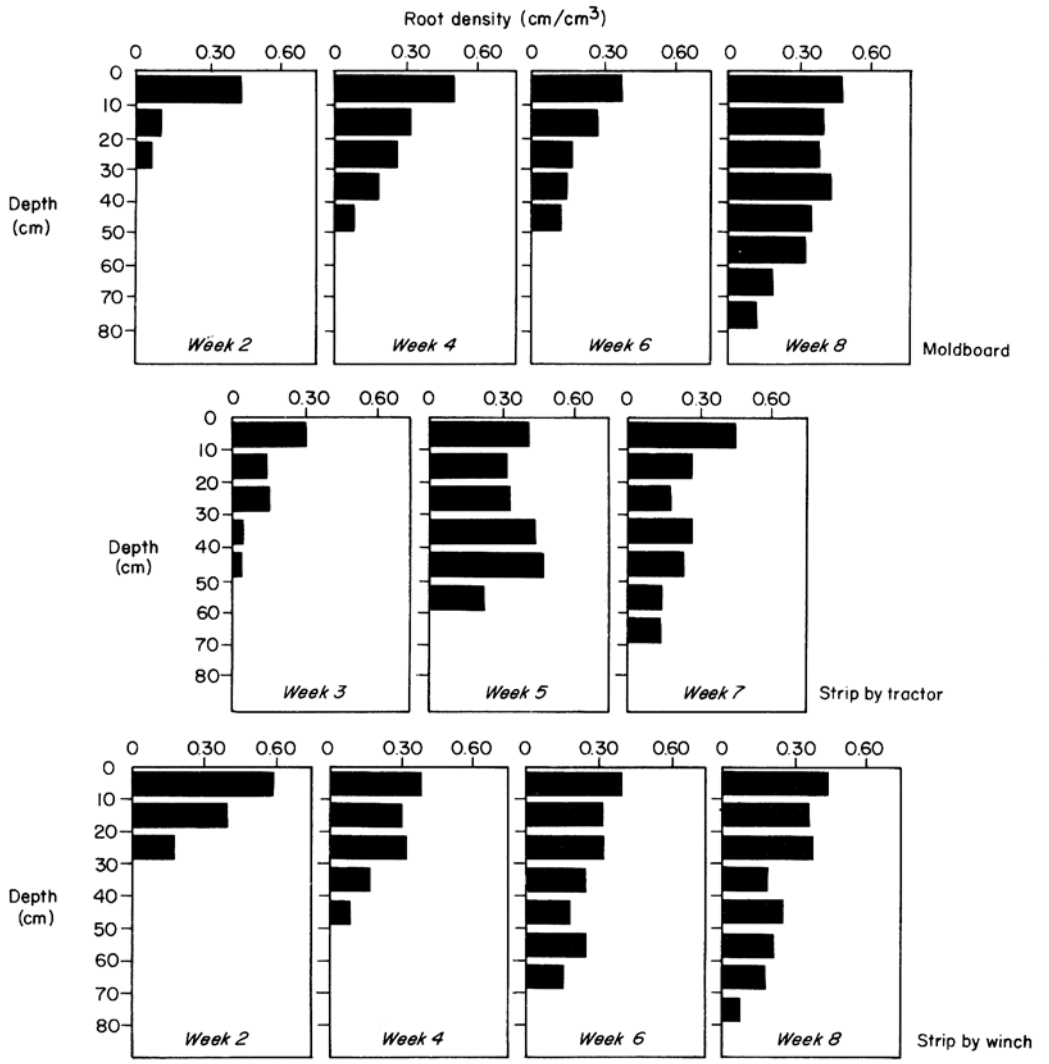


13. Effect of cultivar and solar irradiance on grain yield of DS mungbean on previously puddled soil. IRRI farm, 1979-84.

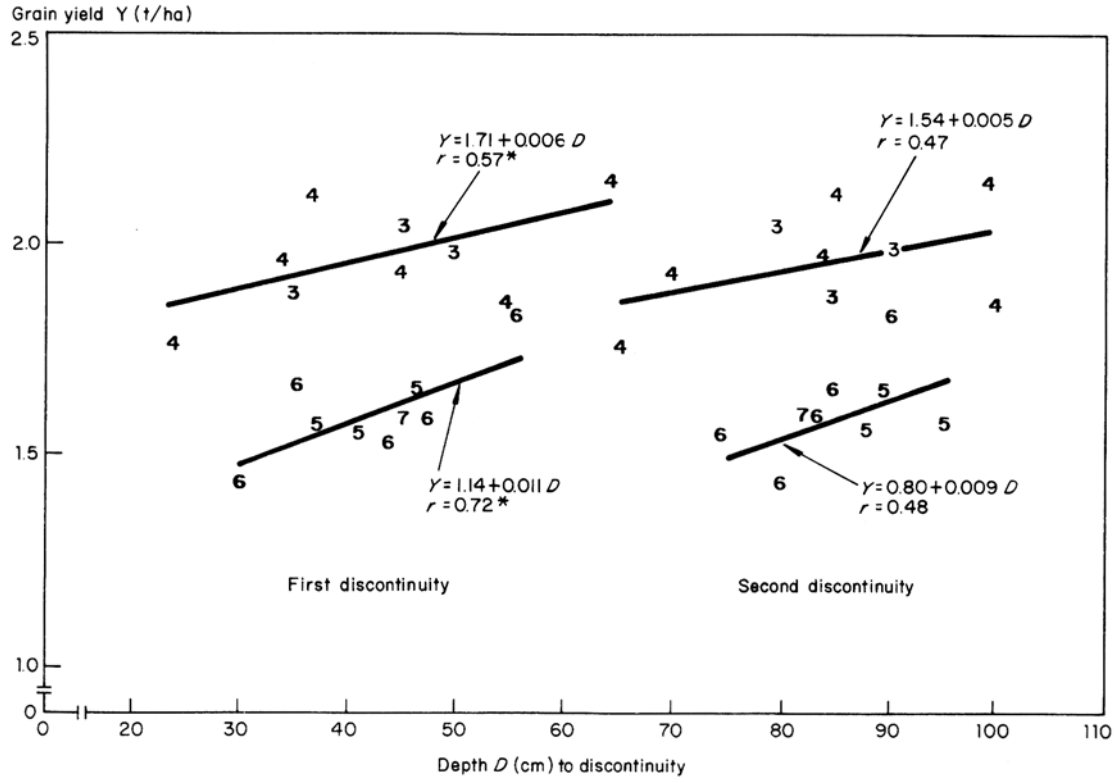
various years plotted against the growing season's solar irradiance, and with or without fertilizer or irrigation. High irradiance alone does not guarantee high yield. However, the 1984 high yields may be due to plants effectively intercepting the irradiance because of the extremely uniform crop stand produced by manual precision seeding. Figure 13 also demonstrates that without irrigation and without fertilizer, the 1984 study gave yields comparable to those previously achieved with both irrigation and fertilizer.

Soil physics also could explain the high yields; deep rooting allowed effective uptake of matric soil water, and despite deep drains, plants might have taken up some groundwater. Figure 14 shows roots penetrated more quickly to depth on strip-tilled than on conventionally tilled plots; roots on all plots eventually penetrated to 70 or 80 cm.

For each plot, soil-water content was measured regularly by neutron moderation and gravimetric sampling. The results showed average water uptake of 180 mm, about three-fourths of the crop's water requirement of about 250 mm. The fact that the water requirement was largely satisfied reinforces



14. Effect of tillage on root distribution in mungbean from 2 through 8 wk after sowing. Field F13, IRRI, 1984 DS.



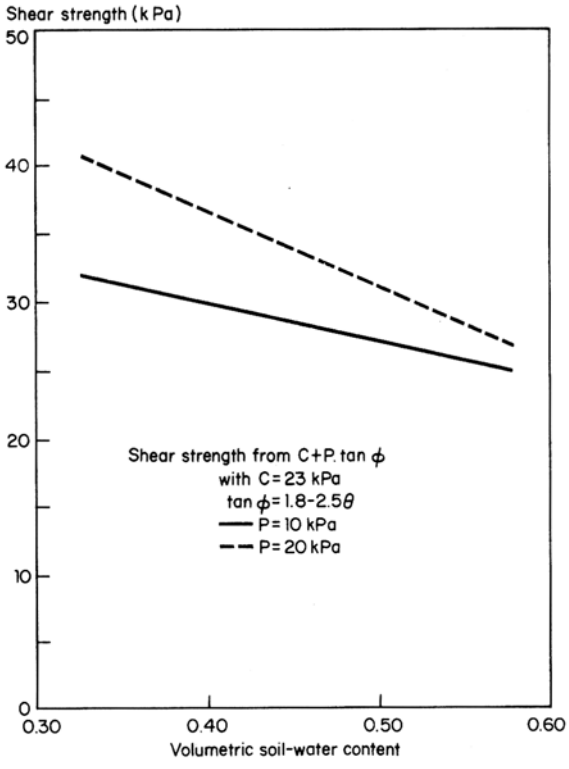
15. Relation of grain yield of DS mungbean to depth to the stronger soil horizons and to delay between field draining and seed planting. Field F13, IRRI, 1984 DS. Each number along the lines represents the number of days between draining the field and planting the particular plot.

the possibility that deep rooting and effective uptake of matric soil water contributed to high yields.

Soil profile cores were taken for each plot with notations of the depths at which there were discontinuous changes to different soil structure and higher mechanical strength. There were two such discontinuities in the top metre of 16 of the 18 plots, and they affected crop rooting and water abstraction. If the grain yield data are correlated with depth to the discontinuities, and if the data are separated according to prompt plantings and delayed plantings (Fig. 15), then it is seen that deeper soils promote higher yields. In fact, for each additional 13 cm of exploitable soil depth, one might expect 100 kg more grain/ha. This confirms a physical aspect of soil fertility for mungbean on this field. On soils with strong layers at depths shallower than 20 cm, encouraging deep roots by strip tillage may be worthwhile.

For the 0-20 cm soil layer of this site, the data in Figure 12 imply that soil shear strength is indeed inherently high, at least over the soil-moisture range 0.3-0.5. Shear strength was calculated from $C + P.\tan\phi$, with averages over all tillage treatments for cohesion C taken as 23 kPa, and for $\tan\phi$ as 1.8-2.5 θ where θ is the volumetric moisture content. Values for the normal load P, representing the pressure exerted by the legume roots, were chosen as 10 and 20 kPa. The shear strengths appropriate to these choices appear in Figure 16. These data will be used to develop theories for soil resistance to root penetration. However, because equipment used to measure these data was designed for engineering measurements of load-bearing strength, these data may not relate to microscale mechanics of roots especially in the seedbed.

The yield decrease due to planting delay averaged 0.4 t/ha, or 19% (Table 10). Therefore the 6% reduction in plant emergence caused by 2 d addi-



16. Shear strength of the 0-20 cm soil layer as related to volumetric soil-water content: for normal stresses of 10 and 20 kPa, and with parameters for C and tanϕ determined from 4 tillage treatments. Field F13, IRRI, 1984 DS.

Table 10. Effect on the grain yield[a] of mungbean of delay (4 and 6 d) between field draining and seed planting. Field F13, IRRI, 1984 DS.

Yield (t/ha)		Yield decrease	
4 d	6 d	t/ha	%
1.96 ± 0.07	1.59 ± 0.04	0.37 ± 0.08	19 ± 4

[a] Av over all tillage treatments.

tional soil drying at seed depth explains only part of the 19% difference. Further examination of site layout showed no significant differences due to gradient in chemical fertility or pest damage.

Measurements of total dry matter yield showed no difference between prompt and delayed plantings. However, harvest index values were significantly lower with delay in planting (Fig. 15).

After mungbean harvest, water infiltration rate was measured for all tillage treatments, to determine whether strip-tilled soil would allow water to percolate at a wasteful rate during land preparation for the succeeding WS rice crop. Results showed that after mungbean in 1984, and after maize in 1983, infiltration rates were essentially the same for all treatments, though possibly higher on the strip-tilled plots. But for all treatments, infiltration rate was so high that it required considerable repuddling to prevent excessive water loss.

Climatic environment and rice

Agronomy, Multiple Cropping, Plant Pathology, and Soil Chemistry/ Physics Departments, and International Rice Testing Program

RICE-WEATHER STUDIES **332**
International Rice Weather Yield Nurseries (IRWYN) **332**
Climatic environment and rice **332**
Temperature and evapotranspiration patterns in upland and lowland environments **333**
RICE ENVIRONMENTAL ANALYSIS **335**
Classification of Asian upland rice environments **336**
Dominant upland rice environments **337**
Classification of rainfed lowland rice environments **337**
AGROHYDROLOGY OF UPLAND RICE **338**
WATER DEPTH AND DEEP WATER RICE **340**
Effect on elongation **340**
Effect on yield **340**

RICE-WEATHER STUDIES

Multiple Cropping Department and International Rice Testing Program

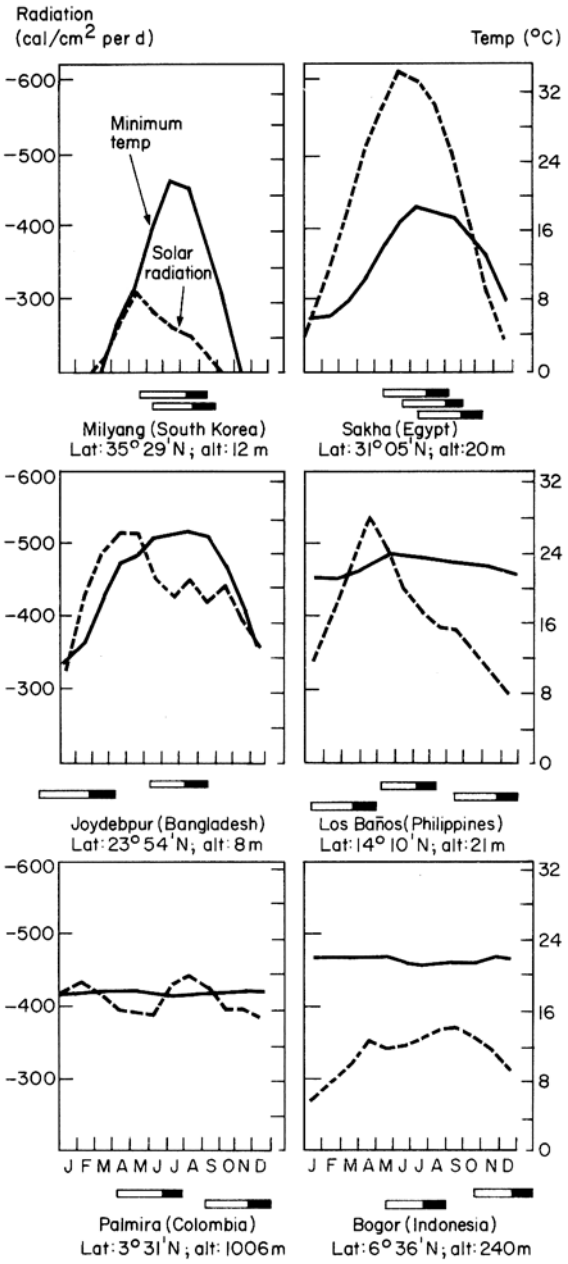
Rice-weather studies, a special International Rice Testing Program (IRTP) project in cooperation with the World Meteorological Organization (WMO), improve our understanding of rice environments. They supplement information on the behavior of promising varieties in diverse climatic environments, including yield performance.

When water and nutrients are not a constraint (as under full irrigation) and with minimal biological stresses, rice yields depend primarily on atmospheric factors such as air temperature and solar radiation. The enormous diversity of temperature-radiation environments in rice-growing areas is illustrated by the long-term climatic conditions at some sites selected for this study (Fig. 1).

Daily weather is recorded at 23 agrometeorological stations which have been partly or completely supplied with recording equipment by the project. Records cover daily rainfall, maximum and minimum temperature, dry and wet bulb temperature, radiation, and windspeed. Data are sent to IRRI for validation; IRRI then sends monthly summaries to cooperators. Radiation is measured with the RIMCO electronic integrating pyranometer, using the Gunn Bellani solar radiation integrator as backup. Readings of these instruments are highly correlated.

International Rice Weather Yield Nurseries (IRWYN) (*Multiple Cropping and International Rice Testing Program*). The IRWYN began in August 1983. Each nursery has nine entries selected from *very early* and *early* nurseries: BG35-2, BG367-4, MRC603-303, IR13429-196-1, IR36, IR50, IR9729-67-3, IR9828-91-2-2, and Taichung Sen Yu 285. Cooperators select the 10th entry. Trials are randomized and replicated with standardized management; N,P,K application levels are chosen to maximize yields. Planting dates are set to ensure that the critical period for yield potential — flowering to maturity — will coincide with levels of radiation and temperature needed for analysis of the weather-yield response.

Preliminary analysis of 35 data sets shows that accumulated temperature can predict the duration of all phenological stages. Yield can be related to accumulated radiation and temperature variables, including day temperature, day-night temperature differences, and minimum temperature during the reproductive phase. Entries can be grouped by their radiation and temperature responses.



1. Monthly minimum temperature and monthly total radiation from selected sites in the IRTP rice-weather project.

Climatic environment and rice (*Multiple Cropping*). Better soil and environmental characteriza-

tion is urgently needed for sites where global networks such as IRTP, INSFFER, and ARFSN operate. Meteorological data gathered and recorded at thousands of sites throughout the world are often difficult to retrieve. Therefore, we organized a climatic data bank to assemble climatic records uniformly for easy retrieval. Data are published as mimeographed reports by the Climate Unit.

Stored data include elements normally gathered at synoptic stations, such as rainfall, maximum and minimum temperature, relative humidity, radiation (or sunshine duration or cloud cover), windspeed, wind direction, and in some instances open pan (class A) evaporation.

Relevant parameters of agricultural interest are estimated: potential evapotranspiration is estimated using the modified Penman method developed by Frere and Popov, day and night temperatures are estimated using Petricevic's method, and vapor pressure (Ea) is calculated using relative humidity (RH) values and saturation vapor pressure (Es) corresponding to the mean daily temperature ($Ea = 0.01\ RH \times Es$).

The final printout contains 16 climatic parameters, expressed in units according to WMO standards. Table 1 presents the data for Los Baños.

During 1984, climatic data of four countries were processed. The Philippine data came from 86 locations (mimeographs available), the Thailand data (44 locations) are being reviewed by the National Meteorological Services of Thailand, the data of Indonesia (90 locations) will be released in 1985, and the National Meteorological Services in India (168 locations) may validate the Indian series for 1985 release.

Temperature and evapotranspiration patterns in upland and lowland environments (*Multiple Cropping*). The seasonal patterns of potential evapotranspiration (PET) and other weather variables at the upland (surrounded by upland crops) and lowland (surrounded by lowland rice) areas of IRRI were compared. During dry season (DS), the aerodynamic components' contribution to PET is important; this contribution was compared for upland and lowland PET.

Daily agrometeorological data [maximum temperature (T max), minimum temperature (T min), solar radiation (SR), windspeed (U), and relative humidity (RH)] were used to estimate PET. Vapor pressure deficit (VPD) and net radiation (Rn) were

Table 1. Agroclimate data for Los Banos, Philippines, 1959-83 averages.[a]

Mo	Total rainfall (mm)	Evaporation (mm)		Radiation (mWh/cm²)	Sunshine hours†	Cloud cover (Oktas)	Temperatures (°C)					Relative humidity (%)	Actual vapor pressure (mbar)	Vapor pressure deficit † (mbar)	Windspeed (m/s)	Wind direction (16 points)
		Total	Mean				Max	Min	Mean †	Day †	Night †					
Jan	51	82	2.7	395	5.4	5	29.0	20.8	24.9	26.4	23.6	86	27.1	4.4	0.7	NE
Feb	25	101	3.6	486	6.8	4	30.2	20.7	25.5	27.2	23.8	84	27.3	5.2	0.7	NE
Mar	29	145	4.7	570	7.9	3	31.9	21.5	26.7	28.6	24.8	80	28.0	7.0	0.7	NE
Apr	39	168	5.6	632	8.8	3	33.8	22.8	28.3	30.3	26.2	77	29.6	8.8	0.7	NE
May	161	158	5.1	571	7.6	4	34.1	23.7	28.9	30.7	26.8	79	31.5	8.4	0.7	NE
Jun	224	129	4.3	509	6.0	5	32.9	23.6	28.3	29.9	26.3	82	31.5	6.9	0.4	SE
Jul	279	117	3.8	471	5.3	5	31.8	23.3	27.6	29.0	25.8	84	30.9	5.9	0.4	VRBL
Aug	264	111	3.6	453	5.0	6	31.6	23.2	27.4	28.9	25.8	85	31.0	5.5	0.4	SW
Sep	253	105	3.5	445	4.9	5	31.5	23.2	27.4	28.8	25.8	86	31.3	5.1	0.4	SW
Oct	250	102	3.3	431	5.3	5	31.0	22.9	27.0	28.4	25.5	85	30.2	5.3	0.4	NE
Nov	255	81	2.7	377	5.0	5	30.2	22.5	26.4	27.8	25.1	86	29.5	4.8	0.7	NE
Dec	157	71	2.3	348	4.6	5	29.1	21.9	25.5	26.8	24.3	87	28.4	4.2	0.7	NE
Summary	1988	1370	3.8	474	6.0	5	31.4	22.5	27.0	28.6	25.3	83	29.7	6.0	0.6	NE

[a] † = estimated value.

also computed. Comparisons were made with class A pan evaporation (Ea). To eliminate extreme fluctuations, 11-d moving averages were used.

Daily PET was estimated by two formulae: modified Penman by Frere and Popov (Ef), and Van Bavel (Eo). The modified Penman PET formula is:

$$Ef = \frac{C^{\bullet} R_n + A_t}{C+1}$$

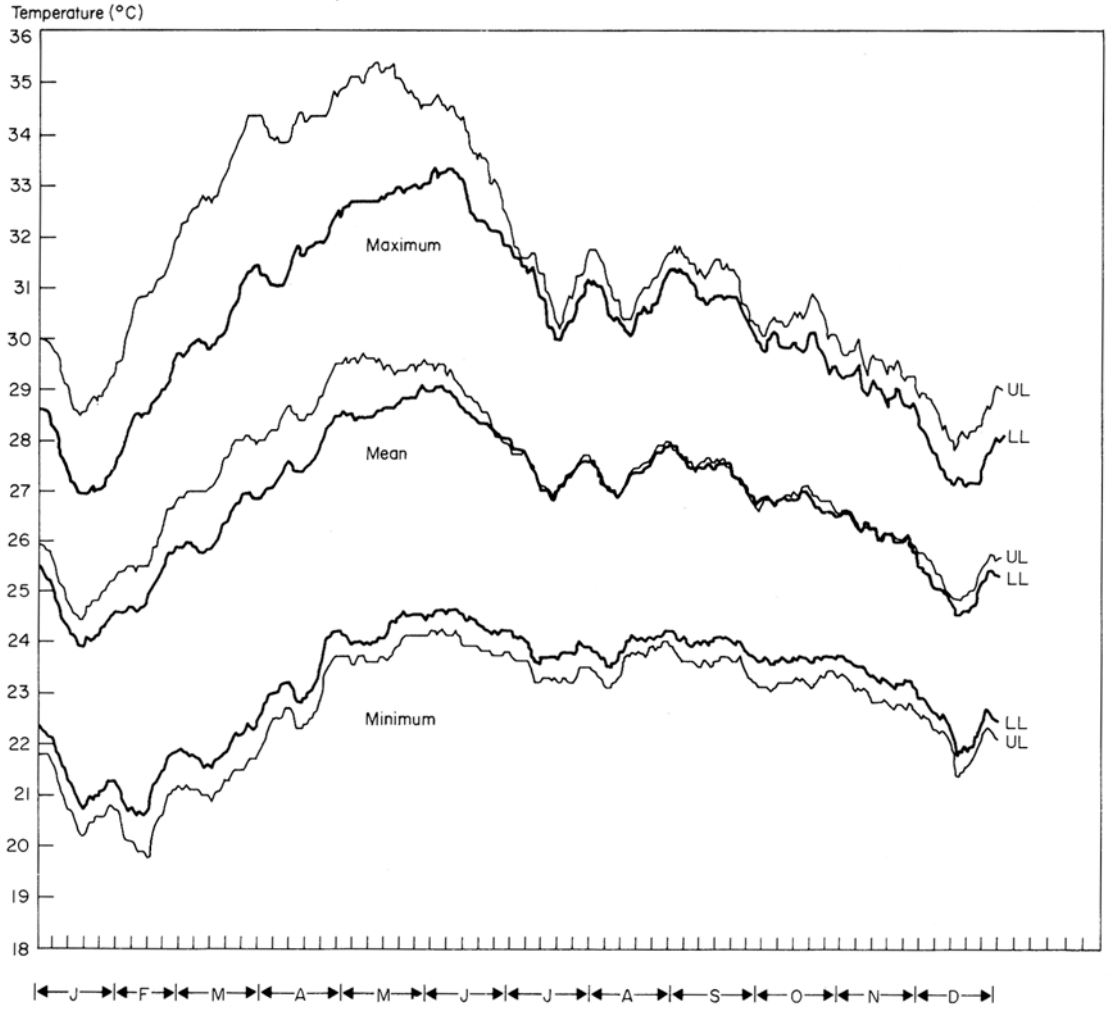
This formula requires estimation of R_n, and calculation of an aerodynamic term (A_t) and a correction term (C). A_t requires VPD, U, T max, and T min; C is a product of the ratio of atmospheric pressure at sea level and at station level (Po/P) and the ratio of slope of saturated vapor pressure curve and the psychrometric constant (Δ/γ). The Van Bavel formula is:

$$E_o = \frac{\Sigma R_n + 3.6\,(VPD)/r_a}{\Sigma + 1}$$

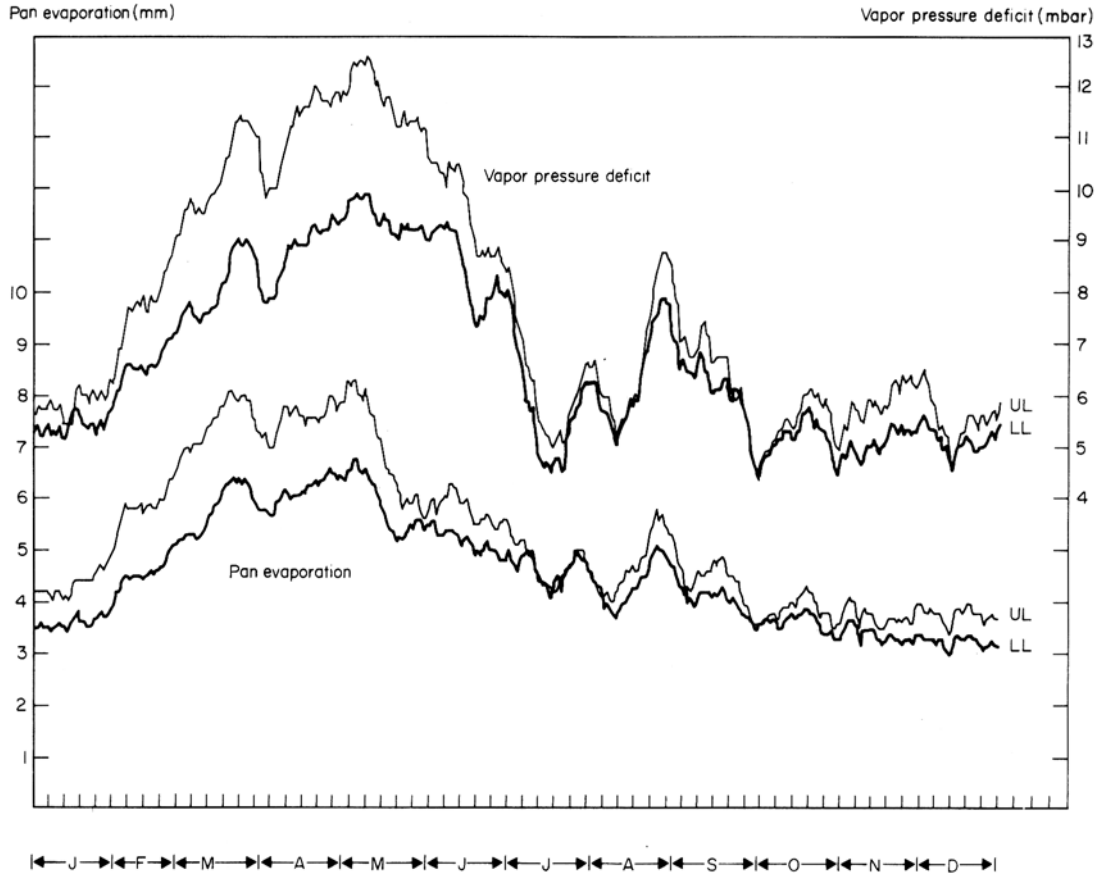
This formula requires an estimation of aerodynamic resistance (r_a):

$$r_a = \frac{[\ln (Z\text{-}d)/Zo]^2}{.168U}$$

Z is the height where U is determined (i.e., 2 m), Zo



2. Seasonal patterns of maximum, mean, and minimum temperatures at the lowland (LL) and upland (UL) agricultural meteorology stations at IRRI. 11-d moving averages, 1981 to 1983.



3. Seasonal patterns of vapor pressure deficits and class A pan evaporation at lowland (LL) and upland (UL) agricultural meteorology stations at IRRI. 11-d moving averages, 1981 to 1983.

is a roughness parameter (1 m for rice); and d is a zero-plane displacement, also related to crop height. Because Z, Zo, and d were all constants in these calculations, $r_a = 30.55/U$.

Figure 2 compares upland and lowland temperatures. Maximum temperature was greater and minimum temperature lower at upland location. Mean temperature was lower at lowland locations in DS, but not during wet season (WS). The DS maximum differed most.

Figure 3 shows that VPD and *Ea* at upland locations were equal to or greater than at lowland throughout the year.

PETs calculated by the *Ef* formula were higher than those by the *Eo* formula, regardless of the environment surrounding the station. Upland differences in estimates were greater during DS. Lowland differences were similar yearlong.

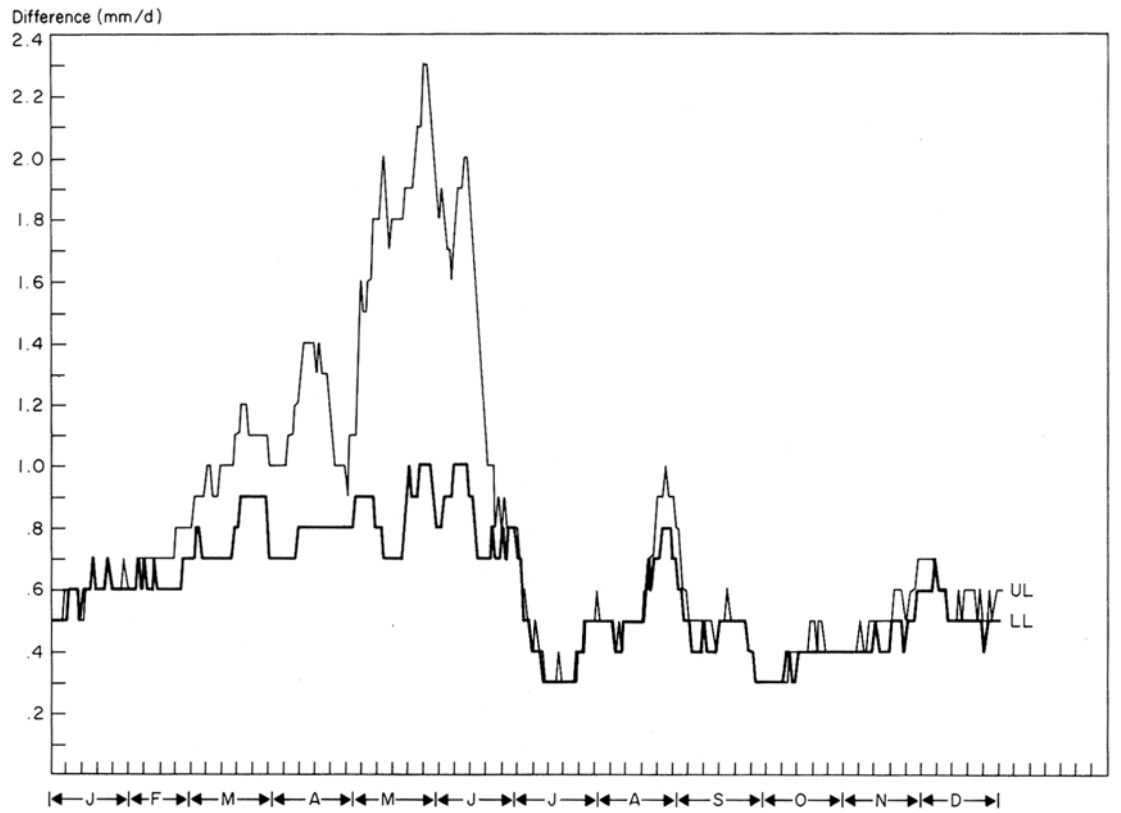
Pan evaporation was estimated (Ee) from *Ef* using pan factors taken from a published table indexed by RH and *U*. *Ea* and *Ee* differed during DS at both stations, especially at upland areas, with *Ea* higher. *Ea* and *Ee* agreed during WS.

Assuming that PET is driven by radiation and aerodynamic components, Rn was expressed in mm water/d and subtracted from *Ef* to examine seasonal contributions. Upland and lowland differences are in Figure 4. The much greater difference at upland areas during DS suggests a stronger aerodynamic component.

RICE ENVIRONMENTAL ANALYSIS

International Rice Testing Program

Understanding rice environments enhances breeding and management of varieties for specific



4. Seasonal differences between potential evapotranspiration estimated by a modified Penman formula and net solar radiation converted to evaporated water equivalents, at lowland and upland agricultural meteorology stations at IRRI. 11-d moving averages, 1981 to 1983.

ecosystems. This is particularly important for rainfed rice because of high variability and instability of yields, and slow adoption of improved production technology.

Areas of upland (UR) and shallow rainfed lowland rice (SRLR) in South and Southeast Asia were analyzed and classified based on environmental data. A computer data base covers rice culture type distribution, soils, and climate for South Asia and Southeast Asia.

Classification of Asian upland rice environments. UR production regions in South Asia and Southeast Asia were previously classified by growing season length (LGS) and soil fertility, in two classes each. The recently revised UR classification is more specific and useful:

1. LGS is divided into 3 classes (short: 0-3 mo, medium: 4 mo, and long: 5-12 mo). Short LGS areas require very early maturing varieties (<100 d), and long LGS areas are assumed to have no limitation to varietal maturity. The 4-mo LGS fits early varieties (110-120 d).
2. Inherent soil fertility is classified using the Fertility Capability Classification (FCC) system, grouping soils by problems they pose for agronomic management of their chemical and physical properties. The classes are

F — Fertile or no major constraint;
A — Adverse, with subclasses composed of
  e — soils with low cation exchange capacity (CEC);
  a — low CEC and potentially very acid;
  aie — low CEC, potentially very acid and potentially high P fixation; and
  b — potentially alkaline.

3. Water balance favorability (WBF) is interaction of rainfall regime (RR) and soil water retention potential (WR).

Table 2. Numerical values for classifying water balance based on water retention potential and rainfall regime for upland rice, South and Southeast Asia.

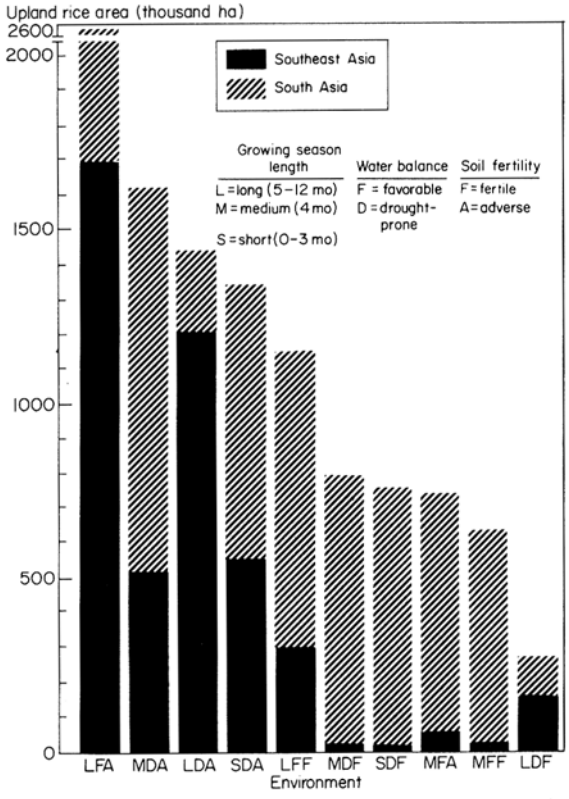
Water retention potential				Rainfall regime			
Slope	Value[a]	Texture	Value[a]	5-mo rainfall	Value	Length of growing season	Value[a]
0 - 8	1.0	Fine	1.0	High to very high (>1500 mm)	1.0	Long (5-12 mo)	1.0
		Medium	0.6			Medium (4 mo)	0.6
		Coarse	0.3			Short (0-3 mo)	0.3
8 - 30	0.6	Fine	1.0	Medium (1200-1500 mm)	0.8	Long	0.8
		Medium	0.5			Medium	0.5
		Coarse	0.2			Short	0.2
>30	0.3	Fine	1.0	Low (1000-1200 mm)	0.5	Long	0.6
		Medium	0.4			Medium	0.4
		Coarse	0.1			Short	0.2
				Very low (<1000 mm)	0.2	Medium	0.2
						Short	0.1

[a]*Water balance class*	*Code*	*Cumulative value (sum of 4 determinants)*
Favorable (F)	4	3.6 - 4.0
Intermediate (I)*	3	3.1 - 3.5
Drought-prone (DP)	2	2.4 - 3.0
Highly drought-prone (HDP)	1	<2.3

RR is a function of 3 LGS classes and 4 rainfall classes. WR is determined by 3 soil textural groups and 5 slope classes. The WBF classes represent combined values of 2 RR components and 2 WR components (Table 2). The four WBF classes may be simplified into two: favorable (F and I), and drought-prone (DP and HDP).

Dominant upland rice environments. Ten major UR ecosystems were specified by LGS, WBF, and soil fertility. UR in Southeast Asia (Fig. 5) is concentrated on the ecosystems LFA (long LGS, favorable WBF, adverse soils [1.7 million ha]) and LDA (long LGS, drought-prone WBF, adverse soils [1.2 million ha]). These contrast with the dominant South Asian UR ecosystems of medium-drought-prone-adverse (MDA), medium-drought-prone-fertile (MDF), short-drought-prone-adverse (SDA), and short-drought-prone-fertile (SDF), having either short or medium LGS, and drought-prone or highly drought-prone.

Classification of rainfed lowland rice environments. The rainfed lowland rice crop is not irrigated but soil is flooded at least part of the crop cycle to a maximum sustained depth of 50 cm. This rice type covers more than 38 million ha, mostly in South and Southeast Asia.



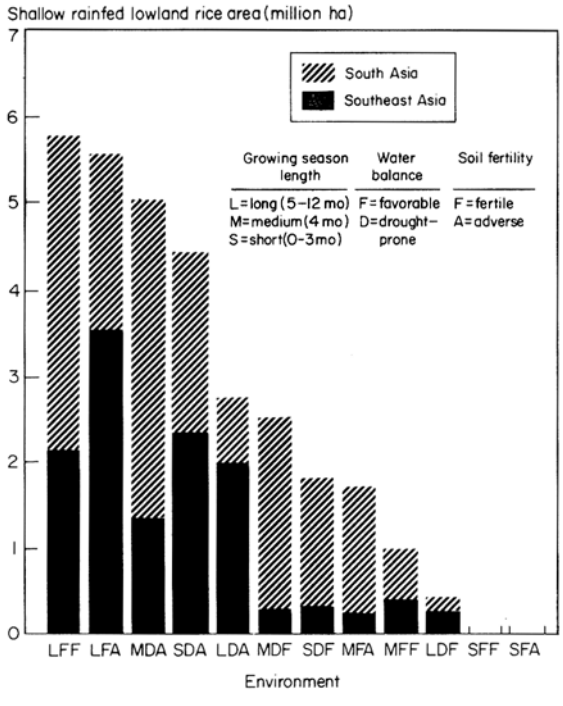
5. Comparative distribution of UR areas in South and Southeast Asia, by major environment. 1984.

The rainfed lowland is subdivided into

- *Rainfed shallow*, areas with maximum sustained water depth of 25 cm. They cover more than 30 million ha in South and Southeast Asia.
- *Rainfed medium-deep*, areas with maximum water depth of 25-50 cm. These areas normally require varieties taller than the semidwarfs to withstand the deeper flood condition.

SRLR areas in South and Southeast Asia were classified into 10 major ecosystems (Fig. 6). Long-favorable-fertile (LFF) is the dominant SRLR ecosystem in South and Southeast Asia, represented extensively in Bangladesh, Burma, Philippines, India, Indonesia, and Nepal. LFF and LFA ecosystems are similar to irrigated rice in field water availability during the cropping season.

In South Asia, MDA, MDF, and SDF ecosystems predominate, mostly in India. Very large areas of ricelands await the benefits of improved genetic materials possessing early or very early maturity, drought stress tolerance, and adaptability to adverse soils conditions.



6. Comparative distribution of major SRLR environments in South and Southeast Asia.

AGROHYDROLOGY OF UPLAND RICE

Soil Chemistry/ Physics, Agronomy, Multiple Cropping, and Plant Pathology Departments

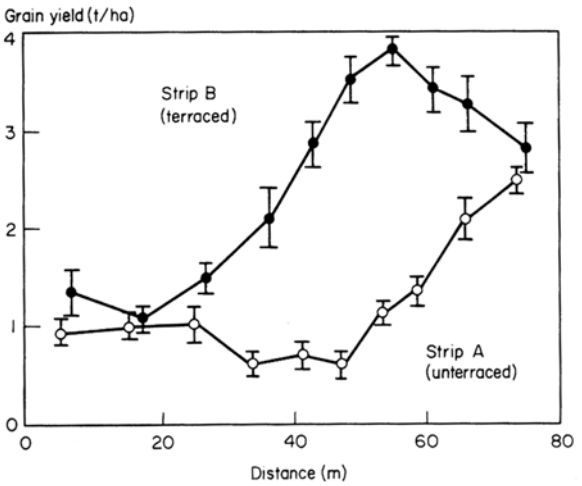
For upland rice on a gently sloping hill toposequence, growth and yield may depend on position up the hill. Position may affect groundwater and nutrient uptake, weed growth, soil temperature (affecting seed and root physiology), and aboveground physical micrometeorological conditions that favor fungal diseases.

In 1983 WS research, IR36 yielded higher in downslope soil with shallower depth to water table and higher soil N content as measured after harvest. Possibly, rainfall transported soil and nutrients downslope.

In 1984 WS, IR36 was grown in four 80-× 11-m strips oriented along a 2% incline on a Tropudalf soil. Two of the four strips were crossed at right angles by a series of vertical wooden barriers (terraces) to restrict aboveground downslope flow of soil and nutrients during rain. Each strip had 10 sections averaging 0.2-m higher elevation than the one below it. On terraced strips, boards separated sections; on unterraced strips, section boundaries were only marked. Soil and crop variables, and incidence of weeds, insects, and diseases were monitored regularly in the 40 sections.

In the 1984 WS, the period of this experiment, June-September, had 10% less rain but 10% more rain days than long-term averages. Water table averaged 1.1 m deep on the upper half of the toposequence and 0.8-1.1 m deep on the lower half. Its rate of recession ranged from 2 to 17 cm/d, and was about 50% larger in the upper half of the slope than the lower. Because rain fell on more than two-thirds of growing season days, surface soil was persistently wet, and soil in the 0-0.2 m layer dried to no more than −0.06 MPa (−0.6 bar), too little to affect rice growth. Yield was probably not affected by groundwater uptake; neither was it significantly related to hillslope position or terracing (Fig. 7).

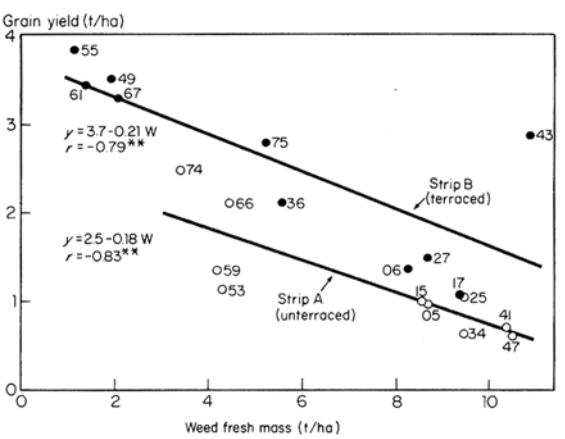
However, surface-soil wetness did reduce rice growth and yield by promoting weeds. From 9 wk after seeding (WAS), wetness prevented weeding; weed and rice grain mass were negatively correlated (Fig. 8). Assuming harvest index of 0.5 for rice, and weed dry mass one-fourth of weed fresh mass, weed dry mass was produced at the expense of an



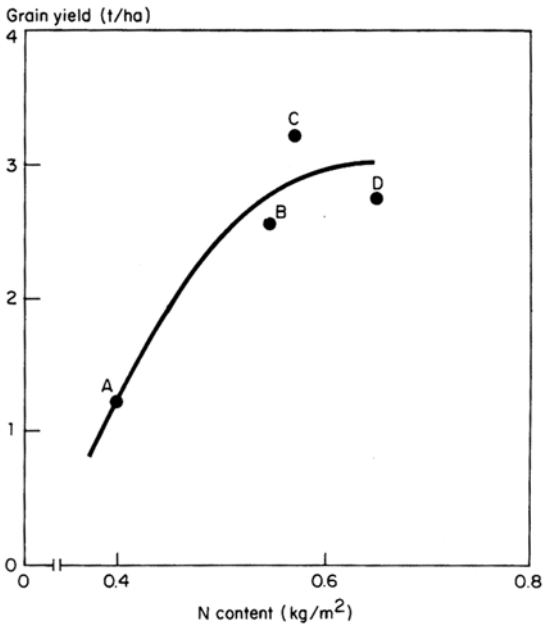
7. Grain yield of IR36 at various distances up a toposequence (strips A and B). IRRI, 1984 WS.

equivalent dry mass of rice plants. Weed growth was not significantly related to hillslope position.

Yield related to soil N content. Although preseeding fertilization and previous management were the same on all strips, N content in the 0-0.4 m layer at 1984 seeding was lower on strip A than on other strips — possibly because the slightly steeper strip A had more soil erosion in the previous 9 yr of annual cropping. Figure 9 shows the low N at seeding is associated with low yield on strip A. Figure 8 shows yield on strip A averaged approximately 1 t/ha lower than on strip B at all elevations and all values



8. Grain yield of upland rice IR36 as affected by weed fresh mass at harvest. IRRI, 1984 WS. Numbers alongside data points indicate distance (m) from bottom of hillslope.



9. Relation of mean grain yield of upland rice IR36 to N content at seeding of the 0-0.4 m layer. 1984 WS, IRRI. Yield and N content were average of 10 points for each of strips A, B, C, D.

of weed mass. Results support the view that N nutrition mainly produced the yield differences between A and B strips, and such differences did not occur between strips B, C, and D.

Rice blast did not relate to slope position in 1984 as it did in 1983. On all parts of the toposequence, rice leaves were invariably wet at 0800, usually continuing wet on rainless mornings until 1000 or even to 1200 or 1300. Plants downslope stayed wet up to 1 h longer than upslope.On rain days, plants at all positions remained wet much longer, sometimes for more than 24 h. Although such wetness could promote rice blast, neither blast nor slight incidence of orange leaf virus significantly affected yield or related to slope position.

For 12 of 40 sections, saturated hydraulic conductivity (k_{sat}) was measured in the laboratory on samples taken at 0.1-m increments to 0.5-m depth. k_{sat} values ranged between 0.5 and 250 cm/d, and did not depend on slope position. The lowest k_{sat} was usually, but not always, in the 0.3- to 0.4-m soil layer. Under 1984 WS soil-moisture conditions, this layer had high strength, with a resistance to cone penetrometer of 2.5 MPa (25 bars) or more throughout the season. In the 0- to 0.1-m layer,

resistance was above 2 MPa from 6 WAS; however, during germination and emergence (0-2 WAS), surface soil was much more moist, and penetrometer resistance was less than 0.1 MPa. Soil strength throughout the 0- to 0.5-m zone was generally slightly greater upslope.

Soil temperature, averaged over the 2- to 30-cm layer, decreased by about 0.07K/10 m of upslope distance. Although statistically significant, this decrease had no practical significance. In fact, in 1983, average soil temperature through the 5- to 30-cm layer increased by 0.05K/10-m upslope distance. Morning (0800) temperatures ranged between 24 and 32° C, and afternoon (1400) values reached 36° C at 5-cm depth and 39° C at 2-cm depth. Temperatures of 36 ° C at 5-cm and 38° C at 2-cm depth were recorded during 0-7 d after seeding; seedbed temperatures close to 40° C can, if maintained, reduce rice germination.

WATER DEPTH AND DEEP WATER RICE

Agronomy Department

Effect on elongation. To investigate plant response to water depth, deep water rice LMN111 was sown on a sloping site at Prachinburi Research Center, Thailand. Six contours were marked at 20-cm height intervals to give a 1-m height difference between the highest contour (level 1) and the lowest (level 6). Seedlings emerged 27 May. Samples were taken from each contour when water reached the highest level and then at 3-wk intervals until maturity (9 Dec).

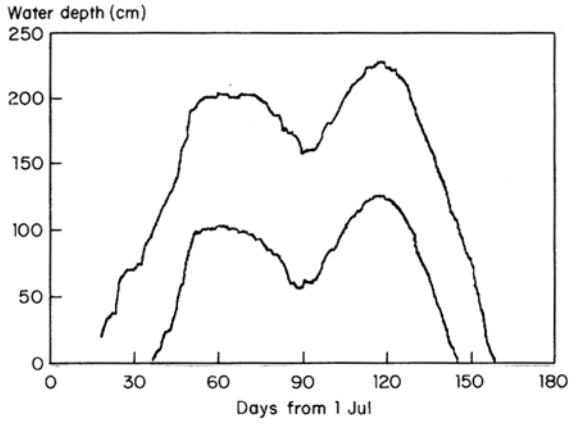
The water pattern was bimodal with the deepest area having a maximum depth of 202 cm on 30 Aug and 230 cm on 30 Oct (Fig. 10). Mean plant height ranged from 330 cm for the deepest water to 263 cm for the shallowest.

Basal internodes were longest in deep water (Fig. 11). The lengths of the 6 internodes totaled 162 cm for level 6, and 96 cm for level 1 (shallow). The difference of 66 cm is the same as the final height difference and reflects differences in response to water depth until the floodwater reached the highest contour. Thereafter all internodes with the same number had approximately the same length. Less elongation of internodes 7 to 12 coincided with a drop in water level.

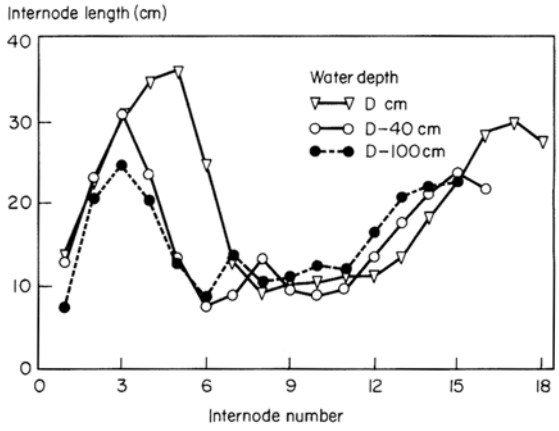
Grain yields ranged from 1.94 t/ha in the deepest water to 0.83 t/ha in the shallowest. This result may have been due to soil conditions or early drought, but indicates that deeper water does not necessarily decrease yields of an adapted deep water rice.

Effect on yield. Deep water rice yield largely relates to duration of flood above a base level, above 90 cm for RD19, as well as on maximum water depth. Response to flood duration may be important in choosing a variety for a given location.

To assess effects of depth and duration, pots containing four plants were moved between water depths. Treatments commenced in mid-October, when water depth reached 75 cm above the plant



10. Changes of water depth with time at the highest and lowest levels of sloping field where plant elongation was measured. Prachinburi Experiment Station, Thailand, 1983 WS.



11. Length of internodes of deep water rice LMN111 grown on a sloping site at Prachinburi Experiment Station, Thailand, 1983 WS. D = deepest water, with maximum depth of 226 cm. The lowest internode is number one.

Table 3. Water regime[a] and grain yield of deep water rice. Huntra Experiment Station, Thailand, 1983 WS.

Treatment	Period (wk) at each depth			Grain yield (g/pot)			
	105 cm	90 cm	75 cm	RD19	LPT123	SPR7270-18	Mean
1	–	–	10	60.5	75.5	34.8	57.0
2	1	2	7	24.1	28.1	28.4	26.9
3	1	3	6	21.6	23.3	25.9	23.6
4	1	6	3	17.6	22.2	20.2	20.1
5	1	9	–	8.3	20.3	3.3	10.7
6	4	1	5	15.6	8.2	6.9	10.2
7	6	1	3	11.9	7.1	10.1	9.7
8	8	2	–	6.6	11.0	1.2	6.3
Mean				20.8	24.5	16.4	
	LSD (0.05) Varieties 4.5, treatments 6.4, interaction 12.1						

[a] Plants were moved progressively to shallower water.

base. Pots were then moved to 105 cm and progressively to shallower water as shown in Table 3. There were eight treatments (time × depth), three varieties, and six replications.

Yield per pot decreased markedly between treatment 1 (control) and treatment 2. Plants with longer periods in 90 cm and 105 cm of water were shown to yield less when deep water stress, measured by the sum of weeks × depth of water, was plotted against grain yield. A close curvilinear relationship was obtained. There was a significant interaction between varieties and treatments. LPT and SPR7270-18 appeared more sensitive to severe stress than RD19.

Panicle number was reduced from a mean of 29.4 per pot in treatment 1 to 6.2 per pot in treatment 8. Mean grain weight per panicle decreased from 1.94 g to 1.02 g.

Constraints on rice yields

Agricultural Economics and Agronomy Departments

MANAGEMENT CONSTRAINTS **344**
Yield constraints on direct-seeded rice **344**
Irrigated sites, dry season **344**
Rainfed sites, wet season **345**
Irrigated sites, wet season **347**
Yield constraints on transplanted rice **348**
Rainfed sites, wet season **348**
Irrigated sites, wet season **349**
SOCIOECONOMIC CONSTRAINTS **350**
Farmer and researcher technology **350**
Profitability of soil nutrients: N, P, K, and Zn **351**
Forms and application methods of urea **351**
Fertilizer and risk **352**
Cash constraints and fertilizer use **353**
Competing activities **353**
Credit **353**
Wet-seeded rice and employment **354**
Marketing constraints **355**
Upland rice **355**
Input use **355**
Yields **356**
Gross margin **356**
Modern variety adoption **356**
Farmer impression of modern and local upland rice varieties **356**
INSTITUTIONAL AND POLICY CONSTRAINTS **357**
Fertilizer-rice price ratios in Asia **357**
Assessing food grain production and demand **358**
Projections of production-demand balances **358**
The Philippine case **358**

MANAGEMENT CONSTRAINTS

Agronomy Department

Yield constraints on direct-seeded rice. *Irrigated sites, dry season.* The yield gap between farmers' inputs and researchers' inputs, and the relative contributions of fertilizer, weed control, and insect control to the yield gap were measured on 11 farms in Nueva Ecija, 2 in Bulacan, and 15 in Camarines Sur. Also measured were yield responses to applied N, P, and K, including various forms of N and application methods.

Table 1. Input levels in yield-constraint experiments on direct-seeded, irrigated rice farms in 3 areas in the Philippines, 1984 DS.

Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
		N	P	K	M	C	F	G
				Nueva Ecija				
Farmers'	11	106	14	7	0	1.0	2.2	0.1
Researchers'	11	87	13	25	1.0	1.0	3.1	2.3
				Bulacan				
Farmers'	2	52	12	6	0	1.0	3.5	0
Researchers'	2	87	13	25	1.0	1.0	3.0	2.0
				Camarines Sur				
Farmers'	15	61	7	7	0.1	1.2	1.5	0
Researchers'	15	87	13	25	1.0	1.1	3.0	2.0

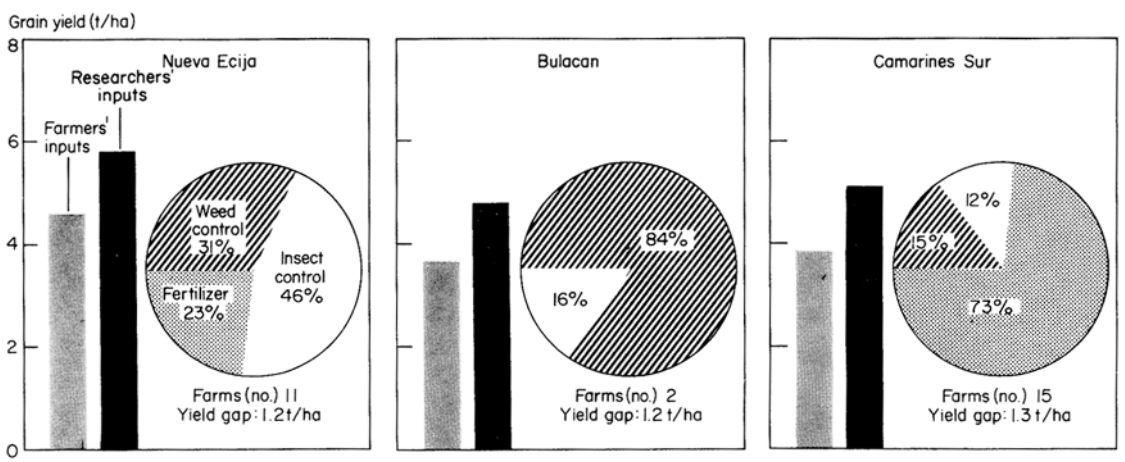
[a]Av no. of mechanical (M) weedings by hand, and chemical (C) herbicide applications. [b]Av no. of foliar (F) sprays (monocrotophos, gusathion, etc.) and granular (G) applications (carbofuran, diazinon, etc.) to floodwater.

In Nueva Ecija, farmers' fertilizer rates averaged 106-14-7 kg NPK/ha (Table 1). Insect control was mainly by foliar sprays with insecticides, averaging 2.2 applications. To control weeds, farmers applied at least one foliar spray of preemergence herbicides. Most farmers grew IR36 at high seeding rates, ranging from 180 to 270 kg/ha.

Farmers' yield averaged 4.6 t/ha while the researchers' was 5.8 t/ha. Improved insect control contributed 46% to the 1.2 t/ha yield gap and improved weed control (granular butachlor at 1.0 kg ai/ha applied 3 d before seeding) accounted for 31% (Fig. 1). High fertilizer use contributed only 23% because the farmers' average N rate was high.

Application of complete fertilizer at 87-13-25 kg NPK/ha yielded an average 5.8 t/ha, similar to yields of NK (5.6) and NP (5.7) treatments. Plots receiving no N yielded 4.0 t/ha. Zero fertilizer and PK treatments produced similarly low yields, suggesting that only N application was necessary to achieve high yields.

Yields responded to applied N (58 kg/ha) regardless of source and application method at both farmers' and researchers' cultural practices. Deep point-placed urea supergranules (USG) produced higher yields than researchers' split-applied prilled urea (PU) or sulfur-coated urea (SCU) broadcast and incorporated. However, USG was significantly superior to PU and SCU only on 2 of 11 farms. Generally, farmers timed N application (15 and 30 d after seeding) as efficiently as did researchers.



1. Av yields with farmers' and researchers' inputs and relative contributions of fertilizer, weed control, and insect control to yield gap on direct-seeded irrigated farms in 3 Philippine provinces, 1984 DS.

Table 2. Input levels in yield-constraint experiments on direct-seeded rice in 3 areas in the Philippines, 1984 WS.

Water regime	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P	K	M	C	F	G
			Nueva Ecija-Pangasinan						
Rainfed	Farmers'	3	46	9	3	0	1.0	1.3	0
Rainfed	Researchers'	3	60	13	25	1.0	1.0	3.0	2.3
			Bulacan						
Rainfed	Farmers'	5	33	9	8	0	1.0	1.2	0
Rainfed	Researchers'	5	60	13	25	0	2.0	2.0	3.0
Irrigated	Farmers'	2	28	7	15	0	1.0	3.0	0
Irrigated	Researchers'	2	60	13	25	0	2.0	2.0	3.0
			Camarines Sur						
Rainfed	Farmers'	8	28	0	0	0.6	1.0	2.1	0
Rainfed	Researchers'	8	60	13	25	1.1	1.5	3.1	3.0
Irrigated	Farmers'	1	40	0	0	0	1.0	2.0	0
Irrigated	Researchers'	1	60	13	25	1.0	2.0	3.0	3.0

[a]Av no. of mechanical (M) weedings, by hand or rotary weeder, and chemical (C) herbicide applications. [b]Av no. of foliar (F) sprays (azodrin, gusathion, etc.) and granular (G) applications (furadan, diazinon, etc.) to floodwater.

In Bulacan, farmers applied an average 52 kg N/ha (Table 1). They averaged 3.5 insecticide foliar sprays and one weed control spray. Yields with farmers' inputs averaged 3.6 t/ha while those with high inputs averaged 4.8 t/ha. High level weed control accounted for 84% of the 1.2 t/ha yield gap and insect control, 16% (Fig. 1).

NPK applications at 87-13-25 kg/ha yielded 4.8 t/ha and PK yielded 3.9 t/ha, similar to the 4.1 t/ha grain yield without fertilizer. Yields did not differ significantly between farmers' and researchers' methods of application of 58 kg N/ha, mostly because of weed regrowth and lack of irrigation water.

Camarines Sur farmers averaged 61 kg N/ha (Table 1), with little use of P and K. Farmers' insect control averaged 1.5 insecticide foliar sprays. Weed control averaged 1.2 applications of preemergence herbicides. Yields averaged 3.8 t/ha with farmers' inputs and 5.1 t/ha with researchers'. Of the 1.3 t/ha yield gap, fertilizer accounted for 73%; weed control, 15%; and insect control, 12% (Fig. 1).

Yields at 87-13-25 kg NPK/ha averaged 5.1 t/ha. Without N, yields averaged 3.3 t/ha, as in plots receiving no fertilizer. Yields from NK and NP combinations were similar to those from NPK, suggesting P and K application is not necessary on these sites.

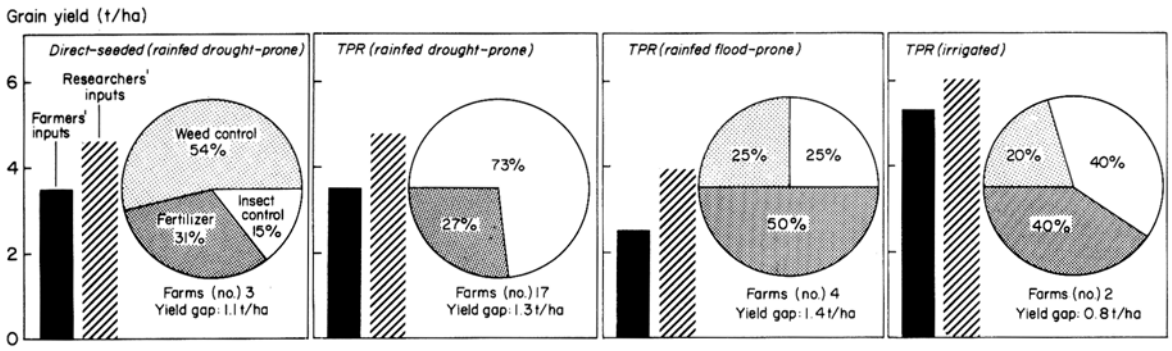
Yields increased substantially with 58 kg N/ha for all N sources and application methods. The researchers' split-applied PU, deep point-placed USG, and basally incorporated SCU yielded similarly regardless of cultural practices. The farmers' split-applied PU yielded lower than the researchers' split by 0.2 t/ha at farmers' cultural practices, and 0.3 t/ha at researchers'.

Rainfed sites, wet season. Wet season (WS) trials in Nueva Ecija were conducted in three drought-prone sites. Farmers' fertilizer levels averaged 46-9-3 kg NPK/ha (Table 2). All three farmers applied herbicides to control weeds. Insect control averaged 1.3 foliar insecticide applications. On farms of direct-seeded rice, yield from farmers' inputs averaged 3.5 t/ha. Improved weed control contributed 54% of the 1.1 t/ha yield gap; high fertilization, 31%; and improved insect control, 15% (Fig. 2). Yield of drought-tolerant IR14753-49-2 was compared with farmers' yields of IR36. The farmers' variety outyielded the promising line by 1.4 t/ha (Table 3).

A separate experiment evaluated response to fertilizer combinations. N was the only fertilizer needed to achieve high yield (Table 4). Zn at 4.5 kg/ha did not increase grain yield.

Methods of applying PU and USG produced different yields. At 58 kg N/ha, USG point-placement by hand and researchers' split-applied PU under good water management produced similar yields, significantly higher than those from farmers' split-applied PU and band placement of PU using spring auger.

The yield gap between farmers' and researchers'



2. Av yields with farmers' and researchers' inputs and relative contributions of fertilizer, weed control, and insect control to yield gap on drought-prone rainfed farms in Nueva Ecija-Pangasinan sites, Philippines, 1984 WS.

inputs in Bulacan was determined from five farms. The farmers' averaged 33 kg N/ha (Table 2). Weed control averaged 1 chemical spray and insect control 1.2 sprays. Yield level and yield gap were lower in direct-seeded than in transplanted rice (TPR) (Fig. 3). High insect control contributed 53% to the 0.3 t/ha yield gap while high fertilizer accounted for 33%. The direct-seeded test cultivar IR14753-49-2 yielded 1.1 t/ha lower than the farmers' variety (mostly IR36) at high inputs and cultural practices (Table 3).

A study on two farms measured yield response to fertilizer combinations and Zn applications. NPK application produced 2.6 t/ha while N alone produced 2.2 t/ha (Table 4). Zn application at 4.5 kg/ha increased grain yield by 0.2 t/ha.

A separate experiment on three farms evaluated methods of applying PU and USG. USG point-placement by hand produced 2.3 t/ha, similar to other methods.

In Camarines Sur, eight trials measured yield gap. Farmers averaged 28 kg N/ha without P and K (Table 2). Three of eight farmers did not apply fertilizer. All farmers used preemergence herbicides; 5 also hand weeded at 20 to 30 d after seeding. Farmers averaged 2.1 insecticide foliar sprays (Table 2). Yields with farmers' inputs averaged 3.8 t/ha. High level and improved application of fertilizer accounted for 75% of the 1.4 t/ha yield gap (Fig. 4). The drought-tolerant IR19743-72-2 had a slight yield advantage over farmers' IR36 at high inputs and cultural practices despite its exposure to

Table 3. Yields of farmers' varieties and test varieties at high levels of inputs on rainfed farms in 3 areas in the Philippines, 1984 WS.

Crop establishment	Water regime	Sites (no.)	Yield (t/ha)		
			Farmers' variety[a]	Test variety[b]	Difference
		Nueva Ecija-Pangasinan			
Direct-seeded	Drought-prone	3	4.6	3.2	−1.4
TPR	Drought-prone	16	4.8	4.8	0
TPR	Flood-prone	4	3.9	3.7	−0.2
		Bulacan			
Direct-seeded	Drought-prone	5	3.3	2.2	−1.1
TPR	Drought-prone	3	4.4	3.1	−1.3
		Camarines Sur			
Direct-seeded	Drought-prone	8	5.2	5.4	0.2
TPR	Drought-prone	2	6.5	5.5	−1.0

[a]Dominant farmers' variety was IR36 in Nueva Ecija-Pangasinan and Bulacan, and IR56 in Camarines Sur. [b]Test varieties were IR14753-49-2 and IR19431-72-2 for drought-prone sites and IR26708-2-2-3-1-P_5 for flood-prone sites in Nueva Ecija-Pangasinan, IR14753-49-2 in Bulacan, and IR19431-72-2 in Camarines Sur.

Table 4. Yield responses to N, P, K, and Zn on rainfed and irrigated farms in 3 areas in the Philippines, 1984 WS.

Crop establishment	Water regime	Sites (no.)	Yield[a] (t/ha)					
			N	NK	NP	NPK	Without Zn	With Zn
		Nueva Ecija-Pangasinan						
Direct-seeded	Rainfed, drought-prone	1	4.6	4.5	4.9	4.6	4.6	4.2
TPR	Rainfed, drought-prone	8	4.8	4.6	4.6	4.7	4.7	4.6
TPR	Rainfed, flood-prone	3	3.7	3.8	3.7	3.6	3.6	3.9
TPR	Irrigated	2	4.6	4.6	4.1	4.0	4.0	4.3
		Bulacan						
Direct-seeded	Rainfed, drought-prone	2	2.2	2.4	2.5	2.6	2.6	2.8
TPR	Rainfed, drought-prone	4	4.3	4.3	4.6	4.6	4.6	4.4
Direct-seeded	Irrigated	1	3.0	2.5	2.9	2.7	2.7	2.6
TPR	Irrigated	2	5.7	5.3	5.2	5.5	5.5	5.2
		Camarines Sur						
Direct-seeded	Rainfed, drought-prone	6	4.5	4.7	4.7	4.7	4.7	4.9
TPR	Rainfed, drough-prone	2	4.8	4.7	5.2	5.5	5.5	5.8
Direct-seeded	Irrigated	3	3.9	3.9	4.0	3.8	3.8	3.8
TPR	Irrigated	1	3.3	3.6	3.1	3.6	3.6	3.6

[a] Fertilizer levels: 60 kg N/ha, 13 kg P/ha, 25 kg K/ha, and 4.5 kg Zn/ha, broadcast and incorporated.

birds due to longer growth duration (Table 3).

Yield response to applied NPK and Zn was evaluated on six farms. The average yield of direct-seeded rice with complete fertilizer (60-13-25 kg NPK/ha) was 4.7 t/ha, similar to yields with NP and NK formulations. N alone gave 4.5 t/ha (Table 4), suggesting it alone produced the high yields. Zn (4.5 kg/ha) did not significantly increase grain yields over untreated plots.

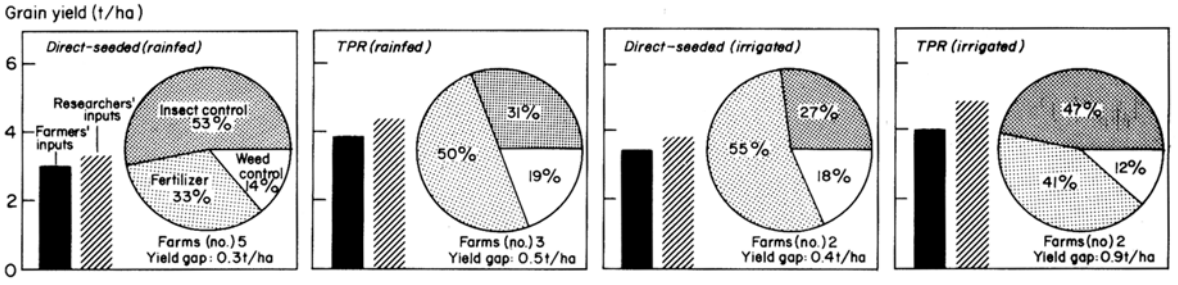
On five farms, neither hand point-placement of USG nor machine deep-placements of USG and PU increased yield over researchers' split application of PU. Completely draining floodwater before incorporating the basal dose of PU did not give higher yield than not draining.

Irrigated sites, wet season. Farmers' averaged 28 kg N/ha on 2 farms in Bulacan. Weed control consisted of 1 chemical spray, insect control of 3 sprays (Table 2). Of the 0.4 t/ha yield gap, improved insect control contributed 27% and high fertilizer, 55% (Fig. 3).

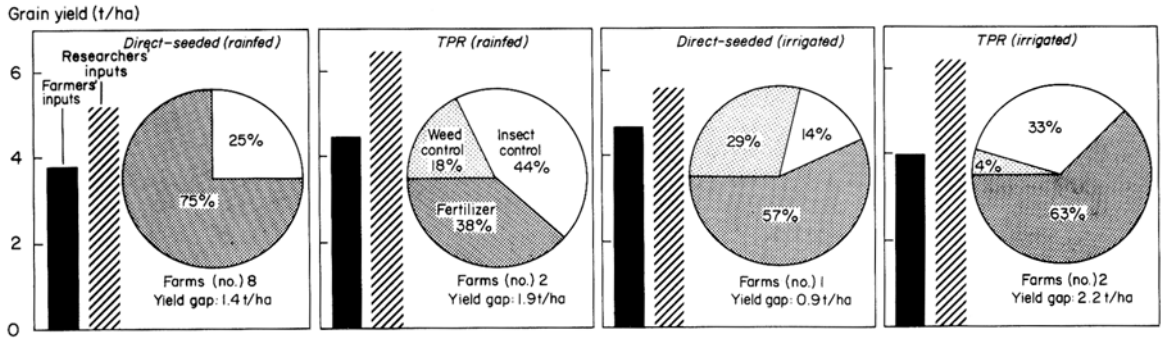
On one farm, yields with NPK were similar to yields without P, K, or PK (Table 4). Zn did not increase grain yield.

On 2 farms, USG point-placement by hand gave 3.1 t/ha, similar to other application methods. PU applied with researchers' split method under farmers' water management yielded only 2.3 t/ha.

In Camarines Sur, one trial involved irrigated direct-seeding. The farmer applied fertilizer at 40 kg N/ha without P or K (Table 2). Yields with farmers' inputs averaged 4.7 t/ha. High inputs increased yield by 0.9 t/ha with more than 50% due to fertilizer (Fig. 4).



3. Av yields with farmers' and researchers' inputs and relative controbutions of fertilizer, weed control, and insect control to yield gap on rainfed and irrigated farms in Bulacan, Philippines, 1984 WS.



4. Av yields with farmers' and researchers' inputs and contributions of fertilizer, weed control, and insect control to yield gap on rainfed and irrigated farms in Camarines Sur, Philippines, 1984 WS.

On three farms, N alone produced yields similar to those with NK, NP, and NPK combinations (Table 4), suggesting that only N is necessary for high yields. Zn did not increase yield.

Trials on three farms evaluated methods of applying PU and USG. Point-placement of USG plus topdressing of PU at 5-7 d before panicle initiation produced 2.5 t/ha. Other methods produced lower yields. PU applied through researchers' split method but under farmers' water management yielded only 1.2 t/ha.

Yield constraints on transplanted rice. *Rainfed sites, wet season.* Seventeen trials on drought-prone and four trials on flood-prone areas were conducted on Nueva Ecija-Pangasinan sites to determine yield gap input contributions. Farmers' average N application equaled the researchers' rate (Table 5). Farmers' insect control averaged 1.4 foliar insecticide applications, and weed control averaged 0.4 application of postemergence herbicides. With farmers' inputs on drought-prone sites, yields averaged 3.5 t/ha, higher by 1.0 t/ha than on flood-prone sites. On drought-prone sites, improved insect control accounted for 73% of the 1.3 t/ha yield gap, and fertilizer contributed 27%. In the flood-prone area, the average yield gap was 1.4 t/ha with fertilizer accounting for 50% and insect control and weed control each contributing 25% (Fig. 2). Farmers in the drought-prone area grew mostly IR36 while in the flood-prone area, the dominant

Table 5. Input levels in yield-constraint experiments on TPR in 3 areas in the Philippines, 1984 WS.

Water regime	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P	K	M	C	F	G
			Nueva Ecija-Pangasinan						
Rainfed	Farmers'	21	57	4	2	0	0.4	1.4	0
Rainfed	Researchers'	21	60	13	25	1.0	1.0	2.7	2.5
Irrigated	Farmers'	2	63	8	10	0	1.0	2.5	0.5
Irrigated	Researchers'	2	60	13	25	1.0	1.0	3.0	2.0
			Bulacan						
Rainfed	Farmers'	3	47	13	7	0	0.7	1.3	0.7
Rainfed	Researchers'	3	60	13	25	0	2.0	2.0	3.0
Irrigated	Farmers'	2	37	11	22	0	0	0.5	0
Irrigated	Researchers'	2	60	13	25	0	2.0	2.0	3.0
			Camarines Sur						
Rainfed	Farmers'	2	14	0	0	0	1.0	1.0	0
Rainfed	Researchers'	2	60	13	25	1.0	1.0	3.0	3.0
Irrigated	Farmers'	2	74	1	0	0	1.5	1.5	0
Irrigated	Researchers'	2	60	13	25	1.0	1.0	3.0	3.0

[a] Av no. of mechanical (M) weedings, by hand or by rotary weeder, and chemical (C) herbicide applications. [b] Av no. of foliar (F) sprays (azodrin, gusathion, etc.) and granular (G) applications (furadan, diazinon, etc.) to floodwater.

variety was IR42. In both areas, farmers' varieties and the test lines IR14753-49-2, IR19431-72-2, and IR26708-2-2-3-1-P_5 produced comparable yields (Table 3).

N was the only fertilizer needed for high yields (Table 4). Zn at 4.4 kg/ha did not increase grain yield in drought-prone sites but increased it by 0.3 t/ha in flood-prone areas.

On 5 farms, yields from researchers' split-applied PU (first N dose applied basally without standing water) averaged 4.5 t/ha and hand point-placed USG averaged 4.4 t/ha. The farmers' split-applied PU produced only 3.8 t/ha. Band-placement of PU with spring auger and deep-placement of USG using press wedge produced low yields because neither machine discharged fertilizer uniformly, suggesting need for mechanical improvements. Tungro virus reduced yields in three of five sites.

Bulacan farmers applied 47 kg N/ha (Table 5). They used both foliar and granular insecticides, averaging 1 application. Weed control consisted of 1 foliar spray. Yield levels and yield gaps were higher in TPR than in direct-seeded rice (Fig. 3). High fertilizer accounted for 50% of the 0.5 t/ha yield gap and high insect control, 31%. The test cultivar IR14753-49-2 yielded 1.3 t/ha lower than the most common farmers' variety (IR36) at researchers' inputs and cultural practices.

N and NK applications yielded 4.3 t/ha while both NP and NPK treatments produced 4.6 t/ha (Table 4). Zn at 4.4 kg/ha did not increase grain yield.

USG point-placement by hand produced 4.1 t/ha while both PU applied with spring auger and researchers' split with farmers' water management produced 3.9 t/ha. Other methods of N application produced lower yields.

In the rainfed areas in Camarines Sur, farmers applied little N, averaging 14 kg N/ha, and no P and K. Weed control consisted of 1 preemergence herbicide application, and insect control of 1.0 foliar spray (Table 5). Yields with farmers' inputs averaged 4.5 t/ha. Improved insect control contributed 44% while high fertilizer accounted for 38% of the 2.0 t/ha yield gap (Fig. 4). The farmers' variety (mostly IR56) outyielded the drought-tolerant IR19743-72-2 by 1.0 t/ha at researchers' inputs and cultural practices because of lodging damage (Table 3).

Yields from NPK averaged 5.5 t/ha. Plots without P and K produced 4.7 and 5.2 t/ha, respectively. With N alone, yields averaged 4.8 t/ha. Results suggest both N and P should be applied to obtain high yield. Zn application (4.4 kg/ha) did not significantly increase yields.

As in irrigated areas, rainfed trials showed that neither hand point-placement of USG nor machine deep-placement of USG and PU increased yield over researchers' split application of PU.

Irrigated sites, wet season. On the Nueva Ecija-Pangasinan test sites, yield gap was determined from two farms. Farmers' N level was similar to that of researchers' (Table 5). Insecticide applications averaged 2.5 foliar sprays, with one farmer adding a granular application. Farmers controlled weeds by at least one herbicide application. Yields from farmers' inputs averaged 5.2 t/ha, lower by 0.8 t/ha than from researchers' inputs. High level of fertilizer and improved insect control each contributed 40% to the yield gap, and weed control 20% (Fig. 2).

In a separate experiment, N alone and NK combination yielded similarly at 4.6 t/ha (Table 4). NP and NPK treatments produced similarly low yields because of rice tungro virus. Applying 4.5 kg Zn/ha increased yield 0.3 t/ha over untreated check, but the increase was not statistically significant.

The researchers' split-applied PU under good water management produced the highest yield of methods evaluated. However, the difference could not be attributed to treatment because rice tungro virus severely damaged one trial.

In Bulacan, farmers applied 37 kg N/ha (Table 5). They did not control weeds, but one of two farmers sprayed foliar insecticide once. High insect control contributed 47% and high fertilizer 41% of the yield gap of 0.9 t/ha (Fig. 3).

Response to N, P, K, and Zn applications was evaluated on two farms. N alone produced 5.7 t/ha while NPK yielded 5.5 t/ha. NK and NP applications produced lower yields (Table 4). Zn did not increase yields.

The farmers' and researchers' split-applied PU with farmers' water management yielded 5.5 and 5.4 t/ha, respectively, higher than yields from other methods.

The yield gap in Camarines Sur was determined from two farms. Table 5 shows input levels. Farmers applied 74 kg N/ha and researchers 60 kg N/ha. Farmers controlled weeds by preemergence

herbicides, averaging 1.5 applications. Insect control averaged 1.5 foliar sprays. Yields with farmers' inputs averaged 4 t/ha. High inputs increased yields by 2.2 t/ha with more than 50% contributed by fertilizer (Fig. 4).

N, P, and K response was not measured because of severe lodging (Table 4). Zn did not further increase yield.

Another experiment showed neither hand point-placement of USG nor machine deep-placements of USG and PU increased yields over researchers' split applications of PU.

SOCIOECONOMIC CONSTRAINTS

Agricultural Economics Department

Socioeconomic constraints often influence the effective use of modern rice technology. Some constraints relate to on-farm profitability of technology and farm-household circumstances, and others operate at the institutional level.

Farmer and researcher technology. Budget analysis of constraints experiments showed that the added output value of researcher practices was $20-190/ha above that of farmers. However, researcher practices cost $150-225/ha more than did farmer practices. Thus, despite generally greater yields, researcher technology was not more profitable than that of the farmers in either the irrigated or rainfed sites in Central Luzon or Bicol regions in either WS or DS.

Table 6 presents benefit-cost ratios of three inputs: fertilizer, insect, and weed control. The B:Cs for researcher weed control practice in wet-seeded rice (WSR) were extremely attractive in DS. In WS, however, the researchers' practice was no more profitable than the farmers' except in rainfed TPR in Camarines Sur and WSR in Nueva Ecija. The researchers' insect control was too costly to generate a higher return than the farmers', while the researchers' fertilizer practice was more profitable than the farmers' in Nueva Ecija in DS and in

Table 6. Economic performance of anticipated high levels of 3 inputs and farmer practices, Philippines, 1984.

Location, water regime, crop establishment	Sites (no.)	Increase or decrease over farmer level					
		Fertilizer[a]		Insect control[c]		Weed control[d]	
		Profit[b] ($/ha)	B:C	Profit[b] ($/ha)	B:C	Profit[b] ($/ha)	B:C
				Dry season			
Bulacan							
Irrigated, WSR	2	−10	neg	40	1.3	33	50.0
Camarines Sur							
Irrigated, WSR	15	12	1.2	−121	neg	23	26.0
Nueva Ecija							
Irrigated, WSR	11	19	3.6	−107	neg	51	50.0
				Wet season			
Bulacan							
Rainfed, WSR	5	9	1.2	−69	neg	−4	neg
Rainfed, TPR	3	41	2.4	−89	neg	−5	neg
Irrigated, WSR	2	1	1.0	−116	neg	−15	neg
Irrigated, TPR	2	39	2.3	−58	neg	−5	neg
Camarines Sur							
Rainfed, WSR	8	32	1.6	−101	neg	−21	neg
Rainfed, TPR	2	61	2.2	−7	neg	34	2.7
Irrigated, WSR	1	−12	0.8	−142	neg	−35	neg
Irrigated, TPR	2	102	3.0	−56	neg	−8	neg
Nueva Ecija							
Rainfed, WSR	3	−6	0.8	−117	neg	38	2.8
Rainfed-bottomland, TPR	5	−13	0.5	−135	neg	5	1.2
Rainfed-plateau, TPR	17	−3	0.9	−53	neg	−21	neg
Irrigated, TPR	2	5	1.2	−91	neg	−2	neg

[a]Researcher fertilizer was 87-13-25 kg NPK/ha in DS and 60-13-25 kg in WS. [b]At rough rice price of $125/t in Bulacan and Nueva Ecija and $123/t in Camarines Sur. neg = negligible. [c]Researcher insect control cost $150/ha in DS and $132/ha in WS. [d]Researcher weed control cost $9/ha in DS and $22/ha in WS.

rainfed and irrigated TPR in Bulacan and Camarines Sur in WS.

Profitability of soil nutrients: N, P, K, and Zn. It was profitable to apply N rates as high as 87 kg/ha to irrigated WSR in Camarines Sur and Nueva Ecija in DS, but only marginally so in Bulacan (Table 7). It was not profitable to apply 60 kg N/ha during WS, nor were P and K applications profitable at 30 kg/ha. Zn application was profitable under rainfed conditions (WSR) in Bulacan and Camarines Sur, and under rainfed-bottomland (TPR) and irrigated (TPR) conditions in Nueva Ecija in WS.

Table 7. Profitability of N, P, K, and Zn application in farm field experiments, Philippines, 1984.[a]

Location, water regime, crop establishment	B:C			
	N	P	K	Zn
	Dry season			
Bulacan				
Irrigated, WSR	1.3	1.1	neg	n. a.
Camarines Sur				
Irrigated, WSR	2.5	0.4	0.3	n. a.
Nueva Ecija				
Irrigated, WSR	2.4	0.6	0.3	n. a.
	Wet season			
Bulacan				
Rainfed, WSR	1.1	1.0	0.6	7.3
Rainfed, TPR	0.8	0.9	0.2	neg
Irrigated, WSR	neg	0.7	neg	neg
Irrigated, TPR	neg	0.7	0.8	neg
Camarines Sur				
Rainfed, WSR	0.4	0.1	0.2	9.4
Rainfed, TPR	1.5	.6	1.0	12.9
Irrigated, WSR	neg	neg	neg	0.1
Irrigated, TPR	0.7	0.2	1.9	neg
Nueva Ecija				
Rainfed-plateau, TPR	neg	0.5	0.6	neg
Rainfed-bottomland, TPR	neg	neg	neg	13.0
Rainfed-plateau, WSR	neg	0.2	neg	neg
Irrigated, TPR	neg	neg	neg	16.2

[a]n. a. = not available, neg = negligible.

Forms and application methods of urea. In DS, deep-placed USG and broadcast SCU usually gave higher net benefits than farmer practice (Table 8). At researchers' weed and insect control, PU under researcher practice, deep-placed USG, and SCU gave similar or higher net benefits than farmer practice for irrigated WSR in Camarines Sur and Nueva Ecija.

During WS, zero N provided highest increase in net benefits over farmer practice in Bulacan, implying unprofitability of applying N at 58 kg/ha (Table 9). In Camarines Sur and Nueva Ecija, PU using the researcher practice, and deep-placed USG plus PU increased net benefits over farmer practice.

Marginal and minimum return analyses were combined to determine whether alternative N technologies provide adequate rates of return and whether the technology is more or less risky than farmer practice. A reasonable rate of return in the study areas should exceed 80%. Deep-placed USG at 58 kg N/ha and PU at 58 kg N using farmer practice appear to be the most appropriate technologies for irrigated WSR in Bulacan and Nueva Ecija (Table 10). In Nueva Ecija, the minimum returns of these treatments exceeded those of the farmer, implying that they were not more risky than farmer practice. Here, minimum return analysis

Table 8. Profitability of various N forms[a] compared with farmer fertilizer practice for irrigated WSR at 3 Philippine sites, 1984 DS.

Location	Net benefit ($/ha)					
	Farmer practice	Zero N	Ordinary PU FS	Ordinary PU RS	USG	SCU
			Farmer weed control and insect control			
Bulacan	125	154	187	134	194	145
Camarines Sur	231	186	−31	69	236	232
Nueva Ecija	219	215	262	275	293	260
			Researcher weed control and insect control			
Bulacan	96	67	99	90	50	55
Camarines Sur	108	31	96	120	110	117
Nueva Ecija	153	87	141	173	183	158

[a]At 58 kg N/ha as ordinary PU at farmers' (FS) or researchers' (RS) level, USG deep-placed by hand, or SCU broadcast and incorporated.

Table 9. Profitability of various N forms[a] and application methods compared with farmer practice, Philippines, 1984 WS.

Location, water regime, crop establishment	Increase or decrease ($/ha) over farmer split						
	Zero N	Researcher split[b]	Researcher split[c]	Ordinary PU DPM[d]	Ordinary PU DPH[e]	USG DPM[f]	USG + Ordinary PU DPH + B[g]
Bulacan							
Rainfed, WSR	28	6	−13	2	3	3	−12
Rainfed, TPR	54	28	−13	37	52	0	−20
Irrigated, WSR	99	8	67	58	67	63	57
Irrigated, TPR	19	−3	−131	−84	−77	−121	−118
Camarines Sur							
Rainfed, WSR	−19	22	17	0	3	2	16
Rainfed, TPR	−73	18	26	−35	18	−35	22
Irrigated, WSR	37	−27	5	18	−4	27	69
Irrigated, TPR	−5	−8	39	−15	13	−24	38
Nueva Ecija							
Rainfed, WSR	−13	44	61	31	51	18	19
Irrigated, WSR	−27	0	76	−60	−19	21	9

[a]At 58 kg/ha N. [b]N applied in 2 equal split doses: basal broadcast and incorporated 5-7 d before panicle initiation and with farmer water management. [c]With researcher water management. [d]Deep placement by machine (DPM) using spring auger. [e]Deep point placement by hand. [f]DPM using press wedge. [g]Broadcast.

supports the result based on rate of return. In Camarines Sur, farmer practice was best under irrigated WSR conditions.

Fertilizer and risk. Some rice experts argue that fertilizer-responsive modern varieties have not realized their potential because farmers seek to avoid the risk associated with applying high-profit N rates. Because farmers cannot predict or control random factors such as pests and weather, they may be reluctant to risk heavy investment in fertilizer.

To test fertilizer risk aversion, a random coefficient model (RCM) was used to estimate the variability in N response of IR36 over time. The model was applied to 7 yr of N response experiments by IRRI's Agronomy Department (Table 11). N response increased at a decreasing rate with maximum yields being achieved at N rates of 109 kg/ha in DS and 81 kg/ha in WS (Fig. 5). In DS, the marginal product at the mean N rate of 84 was 11 kg grain/kg N. In WS at 60 kg N/ha, it was

Table 10. Minimum return analysis of 1984 DS experiments, Philippines.

Location, water regime, crop establishment, N rate	Worst net return ($/ha)	Av of 2 worst net returns ($/ha)	Av of all net returns ($/ha)	Marginal rate of return (%)
Bulacan: Irrigated, WSR				
58 USG[a]	–	–	194	162.5
58 Ordinary PU[b]	–	–	187	81.0
Zero N[c]	–	–	154	0
Camarines Sur: Irrigated, WSR				
87 Ordinary PU[d]	153	154	242	9.8
58 USG[a]	123	141	237	32.9
Farmer practice	165	170	231	171.7
Zero N[c]	143	144	186	0.0
Nueva Ecija: Irrigated, WSR				
58 USG[a]	203	211	294	455.4
58 Ordinary PU[e]	143	165	275	0.0
58 Ordinary PU[b]	148	159	262	115.1
Zero N[c]	83	105	215	0.0

[a]Deep placed by hand, farmer P, K, insect control, and weed control levels. [b]Using farmer method, farmer P, K, insect control, and weed control levels. [c]Farmer P, K, insect control, and weed control levels. [d]Using researcher method, 13 kg P/ha, 25 kg K/ha, farmer weed control, and researcher insect control. [e]Using researcher method, farmer P, K, insect control, and weed control methods.

Table 11. Generalized least squares estimates of quadratic N response function, 1976-82 pooled data.

	Expected value of random coefficient[a]	
	DS	WS
Intercept	3110.75	2724.21
	(71.34)	(50.65)
N (kg/ha)	45.96	32.13
	(2.04)	(2.28)
N squared (kg/ha)	−0.21	−0.20
	(0.01)	(0.02)

[a] Asymptotic standard errors in parentheses. All coefficients significant at the 1% level.

8 kg grain/kg N. Yield variability increased at an increasing rate — faster in WS than in DS.

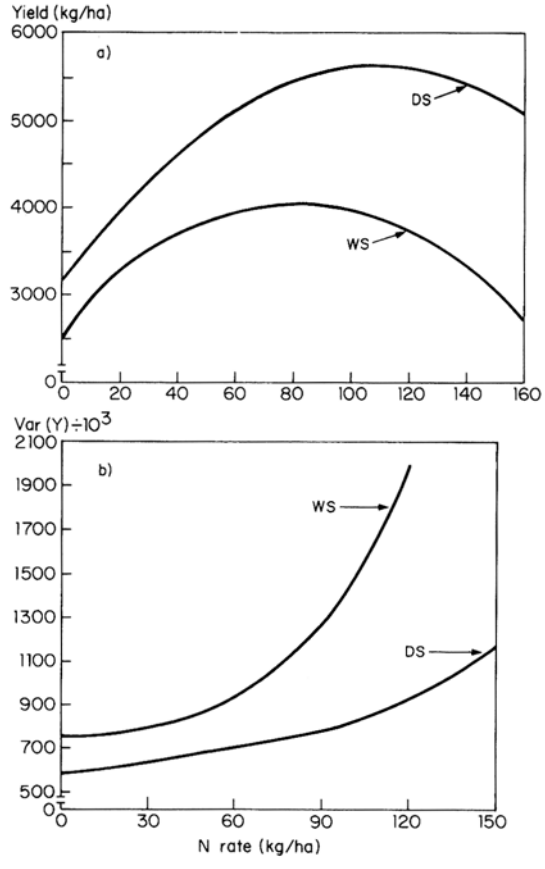
Optimal N rates, using farm-effective prices, were 69 kg/ha in DS and 52 in WS. For moderately risk-averse farmers, optimal N rates were 63 kg N/ha for DS and 46 for WS crops of IR36. Thus, optimal N rates were 9% lower in DS and 12% lower in WS than those of risk-neutral farmers — quite similar to N rates used by farmers in Laguna Province, IRRI's site. Risk-neutral and risk-averse optimal N rates vary little because profit variability increases quite slowly at low to moderate N rates, then quite sharply at high N rates, which are beyond the high profit level (Fig. 5). At lower N rates the rate of profit increase is more than twice the increase in profit variability (measured by its standard deviation), often taken as the cut-off point to make a technology unattractive to most farmers.

Cash constraints and fertilizer use. Only 18% of farmers fertilized their rainfed rice in Bicol. These farmers are poor; about 80% have incomes below the Philippine poverty line. Limited access to cash may constrain fertilizer purchases because rural families often earn income in activities which compete with rice production for scarce capital. Therefore, this research examined cash constraints on fertilizer use by studying the entire household economy of 42 Bicol households.

Competing activities. Nonrice activities accounted for roughly half of the family's annual income. The average household engaged in up to five activities in addition to rice farming. Some, such as pig raising or marketing of paddy or dried fish, required large cash investments and therefore competed with rice production for scarce capital. Such activities might provide quicker returns to investment than rice farming where returns are not realized in less than 4-6 mo. Therefore the analysis measured the level, stability, and immediacy of returns from those activities compared to rice production.

Credit. Eighty-three percent of the sample borrowed funds to finance rice production activities such as land preparation and transplanting (none used fertilizer). Two-thirds borrowed from moneylenders at an average interest rate of 140% a year. Most of this group were heavily indebted, often borrowing 40% of their annual income from 4 to 5 moneylenders. Thus, transaction costs further increased the cost of borrowing.

The remaining one-third of borrowers received loans as inputs and most fertilized rice. These farmers also paid significantly lower interest rates.



5. a) Mean N response function of IR36 in DS and WS. b) Variability in yield of IR36 at various N levels in DS and WS. IRRI, RCM model, 1976-82.

Table 12. Preharvest labor use by activity group and type of labor. Philippines, 1984.

Activity	Preharvest labor[a] (workdays/ha)									
	WSR					TPR				
	Operator	Family	Exchange	Hired	Total	Operator	Family	Exchange	Hired	Total
Land preparation[b]	3.12	3.61	0.29	5.22	12.24 (37.9)	4.40	2.62	0.20	3.97	10.89 (17.5)
Irrigation	5.01	0.79	0.70	0.48	6.98 (21.6)	2.30	0.69	0.00	1.86	4.90 (7.8)
Sowing or transplanting[c]	0.26	0.20	0.78	0.10	1.34 (4.1)	0.06	0.00	0.18	31.48	31.70 (50.5)
Crop care[d]	1.86	1.04	0.50	0.86	4.28 (13.2)	1.26	0.68	0.23	1.36	3.53 (5.6)
Weeding	2.96	2.08	0.62	1.76	7.42 (23.0)	2.89	3.16	0.00	5.67	11.71 (18.6)
Total	13.23 (41.0)	7.72 (23.9)	2.89 (8.9)	8.42 (26.1)	32.26 (100)	10.67 (16.99)	7.15 (11.39)	0.61 (0.97)	44.34 (70.65)	62.77 (100)

[a]Values in parentheses are percentages. [b]Includes seedbed preparation for TPR. [c]Includes pulling and bundling of seedlings. [d]Spraying, broadcasting of herbicide and insecticide.

Some had sufficient collateral to borrow from subsidized credit programs. Others had long-term arrangements with paddy dealers to sell some of their harvest at slightly below the prevailing price.

Seventeen percent of the sample financed rice production with their own resources. These households were relatively well off but did not apply fertilizer regularly. The results generate the hypothesis that fertilizer application may not be profitable given the high cost of borrowing money. Since farmers are already heavily indebted, further borrowing to purchase fertilizer might threaten their solvency.

This research will continue to model the household economy and test generated hypotheses.

Wet-seeded rice and employment. Asian rice farmers have adopted wet seeding of rice because it eliminates transplanting costs, and with currently available herbicides, weeds can be effectively controlled. The real cost of herbicides has fallen compared to labor, and labor costs of transplanting have increased. WSR also allows early crop establishment, thus increasing cropping intensity, rice productivity, and employment in rainfed areas.

Wet seeding is expanding rapidly in irrigated areas, including the Philippines, Malaysia, and Thailand. We studied wet seeding in Central Luzon, the Philippine "rice bowl." Results show minimal crop intensification with similar yields for WSR and TPR. However, WSR required only 32 preharvest workdays per hectare compared to 63 for TPR (Table 12). The biggest labor saving is in crop establishment, but weeding labor also falls.

With WSR, labor shifts from hired to household (Table 13). Hired labor comprised 71% of preharvest labor on TPR farms and 26% on WSR farms. If transplanting and associated activities are excluded, TPR farms still use more hired labor: 41% against 27%. Almost two-thirds of the work force for WSR was provided by the farmer and his resident family, with some exchange labor, especially in seed broadcasting. Given scarcity of off-farm and nonfarm employment in Central Luzon, the opportunity cost of family labor is probably

Table 13. Preharvest labor force with and without transplanting. Philippines, 1984.

Labor	Preharvest labor[a] force (%)					
	WSR			TPR		
	HH	E	H	HH	E	H
Including sowing or transplanting	65	9	26	28	1	71
Excluding sowing or transplanting	66	7	27	57	1	41

[a]HH = household (family) labor, E = exchange labor, H = hired labor.

lower than the wage of equivalent hired labor; hence using family labor reduces the real cost of rice production.

The budget figures for TPR and WSR in the 1984 DS survey confirm trends shown by IRRI's Loop Survey data (Table 14). The 1984 data show slight increases in payments to land, a slight drop in payments to hired labor for TPR, a large reduction for WSR, and large increases in payments to current inputs, especially with WSR. The substitution of current inputs for labor and land is due to farm mechanization, direct seeding, and the adoption of herbicides and pesticides.

Marketing constraints. Farmgate rice prices in Bicol are among the lowest in the Philippines. In 1980-82, they averaged 16% less than prices in Central Luzon, the major rice producing area. Prices were lower in only one other Philippine region, Eastern Visayas. Low prices reduce incentives to adopt new technology. To understand why Bicol prices are low, we studied rice marketing in Camarines Sur Province. We interviewed participants in the marketing chain, including 45 farmer-cooperators.

Of total WS rice output, 21% was paid to harvesters, threshers, or landlords. Another 12% was retained for seed. Home consumption was 33%. This left 34% (a small proportion of output) to market. One-third of farmers sold no rice.

Almost one-half of rice sales were to wholesaler-retailers. These traders mill paddy at a service mill and sell rice to retailers in Naga City or remote, mountainside barrios. One-third is sold to wholesalers owning their own mills. Other buyers are barrio-based assemblers, consumers, retailers, and the National Food Authority (NFA).

Forty percent of farmers chose buyers who offered good prices, but 35% chose buyers who were sources of loans. Fourteen percent said they had access to only one buyer. Only two farmers sold to NFA; those who did not cited the agency's strict quality requirements and practice of paying by check.

Lack of choice of buyers or the tying of sales to loans may contribute to low rice prices. Comparing marketing costs and returns with price margins did not reveal any monopoly profits, however. The return to trader capital averages slightly less than the 23% annual interest traders pay on bank loans.

Table 14. Factor shares in historical perspective, Central Luzon, Philippines, 1970-84.

	Earnings by group or factor					
	Loop Survey				1984 DS survey	
	1970	1974	1979	1980	TPR	WSR
	Factor shares (%)					
Land	25	26	14	12	15	15
Current inputs	9	17	18	22	29	36
Labor	28	40	34	30	25	20
Capital	10	10	20	20	25	20
Residual	28	7	14	17	12	10
	Payments to income groups (%)					
Landlords	23	20	13	11	15	15
Current inputs	9	17	18	22	29	36
Hired labor	16	24	23	22	21	16
Hired capital	4	5	7	5	7	7
Farm family	48	34	39	40	23	21

Thus, marketing costs determine the spread between farm and retail prices. Improvements in transportation infrastructure would reduce margins and allow farmers better access to buyers.

The 29 farmers who sold rice received an average of $0.08/kg paddy, but prices varied widely. Moisture content was the most important price determinant, and lowered price by $0.02/kg. High moisture means weight loss during drying, and deterioration of paddy not dried immediately after harvest. Typhoons and floods worsen harvest quality, and the frequent Bicol storms may contribute to low average prices. Varieties with grain quality that better withstands environmental stress and cheaper means of mechanical drying could help Bicol farmers obtain a better paddy price.

Upland rice. Although upland is only 7% of the total Philippine rice land, it is 20% of the rice area on Mindanao Island.

The Ministry of Agriculture and Food established a multiple cropping production program (MA-MCPP) in Zamboanga del Sur Province in 1979. We conducted a farm-level survey to assess productivity of improved (MV) and local (LV) upland rices, and to examine MV adoption. Three groups of farmers were interviewed: MA-MCPP participants (80), farmers growing MV but not project members (44), and LV growers (55).

Input use. Labor use was significantly higher among program participants (117 d/ha) and MV

growers (106 d/ha) than among LV growers (96 d/ha). Land preparation, weeding, and harvesting and threshing dominated labor use (Table 15). All MA-MCPP cooperators applied fertilizer as did 82% of other MV growers and 35% of LV farms. On the average, cooperators applied 75-15-0 kg NPK/ha, significantly higher than the 54-12-0 kg NPK and 16-4-0 kg NPK applied by the 2 other groups.

Yields. MA-MCPP participants reported significantly higher mean yields (3.3 t/ha) than nonparticipants growing MVs (2.9 t/ha) or LV (1.6 t/ha).

Gross margin. MV-producing owners earned significantly higher gross margins ($70-85/ha) than did tenants producing MVs (about $45/ha), who in turn earned double that of tenants growing LV upland rices (less than $20/ha) (Table 16).

Modern variety adoption. Factors associated with adoption of MVs were analyzed via a probit regression model (Table 17). The model correctly predicted nearly 80% of adopters and nonadopters. Asymptotic t tests showed farm size, landscape position, fertilizer availability, cooperative membership, and extension contact were significantly associated with MV adoption. Institutional aids — access to credit and fertilizer, and extension — enhanced MV adoption.

Farmer impression of modern and local upland rice varieties. Nearly two-thirds of MV growers believed that MVs yielded higher than LVs, but also recognized that LVs realized a higher market price. The main disadvantages of MVs were the high input cost (25% of respondents) and high percentages of brokens in milled rice. The most cited disadvantages of LVs were their low yield and lodging susceptibility. Farmers did not identify short duration as a desirable feature of MV rices.

LV growers reported not growing MVs because they grew rice for home consumption (a quality

Table 15. Labor inputs for upland rice production, by farmer category. Zamboanga del Sur, Philippines, 1983 WS.

Operation	Labor source[a]	Labor input[b] (d/ha)			
		Participant MV growers	Nonparticipant		All
			MV growers	LV growers	
Land preparation[c]	F	20	22	20	21
	H	16	13	12	14
	T	36 a	35 ab	32 b	35
Seeding	F	5	5	6	5
	H	5	4	4	5
	T	10 a	9 a	10 a	10
Fertilizing	F	3	3	2	3
	H	5	1	1	3
	T	8 a	4 b	3 c	6
Weeding	F	12	15	15	14
	H	18	13	11	15
	T	30 a	28 a	26 a	29
Spraying	F	2	2	–	1
	H	–	–	–	–
	T	2 a	2 a	– b	1
Preharvest	T	86 a	78 ab	71 b	81
Harvest and postharvest	F	1	1	2	1
	H	30	27	23	27
	T	31 a	28 ab	25 b	28
Total	F	43	48	45	45
	H	74	58	51	64
	T	117 a	106 ab	96 b	109
Number of farmers		80	44	55	179

[a] F = family, H = hired, T = total. [b] Separation of means in a row by Duncan's multiple range test at the 5% level. [c] Includes labor of a plowman.

Table 16. Gross margin for upland rice production, by tenure status and farm category, Zamboanga del Sur, Philippines, 1983.[a]

	Value ($/ha)					
			Nonparticipant			
	Participant MV growers		MV growers		LV growers	
	Owner	Tenant	Owner	Tenant	Owner	Tenant
Gross benefit	182 a	143 b	168 a	121 c	91 d	71 e
Variable costs						
Nonlabor[b]	52 a	53 a	39 b	25 c	13 d	13 d
Labor/power[c]	38 ab	42 a	38 ab	39 ab	34 bc	29 c
Interest, cash costs[d]	7	8	6	4	3	3
Total variable costs	97 a	103 a	83 a	68 b	50 c	45 c
Gross margin	85 a	40 bc	85 a	53 b	41 bc	26 c

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. [b]Seed, fertilizer, pesticides. [c]Family labor and power valued at hiring rates. [d]Ten percent per crop.

preference), MV inputs cost too much, and growers lacked the technical information and seeds to grow MVs. The high cost of MV production makes farmers hesitate to adopt MV upland rices.

INSTITUTIONAL AND POLICY CONSTRAINTS

Agricultural Economics Department

Fertilizer-rice price ratios in Asia. In developed countries, a high rice price is a major policy instrument for supporting farm income and achieving food self-sufficiency. In less developed countries, where much of the household budget goes to buy rice, low food price dominates rice policy. To offset effects of a low rice price policy, governments often subsidize inputs and provide irrigation, research, and extension services.

Table 18 presents the average levels of fertilizer use, fertilizer-rice price ratios, and impact of policy on prices of fertilizer and rice in selected Asian countries from 1978 to 1982. The price of fertilizer relative to rice is negatively correlated with fertilizer use per hectare. In Thailand where fertilizer use is about 20 kg/ha, fertilizer price is about 400% of paddy price. In Japan and other East Asian countries where fertilizer application is over 200 kg/ha, fertilizer price is only about 70% of paddy price. Farm size, adoption of MVs, the ratio

Table 17. Probit regression coefficients of determinants of MV upland rice adoption in Zamboanga de Sur, Philippines, 1983.

Variable	Coefficient	Standard error	Asymptotic t-values[a]
b_0 Constant	−1.3778	0.4139	−3.33**
b_1 Education	0.0298	0.0420	0.71
b_2 Family labor	0.0487	0.0872	0.56
b_3 Farm size	0.5660	0.3274	1.73+
b_4 Tenure status	−0.3750	−.2432	−1.54
b_5 Landscape position	0.4662	0.2456	1.90+
b_6 Fertilizer availability	0.8344	0.2470	3.38**
b_7 Cooperative membership	1.0333	0.2506	4.12**
b_8 Extension contact	0.4672	0.2801	1.67+
Log of likelihood function (full model)		−76.88	
Log of likelihood function (constant)		−110.42	
−2 log likelihood ratio (df = 8)		67.08**	
Cases correctly predicted (%)		79.33	

[a]**, + imply significant at the 1 and 10% probability levels.

Table 18. Pattern of fertilizer use on rice, fertilizer-paddy price ratio, and nominal protection rate in selected Asian countries, 1978-82.

	Fertilizer (kg NPK/ha)	Fertilizer: paddy price	Nominal protection rate[a] (%)	
			Urea	Rice
Bangladesh	13	1.89	−23	2
Thailand	21	4.46	43	−35
Burma	22	1.81	−74	−49
Philippines	32	3.67	21	−9
India	53	3.0	15	−21
Pakistan	69	2.46	−19	−35
Malaysia	87	1.44	−27	0
Sri Lanka	96	1.95	−37	−23
Indonesia	112	1.52	−44	0
South Korea	244	0.85	47	135
Taiwan	276	1.18	11	37
Japan	356	0.7	92	300

[a] $NPR = \left[\frac{\text{domestic price}}{\text{border price}} - 1\right] \times 100.$

of irrigated area, and other environmental factors also affect the intercountry pattern of fertilizer use.

Price intervention policies affect fertilizer and rice prices. Comparing domestic to border price of rice and fertilizer, measured by the nominal protection rate, indicates the effect of government policies on prices. The border price (i.e., CIF import unit value for importables and FOB export unit value for exportables) represents the price with no government intervention. Distortions in rice prices are usually greater than in fertilizer prices. Therefore, differences in rice prices are more important in explaining fertilizer-rice price ratios across Asia. Japanese farmers receive a price about 300% above world prices. In exporting countries — Thailand, Burma, and Pakistan — farmers are implicitly taxed by 30 to 50%.

Fertilizer use is subsidized in Bangladesh, Burma, Pakistan, Malaysia, Sri Lanka, and Indonesia. However, since fertilizer cost is only 10 to 20% of output value, this subsidy is not high enough to offset the penalty imposed by an implicit tax of 20% or more on the rice price in at least 2 of those countries. Farmers in Thailand, Philippines, and India are penalized both by an undervalued rice price and an artificially high fertilizer price. East Asian farmers also pay a high price for fertilizer, but this is more than offset by the very high protection on rice price.

Except in Malaysia, Indonesia, and possibly Bangladesh, price intervention policies in South and Southeast Asian countries tend to lower incentives in rice production.

Assessing food grain production and demand. IRRI collaborates with the International Food Policy Research Institute (IFPRI) on an Asian Development Bank (ADB)-funded project, Assessment of Food Demand/Supply Prospects and Related Strategies for Developing Member Countries of the ADB.

Projections of production-demand balances. The projections of production-demand balances of foodgrains among the developing member countries (DMC) of ADB show a net production shortfall of over 40 million metric tons in 2000, with deficits in paddy rice, maize, wheat, and pulses and a small surplus in other cereals. Deficits of around 18 million metric tons of paddy rice, 17 of maize, and 4 of wheat are projected. Most of the deficit in paddy rice was projected for India, Indochina, Bangladesh, and Indonesia. Pakistan, Thailand, and Burma were projected to continue accumulating major rice surpluses in 2000.

Taiwan and the Republic of Korea account almost entirely for the large projected deficit of maize in the DMCs as feed demand for maize is projected to expand rapidly in these countries. Deficits of more than a million metric tons were also projected for Malaysia and the Philippines. Thailand is the only DMC with a significant projected exportable surplus in maize. Indonesia and Korea were projected to have wheat production shortfall of over 4 million metric tons. The wheat projections for Bangladesh, Indochina, Malaysia, the Philippines, Sri Lanka, and Taiwan showed deficits more than a million metric tons each.

The Philippine case. Methodology to assess rice production and irrigation investment was developed for the Philippines for application to other DMCs. In the Philippines, modern rice-seed-fertilizer technology and irrigation investments have steadily reduced the private and social costs of rice production so that at current world prices the Philippines can maintain economic efficiency. The Philippines can maintain this relative comparative advantage if it keeps down the real costs in rice production expansion by continuing to improve technology and providing irrigation at reasonable costs.

Table 19. Projected supply-demand balances for milled rice in the Philippines under alternative assumptions.

Assumption	Milled rice (thousand t)			
	Effect on net surplus		Projected surplus or deficit	
	1990	2000	1990	2000
1. Base projection	–	–	-44	-98
2. 20% increase in planned irrigation service area, 1990/91-1999/2000	–	+125	-44	27
3. 20% decrease in planned irrigation service area, 1990/91-1999/2000	–	-125	-44	-223
4. 10% increase in on-going and planned irrigation service area, 1985/86-1999/2000	+48	+115	4	17
5. Completion of all on-going irrigation projects; discontinuation of planned irrigation projects	-53	-699	-97	-797
6. 3% growth in real national income per yr 1981-90 (vs 5% base); growth 5%/yr 1991-2000	+106	+136	62	38
7. 3% growth in real national income, 1981-83; zero growth, 1984-86; 3% growth, 1987-90; 5% growth, 1991-2000	+128	+172	84	74
8. Irrigation investment as in scenario (5); real income growth as in scenario (7)	+75	-527	31	-625
9. 25% increase in annual yield growth through shift of the fertilizer response function	+151	+330	107	232
10. 25% decrease in annual yield growth through shift of the fertilizer response function	-155	-349	-199	-447
11. 5%/yr growth in fertilizer consumption (vs base growth of 2.5%)	+76	+166	-32	-68
12. Displacement of 100,000 ha (1989/90) and 300,000 ha (1999/2000) of DS irrigated rice by maize or other crops	-200	-696	-244	-794
13. Per capita rice consumption of 97.3 kg (1990), 100.0 kg (2000)[a]	-212	-245	-226	-343
14. 25% increase in price of maize relative to price of rice	-571	-892	-615	-990
15. 10% higher rate of growth in population	-147	-338	-191	-436
16. 10% lower rate of growth in population	+145	+324	101	226
17. Income elasticity of demand for rice .15 (vs 0.10 in base)	-66	-189	-110	-287

[a] Normative consumption target, assuming implementation of food subsidy or distribution scheme.

The Philippines also has high potential to produce hybrids and open-pollinated improved maize varieties to meet increasing feed demand. Most crops currently imported, such as maize, soybean, and cotton, have high social profitability, implying economic efficiency if these crops are domestically produced as substitutes for imports.

The current investment program of the National Irrigation Administration (NIA) appears nearly adequate to help rice production meet demand. The base projection, assuming completion of all NIA planned irrigation projects, shows small rice production deficits appearing in 1990, increasing to 98,000 metric tons in 2000 (Table 19). These modest deficits could be turned into small surpluses if irrigation service area would increase by 20% beginning in 1990 or by 10% in 1986.

Projected rice deficits for 1990 and 2000 will become reality with reductions in planned irrigation service, decreases in annual yield growth through shift of fertilizer response function, and increases in the rate of per capita rice consumption, population, and rice income elasticity of demand. Therefore, the most appropriate irrigation investment strategy is to maintain planned levels of funding, but reallocate some funds from reservoir systems to communal systems and national diversion systems. Reductions in funding which would decrease incremental production from irrigation should be avoided.

Consequences of new technology

Agricultural Economics and Cereal Chemistry Departments

CHANGING COMPARATIVE ADVANTAGE IN PHILIPPINE RICE PRODUCTION, 1966 AND 1982 **362**
Analysis of social profitability **362**
CONSUMER DEMAND FOR RICE GRAIN QUALITY IN SOUTHEAST ASIA **363**
CONSEQUENCES OF SMALL FARM MECHANIZATION **365**
Mechanization impact in the Philippines, Indonesia, and Thailand **365**
Impact on production **365**
Impact on employment **365**
Impact on income **366**
Impact of mechanical threshing in the Philippines **366**
EVALUATION OF CONSEQUENCES OF NEW CROPPING SYSTEMS **367**

CHANGING COMPARATIVE ADVANTAGE IN PHILIPPINE RICE PRODUCTION, 1966 AND 1982

Agricultural Economics Department

Technological change, such as rice modern varieties (MVs), reduces the cost of producing a unit of rice by increasing the productivity of land and labor. This will allow rice importing countries to produce rice with fewer domestic resources, and to substitute domestic production for imports. Thus, rice technology can change comparative advantage.

This analysis uses data from surveys of rice production in Central Luzon, Philippines, to estimate social profitability in 1966 and 1982. Social profitability estimates use social prices of inputs and output. Social prices indicate long-run opportunity costs, and can differ, because of government policies or market imperfections, from private prices that farmers pay and receive.

Net social profitability (NSP) is the return to producing a unit of rice after deducting from the value of rice the costs of imported inputs, such as fertilizer, and domestic factors, such as labor and land. Rice and imported inputs are valued at world market prices. An increase in the world price of rice will increase NSP, while increases in costs of imported inputs or domestic factors will reduce NSP. Devaluation of the exchange rate will increase the domestic value of rice, and therefore will increase NSP.

Changes in technology such as MVs or irrigation reduce land and labor needed to produce a unit of rice. This reduces factor costs, and hence increases NSP. With MVs, greater imported input costs reduce the positive impact of greater factor productivity. These costs arise from use of the complementary inputs of fertilizer and irrigation services.

Analysis of social profitability. Results of the social profitability analysis show improved NSP and comparative advantage in irrigated rice production in 1982 compared to 1966 (Table 1). Irrigated rice production had negative social profitability in 1966, indicating that this production system was not a socially efficient means of import substitution.

Rainfed farms show greater social profitability than irrigated farms in both years (Table 1). Because they have no irrigation construction cost, rainfed farms have lower factor costs. However, concluding that irrigation investment was a mistake in social efficiency would be incorrect. Although rainfed rice production in the relatively favorable environment of Central Luzon is socially profitable, it is not possible to expand it because favorable rainfed lands are limited. Thus, additional production must come from more intensive irrigated systems.

The components of changes in NSP for irrigated rice give insight into why NSP for irrigated farms increased over time (Table 2). Technological change increased the productivity of land and labor. The increased NSP due to rising factor productivity was larger than the increase in imported input costs. Further, high world rice prices and peso devaluation helped make irrigated production socially profitable.

Table 1. NSP in Philippine rice production, 1966 and 1982.

	1966	1982
Irrigated farms		
NSP[a] (₱/t rice)	−186	79
Yield (t rice/ha)	1.46	2.85
Rainfed farms		
NSP[a] (₱/t rice)	−85	260
Yield (t rice/ha)	1.55	2.11
Rice border price[b] ($/t)	121	242
Official exchange rate[c] (₱/$)	3.91	9.20

[a]Estimated from the social costs of production. [b]Three-year average of CIF (1966) or FOB (1982) values centered on survey year. [c]From *World rice statistics*, IRRI, 1982.

Table 2. Components of the change in NSP of Philippine irrigated rice production, 1966-82 (₱/t rice).

Change in NSP	265
Due to	
Rice price	752
Imported input costs	−270
Exchange rate	813
Factor productivity	426
Land	261
Labor	195
Capital	−30
Factor prices	−1074
Land	−588
Labor	−486
Other costs	−382

CONSUMER DEMAND FOR RICE GRAIN QUALITY IN SOUTHEAST ASIA

Agricultural Economics and Cereal Chemistry Departments

Asian rice production grew faster than population from 1965 to 1980 as a result of MVs, irrigation, and fertilizer. The real price of rice declined in world markets and several Asian countries. Greater supply and falling prices have increased consumer demand for grain quality and national research program demand for high quality cultivars. Improved cooking and eating quality is a main goal of IRRI's breeding program for irrigated environments in the 1980s.

To gain a better picture of consumer preferences for grain quality, we studied consumer demand for quality. Samples of different grades of rice were collected in major urban markets in the Philippines, Thailand, and Indonesia. Price and advertised variety name were recorded. The samples were then analyzed in the Cereal Chemistry Laboratory at IRRI.

The range of characteristic values available to consumers in each country depends on the rice varieties grown there. Producers choose to plant a rice variety desirable for many reasons besides grain quality. Agroclimatic environment varies in the three countries studied here, and varieties planted vary.

In the Philippines, MVs were planted on 85% of the rice area in 1982. They were primarily IRRI MVs with high (greater than 25%) amylose content. The Philippine samples reflect national statistics: 91% MVs with high amylose content averaging 28% (Table 3).

MVs are also widely adopted in Indonesia, where they grew on 60% of the rice area in 1980. Many MVs grown are locally developed varieties with IRRI parents. The most popular local MVs have intermediate (20-25%) amylose content, rather than the high amylose content of IRRI varieties. Indonesian samples were about half MVs and half traditional varieties (TVs). The MV samples had intermediate amylose, averaging 23%, much lower than in the Philippines (Table 3). Many TV samples were javanicas with short, chalky grains. Thus Indonesian samples, on the average, are bolder and chalkier than Philippine samples (Table 3).

Thailand is the world's largest rice exporter, and world market preferences for long translucent grains and good milling quality strongly influence the domestic market. Because IRRI varieties have grain shorter than 7.0 mm, they are not released directly in Thailand. Rather, Thai scientists use IRRI varieties as parents in crosses to develop semidwarf varieties with the physical grain quality demanded by the world market. MVs released in Thailand were planted on only about 10% of the cultivated area in the late 1970s because they are not suited to the rainfed conditions there. The samples collected in Thai markets had a lower percentage of brokens and longer grains than in the two other countries (Table 3). The samples were all traditional indica varieties and averaged intermediate in amylose content. Many Thai samples were aromatic.

Table 3. Av characteristics of rice samples in the Philippines, Indonesia, and Thailand, 1984.[a]

	Philippines	Indonesia	Thailand
Price (¢/kg)	31.1	43.5	34.7
	(4.3)	(7.1)	(5.0)
Whiteness (%)	42.4	39.4	40.5
	(2.7)	(2.5)	(2.7)
Brokens (%)	42.5	37.7	16.3
	(10.7)	(11.3)	(15.4)
Chalkiness score	3.9	8.0	4.1
	(2.0)	(1.8)	(2.2)
Shape (L/W ratio)	3.2	2.5	3.5
	(0.2)	(0.3)	(0.3)
Amylose (%)	27.8	23.4	23.6
	(2.4)	(2.3)	(4.2)
Gel consistency (mm)	41.1	46.8	56.6
	(10.2)	(8.3)	(14.6)
Alkali spreading value	5.7	5.5	5.1
	(0.6)	(0.7)	(0.8)
Aroma (%)	5.6	11.9	31.4
Samples (no.)	107	118	86

[a] Standard deviation is in parentheses.

Regressions of grain quality characteristics on price showed that quality-screening measures in breeding programs explain 60 to 90% of rice price variation in the 3 countries. Thus, these laboratory measures provide good indicators of consumer preferences. The signs and significance of different characteristics vary among countries, however.

Regression parameter estimates show the implicit value of a one unit change in each characteristic to the consumer (Table 4). In the Philippines, the implicit values of all characteristics are significant except gel consistency and shape. However, there were not enough aromatic samples to accurately

Table 4. Best estimates of implicit prices for grain quality characteristics, 1984.

Characteristic and expected sign	Estimated implicit price (¢/kg) per unit change		
	Philippines	Indonesia	Thailand
Percent whiteness (+)	0.34**	1.14**	0.30**
Percent broken (−)	−0.12**	−0.18**	−0.15**
Chalkiness score (−)	−0.38**	0.00	−0.15
Shape (L/W ratio) (+)	2.85	−4.68*	2.47*
Percent amylose (−)	−1.12**	0.14	−0.02
Gel consistency (mm) (+)	−0.01	0.05	0.02
Alkali spreading value (−)	1.94**	1.92*	−0.04
Aroma (+)	—	9.07**	5.89**
R^2	.71	.64	.89

measure an implicit value for aroma. Consumers show the expected preferences for physical quality and amylose content, but the implicit value of alkali spreading value (negatively correlated with gelatinization temperature [GT]) has an unexpected sign. In this sample of predominantly high amylose rices, amylose content alone explained over 50% of price variation.

Indonesian consumers also strongly prefer better milling quality, particularly white (well-polished) rice (Table 4). Other preferences for physical quality appear to differ from those of other countries. Because Indonesian consumers prefer their traditional javanicas with short, chalky grains, there is a negative implicit value for shape and no significant negative value for chalkiness. As in the Philippines, the positive implicit value for alkali spreading value in Indonesia indicates an unexpected preference for low GT. The implicit value of amylose content in Indonesia is not significant, as in the Philippines, perhaps because most Indonesian samples already have the preferred intermediate amylose content. Therefore, consumers do not value further reductions.

The significance of milling quality characteristics (whiteness and brokens) and shape in Thailand reflects the importance of export demand. Aroma is the only significant chemical characteristic.

A comparison of results across countries reveals demand for better milling quality with similar preferences for whiter (more polished) rice with fewer brokens. Rice breeders could continue to breed for head rice recovery, as with the 1970 release of IR20, a variety with nearly double the potential head rice recovery of the earlier MVs, IR5 and IR8.

The hypothesis that consumers prefer intermediate amylose is generally supported. Philippine consumers clearly do not prefer the high amylose content of IRRI MVs, and want it reduced (Table 4). In Indonesia and Thailand, almost all samples had the preferred intermediate amylose content. Indonesian plant breeders have bred MVs with this characteristic; many Indonesian market samples we collected were locally developed MVs with intermediate amylose content, indicating wide adoption. If IRRI incorporated intermediate amylose into IR varieties, this characteristic would be available to national breeding programs and consumers in more countries.

The estimated implicit prices for grain characteristics indicate how consumer welfare would increase following quality improvement. The consumer benefits from two types of quality changes were estimated, and compared with the costs of research to develop better quality varieties. Research costs are the proportion of the IRRI or national research budget devoted to grain quality. Table 5 shows the internal rate of return to research investment to increase head rice recovery or to reduce amylose content. The results show that

Table 5. Returns to research for quality improvement. IRRI, 1984.

	B:C[a]	Internal rate of return[b] (%)
Past		
Better head rice recovery[c] (Philippines and Indonesia, 1970)	49	61
Less amylose[d] (Indonesia, 1981)	8	37
Future		
Less amylose[e] (Philippines, 1985)	9	29

[a]Full adoption of new variety on MV area assumed complete 5 yr after its introduction. Hence consumer benefits start 5 yr after date of improvement and last for 50 yr. Discount rate of 12% percent was used to obtain present values. [b]The discount rate at which present values of benefits and costs are equal. [c]Costs are 15% of the IRRI budget 1962-69. [d]Costs are Indonesian rice research budget for irrigated lowlands, 1969 to 1981, from Salmon. [e]Costs are 15% of IRRI budget 1969-85.

IRRI's past focus on improving physical quality was appropriate because of widespread, high returns.

As might be expected, the estimated returns to quality improvement are not as large as past estimates of returns to research for increasing rice yields, which ranged from 75 to 87%. Returns to quality are large enough, however, to indicate current underinvestment in such research. Of course, in setting research priorities, returns to quality improvement should be compared with potential returns from other research goals.

CONSEQUENCES OF SMALL FARM MECHANIZATION

Agricultural Economics Department

Mechanization impact in the Philippines, Indonesia, and Thailand. Since 1979, IRRI has studied rice farm mechanization in the Philippines, Indonesia (West Java, South Sulawesi), and Thailand.

Impact on production. Surveys of 350 farm households at each site showed significant differences in per hectare yields between mechanized and nonmechanized farms. Differences could largely be explained by irrigation water availability and by higher input levels, especially fertilizer on mechanized farms. Table 6 shows yields and inputs for Philippine sites.

Except South Sulawesi, all sites were in densely populated areas with little scope for farm expansion.

Cropping intensity was not constrained by a shortage of power. Intensity was largely a result of irrigation, particularly in West Java and the Philippines. In South Sulawesi, however, tractor use increased cropping intensity in rainfed areas.

Impact on employment. Labor for land preparation was significantly lower on mechanized farms. Total labor was slightly higher in dry season on mechanized farms in South Sulawesi and slightly lower in wet season (Table 7). Labor use per hectare was less on large farms (Fig. 1). Mechanized farms were larger than nonmechanized farms. Machines were being substituted for family labor as opposed to hired labor. Demand for hired labor on machine-owning farms declined more than on farms renting machine services. In South Sulawesi, displaced labor was reallocated to other production activities where the marginal product of labor is rising (Table 7).

At all four sites, planting and harvesting generated employment for small farmers and landless labor. In Thailand and the Philippines, mechanical threshing is widespread and threshing labor has decreased significantly. Though privately profitable to owners, these machines were only marginally profitable under social cost criteria.

Table 6. Average yield and levels of material inputs in selected villages.[a] Cabanatuan and Guimba, Nueva Ecija, Philippines, 1979 WS and 1979-80 DS.

	Rainfed				Pump				Gravity					
	Wet		Dry		Wet		Dry		Wet			Dry		
	NM	PM	NM	PM	NM	PM	NM	PM	NM	PM	FM	NM	PM	FM
Yield (t/ha)	1.7	1.8	3.4	2.6	2.6	2.4	3.4	3.9	3.3	3.9	3.8	4.4	4.5	4.5
Material inputs														
Seeds (kg/ha)	100	74	119	106	85	88	105	145	124	123	108	163	140	123
Fertilizer (kg/ha)	104	128	350	321	183	151	375	419	263	228	222	462	295	265
– N	25	29	89	78	43	31	86	107	60	52	52	110	70	65
– P	9	14	31	39	18	19	42	35	16	21	16	38	28	20
– K	4	4	12	3	6	7	16	16	11	9	12	18	12	13
Pesticide costs ($/ha)	5	3	12	12	6	4	11	10	11	11	13	18	13	15
Insecticide	4	3	9	9	6		9	7	10	9	12	18	10	12
Herbicide	1	5	3	2	1		2	3	5	1	1.5	.5	3	3
Percentage farms under controlled irrigation	68	32	62	38	67	33	64	36	4	51	44	4	51	45
Sample size (no.)	77	46	19	15	39	15	25	12	7	79	54	7	78	54

[a] NM = nonmechanized, PM = partially mechanized, FM = fully mechanized.

Table 7. Av labor use in selected villages of Sidrap and Pinrang, South Sulawesi, Indonesia, crop year 1980-81.[a]

Task	Labor use (d/ha)							
	Rainfed				Irrigated			
	Nonmechanized		Mechanized		Nonmechanized		Mechanized	
	WS	DS	WS	DS	WS	DS	WS	DS
Seedbed preparation	3.1	1.7	2.6	3.0	3.3	1.9	2.4	2.9
Land preparation	25.9	24.6	17.2	15.8	28.8	21.4	18.1	21.4
Planting	13.9	16.4	14.7	14.5	19.1	16.9	15.1	17.0
Applying fertilizer	0.5	0.7	1.0	1.1	0.7	0.9	1.0	0.8
Applying pesticide	0.3	1.3	1.3	0.9	1.4	1.6	2.3	2.1
Care and cultivation	12.3	7.0	9.9	12.1	8.0	10.2	7.2	11.8
Harvesting	21.0	17.5	25.4	36.4	32.0	30.4	44.8	32.7
Total	76.9	69.1	72.1	83.7	93.2	83.4	90.7	88.6

[a]Source: Consequences of Small Rice Farm Mechanization project, Indonesian Agency for Agricultural Research and Development.

Impact on income. Income is derived from three sources: on-farm, off-farm (work on other farms), and nonfarm. A multivariate analysis of covariance was performed on the income sources to assess possible mechanization effects.

Farm income from all sources was higher on mechanized than on nonmechanized farms over all levels of irrigation. This is true for both annual and seasonal incomes. At three sites, nonfarm income smoothed seasonal irregularities in farm income. Nonfarm earnings were not strongly related to mechanization levels, but were determined by closeness to urban job opportunities.

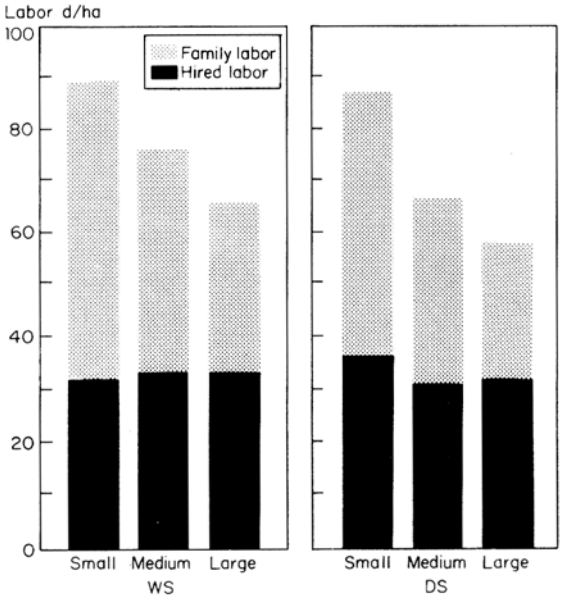
Larger, more mechanized farms had higher farm incomes. Income differences between mechanized and nonmechanized farms were more significant for larger farms, showing economy of scale (Fig. 2).

Cropping intensity contributed to farm income. In the rainfed areas of South Sulawesi, cropping intensity interacted positively with mechanization, suggesting an *enabling* role for mechanized land preparation.

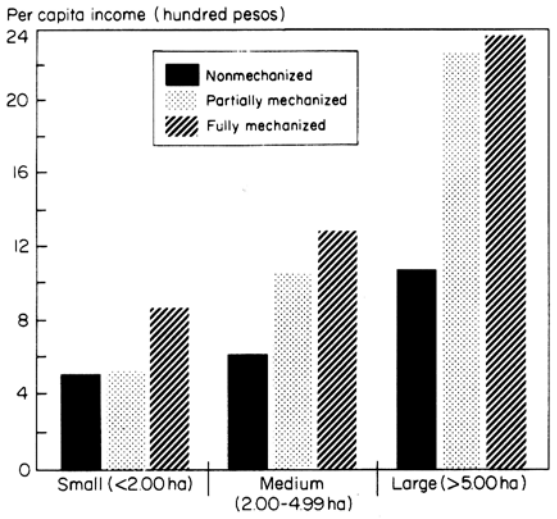
The multivariate analysis showed that mechanization affects the three incomes, partly by releasing household labor for performing off-farm and nonfarm work (Table 8).

For the Philippines and West Java, labor is the most important factor share recipient and any capital for labor substitution has been limited and confined to family and not hired labor. In South Sulawesi, mechanization has not significantly redistributed income away from labor.

Impact of mechanical threshing in the Philippines. A survey of 100 farmers and 100 harvester-threshers was conducted in 6 villages in Central Luzon. At survey time, adoption of small threshers had been complete for 2 yr in the irrigated areas, but was just starting in the rainfed villages. This assessment is confined to irrigated areas.



1. Total labor requirement for rice production by farm size in selected villages. Suphanburi Province, Central Thailand, 1981-82.



2. Per capita income by farm size and mechanization class in rice farm households in selected villages of Guimba and Cabanatuan, Nueva Ecija, Philippines, crop year 1979-80.

Farmers reported these major changes in harvesting-threshing: increased labor by women and younger children, fewer outside workers, and more frequent village meetings to settle sharing rates and wages.

Harvester-threshers believed that mechanical threshers brought more advantages than disadvantages, citing less physical exertion and exposure to the elements and faster operation (Table 9).

The convenience that mechanical threshing provides was reflected in changes in labor composition for harvesting and threshing. For manual beating before mechanization, 82% of the workers were men and only 1% were younger than 15 yr (Fig. 3). With small threshers, women's participation doubled from 18 to 36% while participation by workers below 15 yr rose to 8%. Although the proportion of landless workers remained at 56%, child participation from this class increased from 9 to 11% and those of the small farmer class, from 14 to 20%.

EVALUATION OF CONSEQUENCES OF NEW CROPPING SYSTEMS

Multiple Cropping Department

Evaluation of the impact of new technology usually focuses on changes in production and farm income. Multiplier effects are rarely assessed because it is difficult to trace them through such industries as rice milling, machinery repair, transportation, and agricultural and nonagricultural business. It is also difficult to separate changes in agricultural infrastructure, such as irrigation facilities, and autonomous growth.

Cropping systems research in Iloilo, Philippines, led to changes in technology — chiefly, increased cropping intensity by direct seeding of early-maturing rice varieties. Adoption began in 1975 and

Table 8. Results of multivariate analysis of covariance on the logarithms of on-farm and off-farm or nonfarm incomes of households in selected villages, Sidrap and Pinrang, South Sulawesi, Indonesia, crop year 1980-81.

Overall effect	F-values[a]					
	WS			DS		
	All	Rainfed	Irrigated	All	Rainfed	Irrigated
Mechanization	5.07**	<1	7.23**	<1	1.02	1.39
Irrigation	1.30			4.82**		
Area	20.12***	9.11***	2.37+	41.86***	5.42**	119.94***
Area with mechanization	19.63***	24.57***	1.30	2.87+	<1	8.07***
Area with irrigation	<1			<1		
Household size	<1	<1	<1	<1	<1	1.17
Household size with mechanization	1.70	6.11**	5.23**	<1	<1	<1
Household size with irrigation	<1			<1		

[a] *** significant at 0.1% level, ** significant at 1% level, * significant at 5% level, + significant at 10% level. Source: Consequences of Small Rice Farm Mechanization project, Indonesian Agency for Agricultural Research and Development.

Table 9. Effects of small thresher use on 54 harvester-threshers. Cabanatuan City, Philippines, 1984.

Item	Landless	Small farmer	All
Workers (no.)	44	10	54
	Percent reporting		
Threshing became more convenient.	59	60	59
Threshing operation was faster.	57	40	54
Shares declined sharply.	16	20	17
Shares were received sooner.	11	10	11
Harvesting income increased.	11	20	13
Harvesting income decreased.	4		4

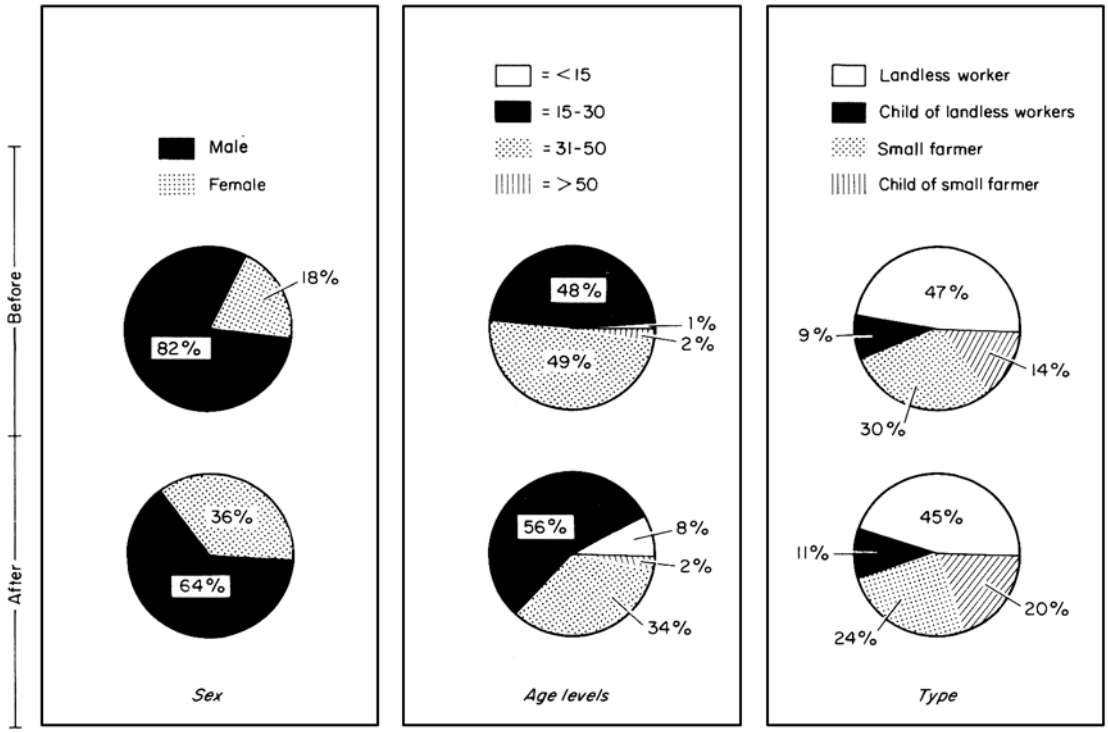
spread rapidly, and irrigation was introduced in 1977 in some areas. To separately measure effects of new technology and irrigation on Oton and Tigbauan municipalities in Iloilo, the economic analysis used an input-output framework.

Structural characteristics of economy sectors before and after development were investigated. The direct and indirect effects on output, income, and income distribution due to the new technology and irrigation projects were analyzed.

Output averaged 9% annual growth and income 6% compared to 5.8% for gross national product (GNP) over the period. Employment increased 3.4% a year compared to the population growth of 2.5 to 3%. Employment increased mainly off farm, in industries indirectly affected by increased production.

Growth was accompanied by structural changes. Agriculture's share of total output declined while that of nonagriculture increased. Agriculture diversified from rice monoculture to various rice-based cropping systems, particularly rice - upland crops. Income increases favored farm households in irrigated and partially irrigated areas, but not those in rainfed upland areas and the nonfarm households.

Consequently, rice production sectors were strengthened relative to those of import and employment. Direct production linkages of sectors within agriculture weakened relative to those



3. Changes in the composition of labor in harvesting and threshing in the Philippines.

between agriculture and nonagriculture. Total linkage indices indicate the development generated strong value-added linkages and income-consumption feedback into the economy and higher multiplier effects, biased toward nonagriculture.

Modern agriculture, requiring industrial inputs usually not available locally, did not hinder the multiplier effects. The impacts of new cropping systems technology and the irrigation program on output and income in the community were enormous, with technology producing twice the impact on output and income as irrigation did.

The indirect benefits went mostly to rice mills, machinery services, and repair sectors.

Because the new cropping systems were highly sensitive to water regimes and also because of the nature of irrigation development, irrigated and partially irrigated households (the relatively better off farm households) captured most of the direct benefit from the development. Moreover, the downstream effects through structural linkages benefited largely the nonagricultural households, the higher income class. As a result, income distribution in the economy was negatively affected.

Results show that agricultural development can substantially benefit nonagricultural services in a rural economy. Even with labor-saving technology such as mechanization, employment growth in a rural economy can keep up with population growth if land use is intensified. Equity of growth and income distribution within agriculture will suffer if development is not adequately directed toward the rural poorest. The situation is worsened by multiplier effects mostly benefiting nonfarm households.

Cropping systems program

Analysis of the physical and biological environment

Multiple Cropping, Agricultural Economics, Agronomy, Entomology, Irrigation Water Management, Plant Pathology, Soil Chemistry/ Physics Departments, and Asian Rice Farming Systems Network

SITE RESEARCH **372**
A partially irrigated rice environment **372**
An upland rice environment **374**

SITE RESEARCH

In 1984, new cropping systems research sites were initiated in Guimba, Nueva Ecija, and in Claveria, Misamis Oriental. The environments in these new sites and the research issues to be addressed differ markedly from those of the previously studied three rainfed lowland sites (Iloilo, Pangasinan, and Cagayan).

In the old sites, limits on intensification are imposed by the field water regime, the effects of puddling on soil properties, and by limited farm resources. The field water regime is determined by rainfall patterns, soil properties, terrain features, and field operations. Strong monsoonal rainfall patterns determine the periods of the year crops can be grown without drought risk. Two crops per year is the practical limit, and wet season (WS) durations range from 6 to 7 mo in Pangasinan and 7 to 8 mo in Iloilo.

A partially irrigated rice environment. In the partially irrigated research site in Nueva Ecija (Central Luzon), in which the Ministry of Agriculture and Food (Region III), the National Irrigation Administration (NIA), the Farmers Irrigation Association, and eight IRRI departments are cooperating, crop intensification remains a central goal but major issues relate to irrigation water distribution and allocation. Table 1 summarizes the physical features of the research area. Major differences in the properties of surface soil on two landforms within the site are in Table 2.

Table 1. Physical characteristics of the cropping systems research target area in Nueva Ecija, Philippines, 1984.

Topography	Broad alluvial plain, with repeating patterns of low rises (*turod*) and shallow swales (*lungog*).[a] Maximum relief is about 1 m, slopes are less than 1%.
Soils	Aeric Tropaquepts; textures range from loams (on rises) to silty clays (on swales); pH are slightly alkaline to slightly acid, CEC range from 22 to 34 meq/100 g soil, available P and K are low.
Climate	Mean monthly temperatures range from 26°C (Jan) to 30°C (Mar). Diurnal variation ranges from 8°C (Jul) to 13°C (Feb). Total annual rainfall is 1,780 mm. The seasonal distribution is typically monsoonal. Monthly totals are greater than 200 mm from Jun to Sep and less than 100 mm from Dec to Apr.

[a]Local terms for land having defined relief patterns.

Table 2. Characteristics of surface soils in 2 landforms.[a] Guimba, Nueva Ecija, Philippines, 1984.

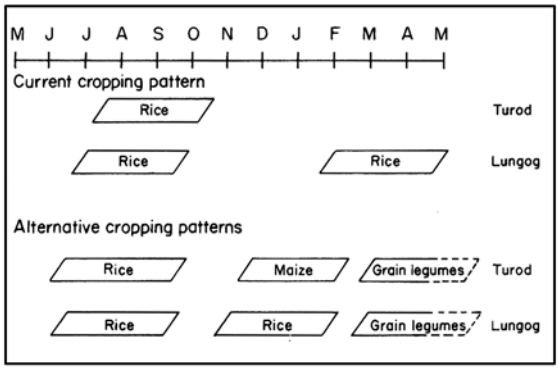
	Turod	*Lungog*
Texture class[b]	Loam	Clay loam to loam
pH (1:1 water)	6.7	7.7
Organic matter (%)	2.3	5.5
Available P (Olsen, ppm)	11	16
Available K (cold H_2SO_4, ppm)	57	35

[a]Means of 4 composited samples from 3 fields. [b]Soil analyzed by NIA Laboratory, Central Luzon State University, Nueva Ecija, Philippines.

In this site, water losses during dry season (DS) rice cultivation are high, especially on the *turod*. Although high seepage and percolation hamper rice cultivation in DS, they also make these soils comparatively favorable for upland crops. Figure 1 shows the rice sequences farmers now cultivate on *turod* (upper) and *lungog* (lower) fields. With adequate water and management, three crops appear possible.

To grow three crops, water now allocated to rice on 40% of the land during DS must be distributed over a larger area. Figure 2 shows when irrigation water will be needed. To produce high yielding DS upland crops in an irrigation system designed for double rice cropping, techniques to distribute water, manage soils, and plant and protect crops must be developed. Production techniques must fit farmers' resources and output must be marketable. Changes in DS water allocation must be made within the framework of irrigators' associations. Irrigation specialists, anthropologists, agricultural economists, and biological scientists are participating to develop and evaluate procedures to induce the institutionalization of improved joint water use decisions by farmers.

The research site, a village within Guimba, Nueva Ecija, was identified in Feb 1984. The 24 farmer-cooperators who are testing alternative cropping patterns have fields located within the 84-ha command area serviced by a deep tubewell. The 35 farmer-cooperators from whom data on farm and household resource flows are being collected operate farms in 4 hydrologic situations. Eight farms are in the command area served by the deep

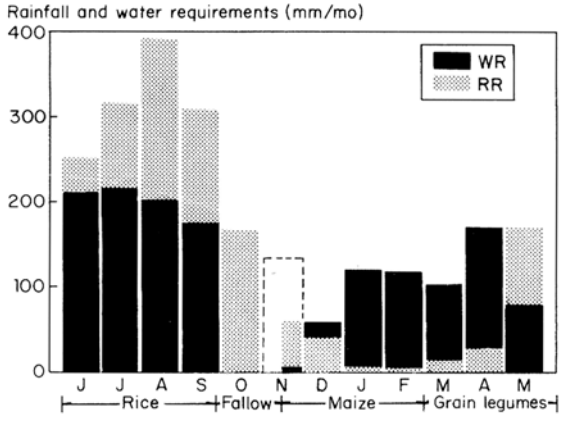


1. Alternative cropping patterns for partially irrigated land in Nueva Ecija Cropping Systems Research Site. *Lungog* land is lower lying than *turod* and therefore easier to irrigate for rice in early DS.

tubewell, 8 are in a communal gravity irrigation system, 7 are served by small, privately owned shallow well pumps, and 12 are operating under rainfed conditions.

Collection and interpretation of secondary data on the physical environment, visits to government offices to obtain demographic information, and interviews with farmers to determine farm resource levels, current production practices, farm output, and social organization were conducted during DS.

In May 1984, a workshop was held at the Maligaya Rice Research and Training Center at Muñoz, Nueva Ecija, to design alternative cropping



2. Monthly rainfall (RR) and estimated water requirements (WR) for a rice - maize - grain legume cropping pattern in the Cropping Systems Research Site, Guimba, Nueva Ecija, Philippines. Irrigation will be necessary to satisfy part of the cropping pattern water requirements.

patterns and outline the research program for the 1984-85 crop year (Jun-May). Table 3 contains the major management practices, estimated material costs, and expected yields for crops tested in rice - rice - upland crop pattern on the *lungog*. Table 4 contains the major management practices, estimated material costs, and expected yields for crops tested in rice - upland rice - upland crop pattern on the *turod*.

Although mungbean and peanut were the only grain legumes tested by farmers during the 1984-85 crop cycle, research plans were outlined for soybean as the third crop for rice - rice - upland crop patterns. A small experiment in 1984 tested responses to inoculation with *Rhizobium japonicum*. Plots were plowed and harrowed using buffalo-drawn implements. Seeds (UPLB-SY2) were planted in rows spaced at 50 cm. Nodules were not formed without inoculant. With inoculant, nodule number and weight did not vary with method and rate. Furrow inoculation, however, increased N concentration in plant tissue. Inoculation increased both the grain and total dry matter yield at maturity. Grain yields averaged 1.5 t/ha with inoculation and 0.5 t/ha without. Yields were not affected by fertilization with 20 kg N/ha.

Because tungro threatened Central Luzon in 1984 WS, each cropping pattern test field was divided and farmer-cooperators planted IR54 and IR56 in addition to IR36 in the *lungog* and IR42 in the *turod*. Yields were similar for varieties and landforms averaging 4.0 t/ha. IR36 was planted in the *lungog* so it would be harvested before WS end, enabling the second rice crop to be started without major irrigation for land preparation.

Responses of rice to N, P, and Zn were determined in the *lungog* and *turod*. The N-P experiments received 20 kg $ZnSO_4$/ha and the Zn experiments received 70 and 13 kg N-P/ha. Within each landform, experiments were transplanted on the same field. N increased grain yield in the *turod* but not in the *lungog*. Grain yield showed no response to P on either landform. Although 20 kg $ZnSO_4$/ha had been applied on the N-P experiment in the *lungog*, Zn deficiency symptoms were visible. Zn increased grain yield on the *lungog* by 1.1 t/ha. On the *turod*, yields were 0.4 t/ha higher where Zn was applied, but the difference was not statistically significant.

An upland rice environment. At the upland research site in Claveria, Misamis Oriental (northern Mindanao), crop intensification is the central goal also, but research needs differ from those in Nueva Ecija. The project seeks to determine the acceptability of state-of-the-art technology for growing sequences of upland rice and associated crops. Seven IRRI departments and the MAF (Region X) are cooperating. Physical features of the site are in Table 5. The potential growing season is long, but soils are low in fertility. Surface soil chemical and textural data from two fields are in Table 6. Samples from 130 fields showed that 75% of the surface soils had pHs below 5, available P

Table 3. Cultural practices for crops included in rice - rice - upland crop pattern being tested on the *lungog* landform, Guimba, Nueva Ecija, Philippines, 1984.[a]

	First TPR	Second TPR	Maize	Mungbean
Variety, field duration	IR36, 90 d	IR36, 90 d	Hybrid, 105 d	Pag-asa, 80 d
Establishment period	10-30 Jun	1-15 Oct	15 Jan-10 Feb	15 Jan-10 Feb
Hill or row spacing	20 X 20 cm	20 X 20 cm	75 cm bet. rows	40 cm bet. rows
Seedlings/hill or plant density	2-3 plants/hill	2-3 plants/hill	50,000-60,000 plants/ha	225,000-250,000 plants/ha
Fertilizer (N-P-K kg/ha)	70-13-0	70-13-0+Zn (10 kg/ha)	80-13-0	None
Tillage	Plow and puddle	Plow and puddle	Plow and harrow once	Plow and harrow twice
Weed control	Thorough land preparation fb butachlor 0.6 kg ai/ha 3-4 DT	Same as first TPR	None	None
Insect control	Economic threshold	Same as first TPR	Detassel + furadan	4 sprays
Disease control	None	None	None	None
Irrigation	Monitor rainfall, suspend pumping when not needed	Same as first TPR	3-4 times	1-2 times
Estimated total material cost ($/ha)	79	79	92	16
Expected yield (t/ha)	4.5	3.5	6.5	1.1

[a]TPR = transplanted rice, fb = followed by, DT = days after transplanting.

Table 4. Cultural practices for crops included in rice - upland crop - upland crop pattern being tested on the *turod* landform, Guimba, Nueva Ecija, Philippines, 1984.

	First crop TPR	Maize	Peanut	Mungbean
Variety, field duration	IR42, 115 d	Hybrid	CEC 101	Pag-asa, 85 d
Establishment period	10-30 Jun	1-20 Nov	15 Feb-5 Mar	15 Feb-5 Mar
Hill or row spacing	20 X 20 cm	75 cm bet. rows	40 cm bet. rows	40 cm bet. rows
Seedlings/hill or plant density	2-3 plants/hill	50,000-60,000 plants/ha	150,000-160,000 plants/ha	225,000-250,000 plants/ha
Fertilizer (N-P-K kg/ha)	70-13-0+Zn (10 kg/ha)	None	80-13-0	None
Tillage	Plow and puddle	Plow and harrow	Zero tillage (rolling injection planter)	Zero tillage (rolling injection planter)
Weed control	Thorough land preparation fb butachlor 0.6/8 ai/ha, 3-4 DT		None	None
Insect control	Economic threshold	Interrow cultivation Detassel and furadan	None	4 sprays
Disease control	None	None	None	None
Irrigation strategy	Monitor rainfall, suspend pumping when not needed	3-4 times	2-3 times	1-2 times
Estimated total material cost ($/ha)	79	92	11	16
Expected yield (t/ha)	4.5	6.5	1.8	1.0

Table 5. Physical characteristics of the cropping systems research site in Claveria, Misamis Oriental, 1984.

Topography	Rolling volcanic ash deposits, deeply incised by streams. Lowest section within the site area is 390 m and the highest is 560 m.
Soils	Oxic Dystropepts; textures range from clays to silty clay loams, pHs in the range 4.0 to 5.0 are most common, but some exceed pH 5.0 CECs are less than 7 to 10 meq/100 g soil. Available P is below the critical level for crops being tested.
Climate	Mean monthly temperatures range from 22°C in Jan to 24°C in May. Diurnal variation ranges from 5 to 7°C. Total rainfall is 2200 mm. Totals are greater than 200 mm from Jun to Nov and less than 100 mm in Mar and Apr.

Table 6. Chemical characteristics of soil profiles at Ane-i and Patrocinio, Claveria, Misamis Oriental, Philippines, 1984.

Chemical and textural analyses	Ane-i		Patrocinio	
	0-15 cm	15-95 cm	0-10/18 cm	10/18-140 cm
pH 1:1/0.01M $CaCl_2$	4.3	4.2	3.9	4.2
Organic C (%)	2.21	0.70	2.12	0.67
Total N (%)	0.21	0.07	0.21	0.07
Exchangeable bases (meq/100 g ads)				
Na	0.02	0.02	0.02	0.03
K	0.59	0.05	0.40	0.05
Mg	0.45	0.32	1.36	1.06
Ca	2.98	0.87	2.50	2.45
CEC (meq/100 g ads)	12.45	7.51	15.90	11.60
Available P (ppm)	5	3	1.0	0.1
Particle size analysis (%)				
Clay	72	86	77	86
Silt	24	13	19	12
Sand	4	1	4	2

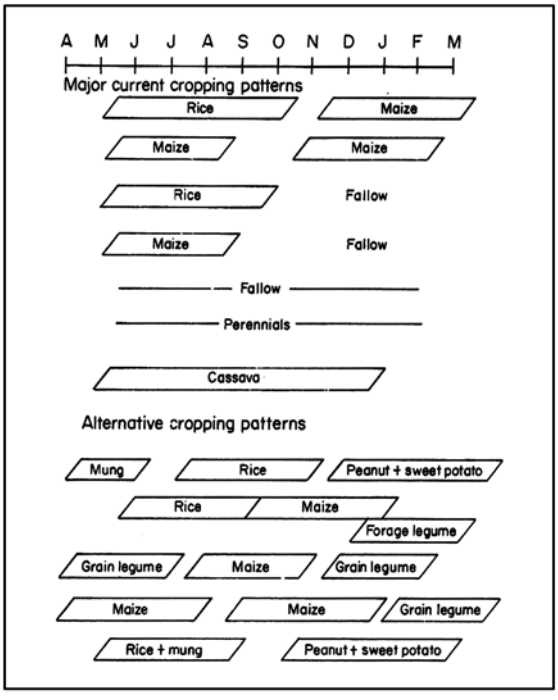
(Olsen) less than 15 ppm, and exchangeable K less than 0.26 meq/100 g air-dry soil.

Current cropping intensity is 1.2, but rainfall is adequate for 2 or 3 crops on most land. Present rice yields average 1.5 t/ha and maize yields 1.2 t/ha. These crops respond well to N, but few farmers apply it. Current major and alternative cropping patterns appear in Figure 3. Production practices for crops in alternative patterns are summarized in Table 7. With one exception, patterns tested require only changes in rice and maize varieties and the addition of a grain or forage legume. These patterns,

Table 7. Cultural practices for crops included in cropping patterns being tested in crop year 1985-86,[a] in Claveria, Misamis Oriental, Philippines, 1984.

	Rice	Maize	Mungbean	Cowpea	Peanut	Sweet potato
Variety	UPL Ri7	DMR-2	Pag-asa	IT 82D-889	UPL PN2	Local
Land preparation	3-4 plowings fb 3-4 harrowings	2 plowing fb 2-3 harrowings for 1st crop, none if 2d crop	2 plowings fb 2-3 harrowings	2-3 plowings fb 2-3 harrowings	1 plowing fb 3 harrowings	1 plowing fb 3 harrowings fb ridging
Seeding rate	100 kg/ha	20 kg/ha	18 kg/ha	20 kg/ha	45 kg/ha	Cuttings
Plant density or row spacing	30 cm	50,000 plants/ha (50-cm rows)	50 cm 250,000 plants/ha	50 cm 250,000 plants/ha	200,000 plants/ha 50 cm	33,000 plants/ha 1 cm
Fertilizer[b] (kg N-P-K/ha)	50-11-0	50-11-0	0-20-0	0-20-0	0-13-0	30-13-25
Weed control	Interrow cultivation at 14 and 35 DE	Interrow cultivation at 14 and 28 DE	Interrow cultivation at 15 and 30 DE	Interrow cultivation at 15 and 30 DE	Interrow cultivation at 14 and 28 DE	Hand weeding at 15 DE, hilling up at 30 DE
Insect control	Economic threshold	Economic threshold plus detasseling 4 of 6 rows after pollen shed	Furadan (0.75 kg ai/ha in seed furrow	Furadan (0.75 kg ai/ha in seed furrow	None	Rotate fields
Disease control	None	None	None	None	Daconil 50 WP 2.2 kg ai/ha at 35 DE	None
Expected yield (t/ha)	3	3	1	1.3	3	15

[a] Cultural practices for forages will be determined after the 1984-85 DS experiments are completed. DE = days after emergence. [b] 3 t lime/ha applied if first crop in the sequence.



3. Major current and alternative cropping patterns to be tested in crop year 1985-86 in Claveria, Misamis Oriental, Philipppines.

however, will require more labor, animal traction, and cash inputs than most current patterns.

The exception is the bottom cropping pattern on Figure 3. It requires intercropping and relay cropping, practices not common in the area to the degree imposed in this pattern. Cash costs for this pattern are low. Furthermore, crops in this pattern keep soil covered almost continuously once the rice - mungbean canopy has developed, and so minimize erosion.

In researcher-managed experiments in 1984 WS, two upland rice yield nurseries were planted on soils in fields adjacent to those described in Table 6. Within each field, yields were highly variable. At Ane-i, mean yield from the 6 most productive entries was 2.8 t/ha (range 2.6-2.9), and the yield of the local check (Dinorado) was 1.9 t/ha. At Patrocinio, mean yield from the 6 most productive entries was only 1.7 t/ha (range 1.5-2.1) and Dinorado, 1.0 t/ha. Entries most promising in the more favorable field (Ane-i) were UPL Ri-5, IR6023-10-1-1, C924-9, C732-14, IAC #1246, and IR10068-18-2. In the less favorable field (Patrocinio), promising entries were IR1078-75-3-0-2, IRAT104, IR8098-41-3, TOX #1785, IAC #1246, and ITA #186. Only IAC #246 was a top entry in both fields.

In five fertilizer trials, rice responses to the amendments tested (N, P, K, and lime) were not stable across locations. Nutrient interactions were important and variability within fields was high. Mean yields ranged from 0.3 to 2.1 t/ha and the root mean square error ranged from 0.17 to 0.55 t/ha.

Cropping systems program

Analysis of the social and economic environment

Agricultural Economics Department

AGROECONOMIC PROFILE OF GUIMBA, NUEVA ECIJA, PHILIPPINES, RESEARCH SITE **378**
- Physical description **378**
- Off-farm resources **378**
- On-farm resources **378**
  - Farm household characteristics **378**
  - Farm characteristics **379**
  - Credit practices **379**
  - Cash resources **379**
  - Other farm assets **379**
- The cropping system **379**
  - Crops cultivated **380**
  - Cropping patterns **380**

FARMERS' ASSESSMENTS OF CROPPING PATTERNS AT GUIMBA, NUEVA ECIJA, PHILIPPINES **380**
- Patterns on low-lying land **381**
- Patterns on elevated land **381**
- Summary of reasons for farmers' choices **381**

AGROECONOMIC PROFILE OF GUIMBA, NUEVA ECIJA, PHILIPPINES, RESEARCH SITE

Farm-level agroeconomic data were gathered through a baseline survey of all 54 farm operators served by the National Irrigation Authority (NIA) P-27 deep tubewell pump system in the villages of Bantug and Banitan in Guimba in 1983 dry season (DS) and wet season (WS). Secondary data were also analyzed.

Physical description. At longitude 120° 46' E and latitude 15° 42' N, the project area is a 20,000-ha rectangle bounded by the Rio Chico, Ilog Baliwag, and Casanova River on the east, Baloy River on the west, the 70-m elevation topoline on the north, and the 30-m topoline on the south.

The major soil, identified by the Bureau of Soils as Code 5 - Quingua silt loam, is medium textured. The P-27 site has flat plains (*turod*) and bottomlands (*lungog*).

The area's climatic classification is D3 (3.4) with >200 mm monthly rainfall June-September, and <100 mm December-April.

The area is served by 20 of the 24 deep tubewell pump systems of the NIA, plus 3 communal gravity systems (CIS) — the Guimba CIS, the Catimon CIS, and the Nagpandayan CIS. Many farms also have shallow well systems — 1,854 registered units as of March 1984.

Off-farm resources. Based on Provincial Development Staff calculations, the agricultural crops in deficit, indicating potential local market, are maize; leafy vegetables like cabbage; fruit vegetables like ampalaya, patola, okra, and pepper; and the legume mungbean. Even those in surplus like the fruit vegetables such as eggplant, tomato, squash, and cucumber, and the root crops like onions, camote, cassava, gabi, and garlic, may have a market in Metro Manila. The Regional Director of the National Food Authority has also assured an unlimited market outlet for maize at $0.08/kg, sorghum at $0.05/kg, soybean at $0.10/kg, mungbean at $0.19/kg, and peanut at $0.20/kg.

Storage and rice milling facilities seem adequate. Threshing, drying, and grinding capacities may, however, become limiting with extensive maize, sorghum, and soybean production.

On-farm resources. *Farm household characteristics.* Table 1 shows the average farm operator was a 39-yr-old male with about 8 yr of formal education,

Table 1. Selected characteristics of farm families in Bantug service area, Nueva Ecija, Philippines, 1983.

Particulars	Farm size class (ha)			All classes (ha)
	0 to 0.99	1 to 1.99	2 & above	
Respondents (no.)	9	30	15	54
Spouses (no.)	6	30	15	51
$\bar{X}$ Dependent children	2	4	4	4
$\bar{X}$ Family members	4	6	6	6
$\bar{X}$ Age				
Operator	31	39	48	39
Spouse	32	37	45	39
Dependent child	6	9	19	11
Years of education				
Operator	7	8	8	8
Spouse	6	7	7	7
Dependent child[a]	3	4	8	6
Farming experience of operator (yr)	10	17	27	18
Labor availability (d/mo)				
Operator	26	27	28	27
Spouse	2	4	–	3
Dependent child	3	12	22	13
Decision-maker (no. responding)				
Farm operations:				
Operator only	8	25	5	38
Jointly with spouse	1	3	9	13
Family income allocation				
Spouse only	5	17	6	28
Jointly with operator	–	17	6	18
Operator only	4	1	3	8

[a] Majority still in school.

Table 2. Selected characteristics of farm types in the Bantug service area, Nueva Ecija, Philippines, 1983.

Particulars	Farm size class (ha)			All classes
	0 to 0.99	1 to 1.99	2 & above	
$\bar{X}$ Total farm area (ha)	0.55	1.26	3.22	1.69
$\bar{X}$ Total area cultivated	0.46	1.25	3.01	1.61
$\bar{X}$ Parcels (no.)	1.22	1.20	2.07	1.44
$\bar{X}$ Area of parcels (ha)	0.56	0.68	1.51	1.14
Tenurial arrangement by parcel (%)				
Owned	55	44	48	47
Rented	27	44	36	39
Share cropped	18	3	6	6
Amortizing owner	–	9	10	8
Comparative irrigation service (%)				
Better	73	56	52	56
Same	27	22	10	18
Worse	–	22	38	26
Soil texture (%)				
Heavy	18	14	3	10
Medium	64	72	87	77
Light	18	14	10	13

and 18 yr of farming. The spouse had similar age and education. The family averaged 4 dependent children at home, average age 11.

Farm operators, except 2 with other employment, worked 27 d/mo on the farm. Spouses, however, were available for farm work only 3 d/mo. Nonschooling dependent children provide up to 13 d/mo.

Twenty-two operators, 11 spouses, and 2 dependent children held nonfarm jobs such as tricycle drivers, vendors or storekeepers, carpenters, government employees, and mungbean dealers.

The farm operator was most often the sole decision maker for farm operations, as was the spouse for family income expenditures. In one-fourth of the households, however, farm operation decisions were made jointly with the spouse, while a third of family financial decisions were made jointly.

Farm characteristics. Farm size ranged from 0.25 to 4.66 ha, averaging 1.69 ha (Table 2). Usually 1 or 2 parcels are cultivated, each averaging 1.14 ha. Most operators perceived their farms to have medium soil texture.

The typical operator owned and rented cultivated land. A few parcels, however, were cultivated under share tenancy.

Credit practices. Eighty-five percent of the 54 operators used 95% of credit for farm operations. Half the loans came from private lenders; one-fourth each from the Land Bank (LB) and the Philippine National Bank (PNB). More of the smaller operators patronized private lenders; those with holdings >2 ha borrowed more frequently from the PNB.

Loans averaged $126/farm. Annual interest ranged from 6% for LB and PNB, to 120% for private lenders. The average was 36% overall: 60% for private lenders, 11% for LB, and 12% for PNB. Loan term averaged 5 mo.

Cash resources. Only one-third of the 54 farmers had surplus cash available from previous crops or income saved to cover expenses of succeeding crops. The amount of previous farm income set aside was based not on size of farm income, but on expected expenditures for the next cropping. Less than 12% of nonfarm income was used for farming operations.

Other farm assets. A typical farm operator had one draft carabao with a plow, harrow (suyod), and a manual backpack sprayer. Some farmers had a lithao (paragos), a sled or a cart or both. A few had more than one carabao and associated implements, shallow well pumps, hand tractors with implements, and even a power minithresher.

Livestock raised by operators had average value of $260. The highest valued animal was the carabao, followed by swine, cattle, goats, and poultry.

Tree crops were unimportant, contributing less than $2 in annual gross receipts to average farm income.

The cropping system. Four types of cropping

systems were in use: rice - fallow (26% of farms), rice - rice (54%), rice - fallow/rice - vegetables (9%), and rice - rice/rice - vegetables (7%).

Crops cultivated. More than 95% of the farm area was planted to crops, with rice the major crop in WS and DS. The whole 87 ha cultivated was planted to rice in WS. In DS, 2.6 ha was planted to upland crops and 41 ha to rice.

IR36 was the dominant variety in both seasons. IR42 was also widely planted, with six other modern varieties and a local variety.

Planting time was mid-July but ranged from May to September for WS. DS rice was planted from December to February, usually in mid- to late January.

Rice yields averaged 3.2 t/ha (Table 3). Yields were 0.4 t/ha higher in WS than in DS, and higher on smaller farms.

Cropping patterns. Fully 50% of the farm area was occupied by the rice - fallow pattern, followed by rice - rice on 42%. By percentage of farm operators, 54% implemented rice - fallow and 63% rice - rice (Table 4).

Overall multiple cropping index (MCI) was 140, i.e. an average of 1.4 crops/yr (Table 4). The rice - rice pattern contributed most to MCI overall and in all farm classes.

Table 3. Rice yield by variety and season in the Bantug service area, Nueva Ecija, Philippines, 1983.

Varieties	Rice yield (t/ha) in given farm class size			
	0 to 0.99	1 to 1.99	2 & above	All classes
Wet season varieties				
IR36	4.6	2.8	3.4	3.3
IR42	4.4	3.6	3.8	3.8
IR52			3.6	3.6
IR50		3.3	3.8	3.4
IR58		1.6		1.6
Other modern varieties		2.7	5.4	4.5
Fancy	___	3.1	___	3.1
Subtotal	4.4	3.1	3.4	3.4
Dry season varieties				
IR36	4.2	2.4	3.8	3.7
IR52			3.1	3.1
Other modern varieties	___	1.9	2.6	2.3
Subtotal	4.2	2.2	3.4	2.9
Two-season average	4.4	2.9	3.4	3.2

Table 4. Number of farm operators planting different cropping patterns in the Bantug service area, Nueva Ecija, Philippines, 1983.

Cropping pattern	Farm size class (ha)		
	0 to 0.99	1 to 1.99	2 & above
Idle	11	3	13
Rice – fallow	22	53	73
Rice – rice	67	50	87
Rice – vegetable[a]		22	37
Fallow – ampalaya		3	
Fishpond	11	___	7
Total[b]	111	131	217

[a]Ampalaya, eggplant, gabi, mungbean, squash, stringbean, tomato. [b]Many farm operators implemented more than one cropping pattern.

FARMERS' ASSESSMENTS OF CROPPING PATTERNS AT GUIMBA, NUEVA ECIJA, PHILIPPINES

When the service area of deep well pump P-27 at Bantug in Guimba, Nueva Ecija, was selected as IRRI's new on-farm cropping systems research site, researchers decided to find out farmers' opinions of the designed cropping patterns and reasons for those opinions. Farmers were eager to participate, anticipating free inputs and advice, irrigation water delivery, and harvests from the 1000-m^2 plots.

Farmers were concerned about water delivery because they had not been able or willing to pay at least 90% of the irrigation fee, and the system was on the verge of being shut down. With IRRI's on-farm research, farmers thought the pump would remain in operation. Because of anticipated benefits, we feared farmers would be biased toward the IRRI cropping system proposals.

To ascertain farmer opinions, we had open discussions with members of 16 households, selected from the 57 having land in the service area. The 16 households were chosen from categories of farm size, tenurial status, and location in the service area; 8 of the heads knew that they were prospective cooperators; the remaining 8 knew they were not selected.

We have data on agricultural motivations and activities collected previously from most of the households.

We also discussed alternative cropping patterns with key informants having land in or near the service area of pump P-27.

Preliminary findings follow. For the cropping patterns to be tested, see the section Analysis of the Physical and Biological Environment.

Patterns on low-lying land. Of the 16 farmers, 9 indicated clear preferences for one or more patterns.

Three cultivators favored *rice - rice - mung*. Two said their soil (clay) did not suit maize or peanut. The third valued rice above any upland crop, and grew rice three times a year on part of his land. Rice, he maintained, requires less attention than upland crops, and upland crops are easily stolen.

The farmer selecting *rice - rice - maize* deemed his land too wet for mung and peanut, and foresaw a problem in marketing soybean.

Two farmers favored *rice - rice - any upland crop*. Neither was fully interested in farming. One said his soil (sandy) was suitable for all crops his father grew in the past. The second said getting sufficient labor for growing upland crops would be a problem.

Two farmers favored a diversified third crop (*rice - rice - several upland crops simultaneously*). One wanted to find out which upland crops would perform best. The other wanted to avoid risk of growing only one.

One cultivator favored *rice - rice*, believing no upland crop could be grown in his field, because the soil was too sticky. Moreover, getting sufficient water was a problem.

Two farmers favored *rice - rice - rice*, but one also considered *rice - rice - mung*. The other was reluctant to grow upland crops because he had grown mung and peanut but did not profit from them. He said upland crops were easily stolen from the field, required a lot of labor, and were difficult to sell.

Patterns on elevated land. Of the 16 cultivators, 10 clearly preferred one or more patterns.

Two farmers chose *rice - maize - mung* because they thought their soil was not suitable for peanut; one noted that the soil was clay.

Two cultivators selected *rice - peanut - mung*. One thought neither upland crop required inputs. The other believed peanut and mung were not prone to pests and diseases; he tried maize but that crop was infested. As to soybean, he expected difficulties in selling it.

One farmer favored *rice - mung - peanut* if no irrigation water was available. He rejected maize because he expected only 25% of plants would survive without irrigation.

The farmer choosing *rice - peanut - maize* noted the soil of his field was sandy.

One farmer selected *rice - any upland crop - any upland crop*, believing any upland crop can be grown if irrigation water is available. As to growing several upland crops at the same time, he felt 1000 m^2 was small for diversification. For commercial success, he thought it better to produce large quantities of the same crop.

One farmer preferred *rice - several upland crops simultaneously - several upland crops simultaneously* because he was used to such diversification.

Rice - rice was preferred by one farmer who did not want to cultivate any upland crop. She tried mung, but it was rat infested. Because her field was far from her house, she did not want to grow maize and have it stolen. She had not tried peanut. As to soybean, she anticipated difficulty in selling it. She said she had no time for growing upland crops.

The farmer preferrring (*rice*) - *rice - mung* had lowland, enabling him to grow rice twice a year. He preferred mung as a second or third crop, because the soil (clay) would still be wet after rice, and he could cultivate peanut or maize which requires dry soil.

One farmer thought his soil (clay) was best suited to *rice - rice - soybean*. He did not anticipate trouble in selling soybean as a substitute for coffee.

Summary of reasons for farmers' choices.

1. *Adaptation to field conditions*. Cultivators often referred to soil characteristics and sometimes to irrigation water availability or lack or excess of moisture.
2. *Distance from house to field*. Some cultivators were averse to growing (some) upland crops because they could not guard yields against theft.
3. *Labor availability*. Farmers mentioned that upland crops required more labor than rice did.
4. *Preference for rice*. Some farmers preferred to grow rice over and above any upland crop. They resorted to growing upland crops only if it was virtually impossible to sow rice in DS.
5. *Crop diversification*. Some farmers preferred diversification to avoid risk of growing a single crop, or to find out which crops perform best. Some farmers, however, were reluctant to diversify because a crop did not give good returns, because they wanted a larger quantity

of one crop to improve its marketability, and because they thought such diversity impractical on a small trial plot of 1000 m^2.

6. *Marketing upland crops.* Some farmers explicitly considered potential for selling the yield of upland crops. Their assessments varied, however. They were optimistic about selling maize, mung, and peanut, because the government-backed National Food Authority seems prepared to buy these crops. But without similar guarantees, they were reluctant to grow soybean.
7. *Seasonal variation and peanut.* Most farmers did not prefer to grow peanut late in DS. A key informant noted that peanut had to be sown from November to January. If sown later, he maintained, cultivators ran the risk of losing yield to rot if rain comes early. Yet, some proposed cropping patterns implied growing peanut late in DS.

Cropping systems program

Pest control in rice-based cropping systems

Entomology and Plant Pathology Departments

DISEASES **384**
- Farmers' recognition of plant diseases **384**
- Soil-borne diseases in upland field **384**
- Integrated disease management **384**
- Chemical control in farmers' fields **384**
- *Trichoderma* spp. in mungbean after rice **385**

INSECTS **386**
- Intensive rice cropping and insect pests **386**
  - Population increases of yellow stem borer **386**
- Farmers' knowledge of pests and pest control **387**
  - Pest epidemics **387**
  - Farmer survey **387**
- Control of maize insect pests **391**
- Chemical control on mungbean **392**
- Insecticide treatment of mungbean seed **394**

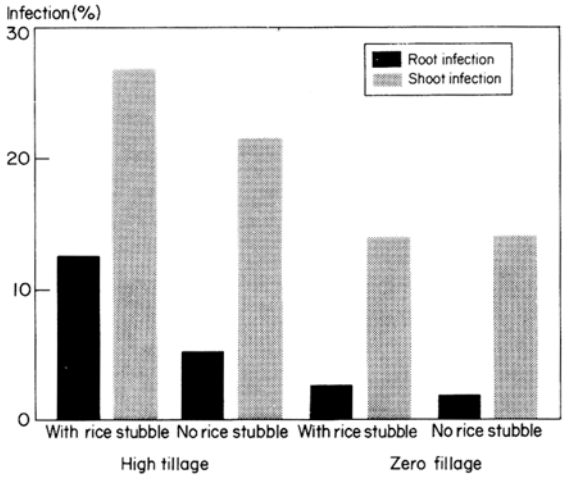
DISEASES

Plant Pathology Department

Farmers' recognition of plant diseases. In a survey of 30 farmers in 2 barangays of Guimba, Nueva Ecija, 80% recognized rice tungro (RTV) disease and 92% had observed it locally. RTV was severe at time of interview. Of the farmers who recognized RTV, 75% sprayed their fields with insecticide to solve the disease problem. Most knew, from government extension personnel, that a certain kind of insect transmits RTV.

Only two farmers observed false smut, and only one recognized it as a disease. No diseases on other crops were known.

Soil-borne diseases in upland field. An IRRI trial examined the effect of stubble and tillage levels on soil-borne diseases of cowpea grown after upland rice. As in the 1983 trial, root infection was significantly lower than shoot or *Fusarium* infection regardless of stubble and tillage; shoot infection was significantly lower in plots with zero tillage level; and both soil-borne diseases were generally lower in plots without stubble (Fig. 1). Root infection was significantly higher in high tillage plots with stubble. Because of the higher incidence of soil-borne diseases in high tillage plots, stand count was significantly lower, particularly in plots with stubble (Table 1). In upland fields, zero tillage and clean culture can reduce soil-borne diseases commonly caused by *Fusarium* sp. and occasionally by *Rhizoctonia solani* and *Sclerotium rolfsii*.



1. Incidence of soil-borne diseases of cowpea after rice in relation to tillage and stubble. IRRI, 1984.

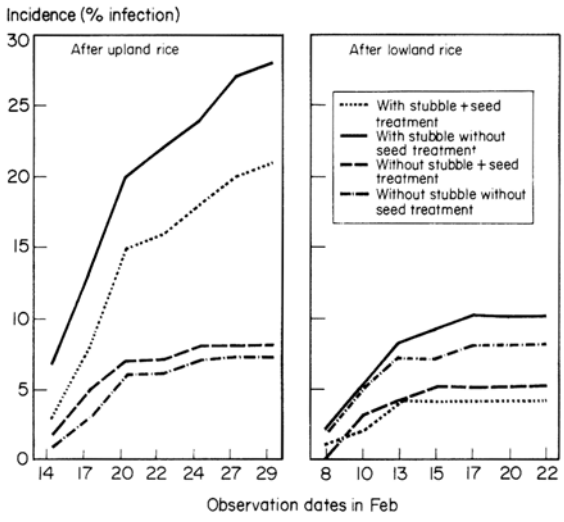
Table 1. Mean stand count of cowpea after rice showing the interaction between tillage and stubble. UDH7-IRRI, 1984.

Stubble	Stand count			
	Tillage		Av	Difference
	High	Zero		
With	98	138	118	−40**
Without	120	138	129	−18**
Av	109	138		
Difference	−22**	0ns		

Integrated disease management. With lowland rice as the first crop, previous research showed spraying at booting stage reduced sheath blight (ShB) infection compared with spraying at 30 d after transplanting (DT), 2 sprayings were better, and the disease was more frequent in plots with stubble. For upland rice as the first crop, fungicidal spraying suppressed ShB development regardless of stubble treatment. At harvest, stubble and sprayings had no effect on sheath rot (ShR) incidence. Two sprayings reduced neck blast more than single sprayings. Grain discoloration was low and erratic. Likewise, grain yields were similar but inconsistent with treatments.

For mungbean as the second crop, soil-borne disease incidence was greater in the field previously planted to upland rice throughout the observation period (Fig. 2). The disease was significantly reduced by the absence of stubble after upland rice and by fungicidal seed treatment after lowland rice. Regardless of field, isolation of infected plants showed that *R. solani* was predominant followed by *S. rolfsii*, *Pythium debaryanum*, and *Fusarium* sp. Although tillage level had no effect on the disease, zero tillage produced stunted plants.

Chemical control in farmers' fields. In Manaoag, Pangasinan, mancozeb - benomyl spray showed significant control of powdery mildew and *Cercospora* leaf spot on mungbean after lowland rice in 1983-84 (Table 2). Because of dry conditions, powdery mildew was expectedly more severe than *Cercospora* leaf spot. Disease control was correlated with grain yield in field 2 which eventually produced a marginal benefit-cost ratio of 2.40 (Table 3). Absence of treatment effect on grain yield



2. Soil-borne disease development on mungbean grown after upland and lowland rice in relation to stubble and fungicidal seed treatment. IRRI, 1984.

in field 1 could be due to late disease appearance.

In the following season, significant control of downy mildew on maize planted before rice was attained by seed treatment with metalaxyl (0.125 and 0.5 g ai/kg seed) regardless of seeding rate. The late maize planting had higher infection than the earlier planting, perhaps due to the fast buildup of inoculum from the early planting. Stands were lower in untreated plots because most infected plants died. However, the control offered by seed treatment was not reflected in yield or gross return, because the infection level was still tolerable in terms of marketable ears.

In the following rice crop, an experiment on frequency and time of spraying fungicide did not show any treatment effect since diseases were nil, primarily because of low rainfall. The evaluation of locally available fungicides against rice diseases in Pangasinan also failed because infection was very low.

In the parallel experiment on rice in Nueva Ecija, leaf diseases were also very low, ranging from 0 to <10% mean infection/leaf. ShB, ShR, and grain discoloration were slightly higher, but treatment effects could not be determined. Stem rot (SR) had very high incidence but no treatment was effective. Despite low neck rot incidence, IR36 and IR42 plots that received 2 sprayings (at 30 DT and at booting stage) had slightly lower infection. Data on grain yield were inconsistent with treatments. In the evaluation of locally available fungicides against rice diseases, no fungicide was effective against SR. The test did not yield any results for other diseases or for grain yield.

***Trichoderma* spp. in mungbean after rice.** Experiments in a farmer's field in Pangasinan did not show change in fungal population, as reported previously, except in *Trichoderma harzianum* which was slightly higher in plots without stubble.

Table 2. Severity[a] of powdery mildew and Cercospora leaf spot of mungbean after rice as affected by fungicidal spraying. Manaoag, Pangasinan, Philippines, 1983-84.

Treatment[b]	% infection/plant					
	Pretreatment observation		First observation after spraying		Second observation after spraying	
	Powdery mildew	Cercospora leaf spot	Powdery mildew	Cercospora leaf spot	Powdery mildew	Cercospora leaf spot
			Field 1			
Sprayed	0	0	0	0.40	41.75	8.04
Unsprayed	0	0	20.06	5.39	65.45	16.63
Difference			-20.06**	-4.99**	-23.70**	-8.59^{ns}
			Field 2			
Sprayed	1.28	0.80	1.66	1.39	4.09	1.42
Unsprayed	1.72	0.46	25.47	7.86	23.87	3.86
Difference			-23.81**	-6.47**	-19.78**	-2.44**

[a] Disease reading on leaves/plant, using scale of 0 to 9: 0 = no infection and 9 = ⩾ 50% leaf area affected. % infection/plant = $\frac{\text{total readings}}{\text{no. of leaves}} \times \frac{100}{9}$. [b] Mancozeb + benomyl sprayed at 1.56 g/litre water at 1500-2000 litres/ha was sprayed at late vegetative to early bud stage.

Table 3. Grain yield and cost and return analysis of mungbean after rice as affected by fungicidal spraying. Manaoag, Pangasinan, Philippines, 1983-84.

Treatment	Grain yield		Gross return[a] ($/ha)	Added return ($/ha)	Added cost[b] ($/ha)	Marginal benefit-cost ratio
	g/16 m²	t/ha				
			Field 1			
Sprayed	2090.47 a	1.31	1400	–	101	–
Unsprayed	2189.98 a	1.37	1467	–	0	–
			Field 2			
Sprayed	2133.80 a	1.33	1429	231	96	2.4
Unsprayed	1788.36 a	1.12	1198	–	0	–

[a]Mungbean at $1.07/kg. [b]Fungicide (mancozeb + benomyl) at $3.57/100 g; labor at $0.22/h of spraying.

Aspergillus spp. and *Penicillium* spp. remained higher than *Trichoderma* spp. The *Trichoderma* treatment had no significant effect on seedling emergence, plant stand, and grain yield. At IRRI, postemergence damping-off was slightly more common in high tillage plots.

INSECTS

Entomology Department

Intensive rice cropping and insect pests. Insect pest epidemics in Asia the past two decades have been blamed on the introduction of modern varieties (MVs), development of irrigation systems, and use of agrochemicals.

Long-term light trap records at IRRI and Titi Serong, Malaysia, from before and after the large-scale introduction of MVs, may help explain these events. Total of trap catches over at least 1 mo eliminates the effects of lunar phases on insect activity.

In rice growing areas adjacent to IRRI, farmers more rapidly adopted MVs than agrochemicals between 1966 and 1970; however, fertilizer and insecticide use rose steadily from 1966 to 1978 before leveling off (Fig. 3). Irrigation facilities in neighboring Santa Cruz and Mabacan River gravity systems were improved from 1969 to 1971 to allow dry season (DS) double cropping. The wet season (WS) area has not appreciably changed. Figure 3 shows the increase in double cropping measured as the ratio of DS to WS area planted. Populations of yellow stem borer (YSB) and green leafhopper (GLH) rose rapidly from 1968 to 1970, while that of brown planthopper (BPH) continued to rise until 1973 before leveling off to a new population equilibrium. In Laguna, epidemics of RTV occurred in 1971 and BPH in 1974.

The IRRI and Malaysia light trap data sets were analyzed to see if the pest increases could be explained by population buildup during one season's crop growth or by carryover populations between crops.

A hypothetical example illustrates the variables that will be compared (Fig. 4). The wet (WST) and dry season (DST) troughs are the starting populations after the previous season, which then rise during a given season to a peak (WSP or DSP). The numbers represent the year (1 = year 1, 2 = year 2). In regression analysis, the slopes (b) were calculated for regression of within-season and between-season comparisons. Different slopes denote density dependence ($b = 1$), density independence ($b = 0$), inverse density dependence ($b > 1$), and undercompensating density dependence ($b < 1$).

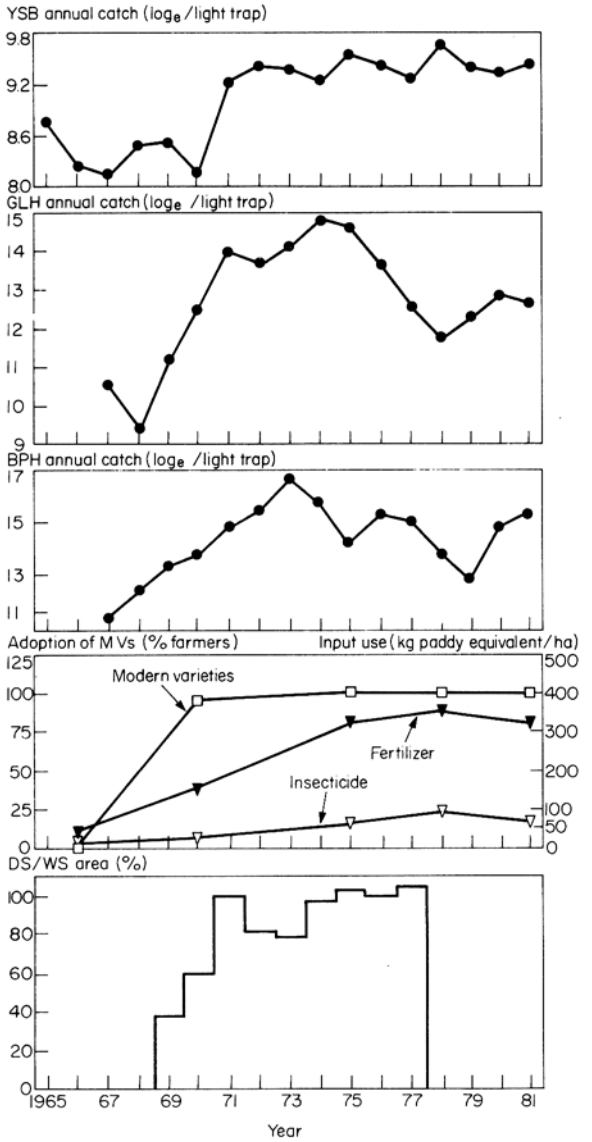
Population increases of yellow stem borer. The IRRI YSB data are most complete and are presented here for WS.

The rate of YSB population increase during 14 WSs from 1968 to 1981 measured by the ratio of the annual WST to WSP was highly correlated, and illustrates undercompensatory density dependence.

The carryover regression from the DS immediately preceding WS suggests that carryover through the fallow between adjacent seasons is essentially density independent.

The carryover regression from WS to WS over the years also suggests that carryover is largely independent of density (Fig. 5).

These regression analyses show that over the period of increasing cropping intensification, within-season growth rates of YSB declined while carry-



3. Changes in insect abundance and adoption of MVs and agrochemicals during a period of change from single to double rice cropping in Laguna, Philippines, 1965-81. Cropping data from NIA records for Mabacan and Santa Cruz River Irrigation Systems.

over ratios increased. In Laguna, the marked rise in the WSP population of YSB from the early 1970s is related to increased survival between WSs, not within-season increase. This tends to rule out other within-season effects such as fertilizer or resurgence due to insecticide, close spacing, or favorable microenvironment of high tillering varieties.

The greater resistance of MVs to YSB, BPH, and GLH further supports the observation that pest epidemics in Laguna are related to the change from single to double rice cropping made possible by irrigation system improvement from 1969 to 1971.

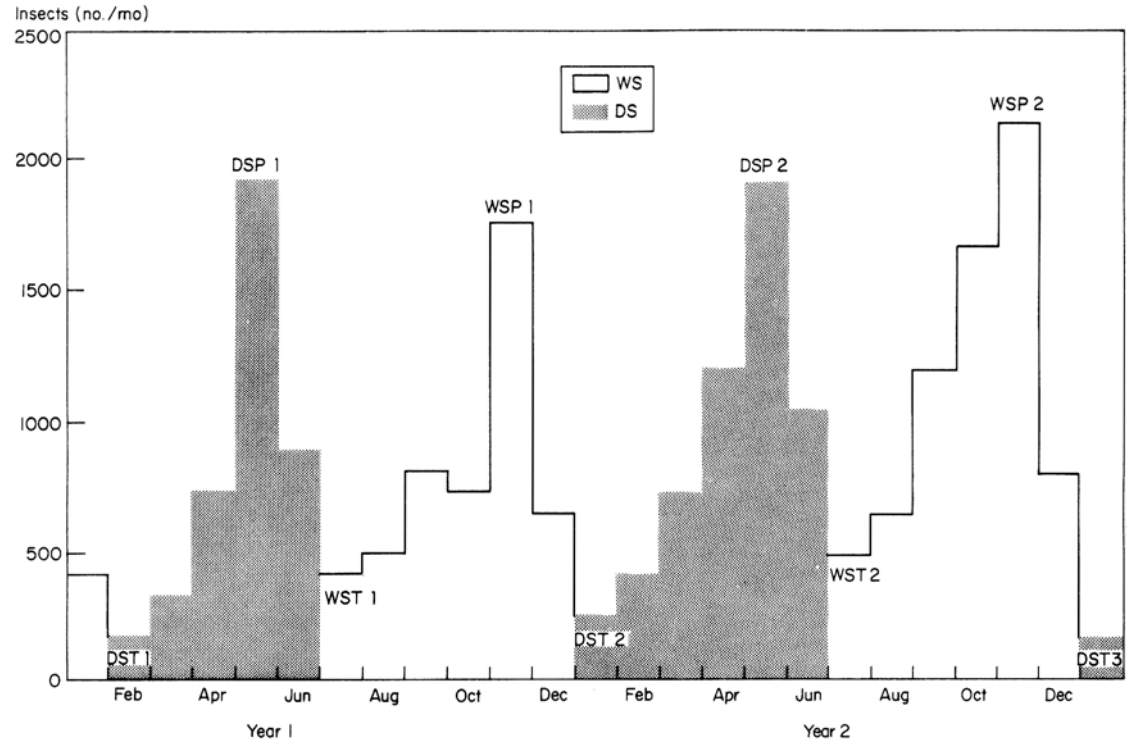
Data for Titi Serong in Malaysia gave the same results. The carryover populations from WS to WS were positively correlated to area double cropped (Fig. 6).

Farmers' knowledge of pests and pest control. *Pest epidemics.* The area of Koronadal, South Cotabato Province, Mindanao, is cropped in a highly mosaic pattern of roughly one-third coconut and assorted upland crops, one-third maize, and one-third lowland rice. The predominant cropping pattern is 2-2.5 rice crops per year with irrigation (81% of farm area as determined by a survey of 50 farmers in 5 villages), with 13% rice followed by maize or mungbean. The average farm size is 2.0 ha.

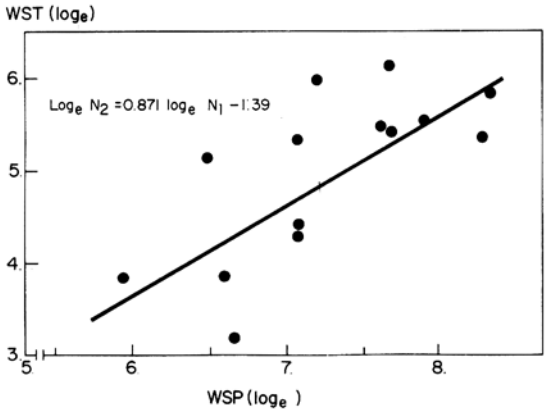
After RTV outbreaks in early 1980s, farmers changed from mainly IR36 to over 30 cultivars in an attempt to eliminate the virus. Many of the new cultivars were susceptible to BPH; crop failures ensued from hopperburn and the newly discovered grassy stunt (GSV) II virus. The pest epidemic was stopped by a synchronous planting project; release of IR60 and IR62 resistant to RTV, GLH, BPH, and GSV II; and the prolonged drought from October 1983 to June 1984.

During the epidemics, farmers lost 1-6 rice crops each (av = 2.2). High populations of BPH aided evolution of biotype 3; in the Philippines, only South Cotabato and neighboring Sultan Kudarat have natural populations of biotype 3. The continuous irrigation, rainfall, and flooded fields have created widespread Zn deficiency. Soil is highly favorable for rice and azolla culture (pH = 6.0, CEC = 17 meq/100 g, and >20 ppm P). During the height of the pest epidemic many hills of rice exhibited combined symptoms of RTV, GSV II, and Zn deficiency.

Farmer survey. Fifty farmers in five villages were surveyed in 1982 to determine their level of knowledge regarding rice pests and their control. Farmers averaged 19 yr experience growing rice. Each farmer enumerated his experience with pest problems affecting each stage of rice. Then he ranked, in order of importance, the pests he listed. A score of 10 was given to the most important pest, down to 1.



4. Hypothetical example of monthly insect light trap collections showing dry and wet season peaks (DSP, WSP) and dry and wet season troughs (DST, WST) for 2 yr.



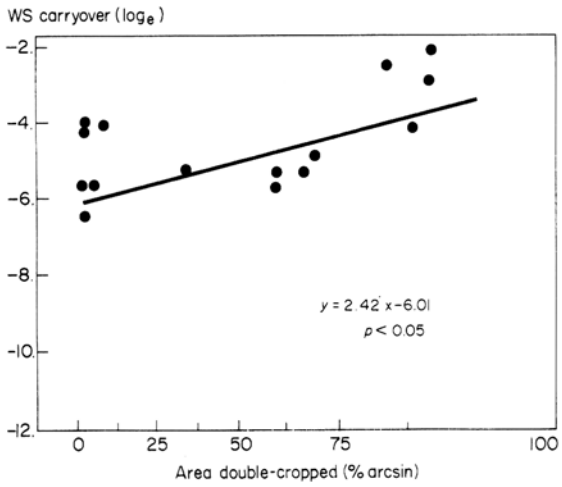
5. YSB catch in the trough prior to WS in relation to numbers at the peak of the preceding WS. Laguna, Philippines, 1961-81.

Values were averaged over all pests. A value of 0 was given to pests not mentioned.

Farmers ranked hoppers and stem borers (SB) equally high (Table 4). Farmers generally did not distinguish GLH from BPH but called them all hoppers. They confused hopperburn symptoms with virus disease symptoms. The rich vocabulary (17 expressions) farmers used to describe SB indicates how important they believe the pest is. Light trap catches reveal all five rice SB species present in Koronadal. The most prevalent were YSB and striped SB followed by surprisingly high numbers of white SB. Dark-headed SB and pink SB were relatively low in number.

The farmers ranked rice seed bugs (mainly *Leptocorisa oratorius* and *Nezara viridula*) above rice leaffolder (LF, mainly *Cnaphalocrocis medinalis*). The prominent leaf feeders were *Naranga aenescens* and *Rivula atimeta* which attacked the posttransplanting crop. Farmers could not distinguish between them.

Half the farmers listed rice whorl maggot (RWM). This was surprising because in other Philippine areas, farmers rarely mentioned this important pest. Armyworm (AW) was recognized because it cuts off panicles. Caseworm (CW) was distinguished from *Naranga* and *Rivula* by the



6. Carryover between WSs calculated from light trap catches of GLH in relation to the percentage of double-cropped farm area in the vicinity. Titi Serong, Malaysia, 1959-75. Data from the Department of Plant Protection and Malaysian Agricultural Research and Development Institute.

unique cutting damage it causes. Other large insect pests were mentioned: mole cricket, greenhorned caterpillar, and lady beetles. Farmers believe lady beetles are pests because they see them feeding on pollen. However, as rice is fertilized before the spikelet opens, pollen-feeding insects cannot prevent fertilization.

Only 10% named fungal diseases. These were grouped as blast even though *Helminthosporium*, ShB, and leaf scald were present. No bacterial diseases were named even though bacterial leaf streak and bacterial blight were evident. Rats were mentioned by only 6% of farmers.

When shown rice pests or damaged plants, most farmers readily recognized rice bugs (RB) and SB, but only about half could distinguish GLH from BPH, recognize RTV, or identify LF and AW damage. Only about one-quarter recognized RWM and less than 10% knew a fungal disease.

Table 4. Rice pests that farmers enumerated and ranked by relative importance. Koronadal, South Cotabato, Philippines, 1983.

Pest		Farmers responding (%)	Importance value[b]
English name	Local name		
Hoppers	Ulmog[c], waya-waya[d]	86	8.6
Stem borers	Tamasok[d]	94	8.6
Deadheart	Aglabbaga ti uggot[c]		
Whiteheads	Agpuraw ti bunga[c]		
Rice seed bugs	Dangaw[c]	94	7.4
Rice seed bugs	Tiyangaw[d]		
Leaffolder	Lukot-lukot[d]	84	6.5
Leaffolder	Balbalkot[c]		
Defoliators		84	6.5
Eats the edge of leaves	Agkaan ti igid ti bulong[c]		
Whorl maggot	Kusim[d]	50	3.8
Whitish leaves	Agpuraw ti bulong[c]		
Armyworm	Arabas[c]	46	3.6
Cuts the panicles	Ginaputol sang bunga[d]		
Caseworm	Kutalo[c]	36	2.6
Cuts the leaves	Nagapang-utod sang dahon[d]		
Mole cricket	Ararawan[c]	18	1.2
Mole cricket	Mara-mara[d]		
Greenhorned caterpillar			
Larva with horn	Igges nga adda sara na[c]	12	1.0
Blast	Nagapintok-pintok ang dahon[d]	10	0.9
Lady beetle	Bakuko[d]	10	0.7
Rat	Utot[c]	6	0.6
Neck rot	Matukkol ti buko ti dawa[c]	4	0.3
Wilting	Malaya ang dahon[d]		
Wilting of the plants	Malaylay ti pagay[c]		
Wilting of leaf tips	Aggango ti murdong ti mula[c]	4	0.3

[a]Names volunteered by 50 farmers in 5 villages and recalled without prior mention of any pest names. [b]Importance value scored on a 10-0 scale: 10 = most important, 0 = not mentioned. Rankings averaged for 50 farmers. [c]Ilocano term. [d]Ilongo term.

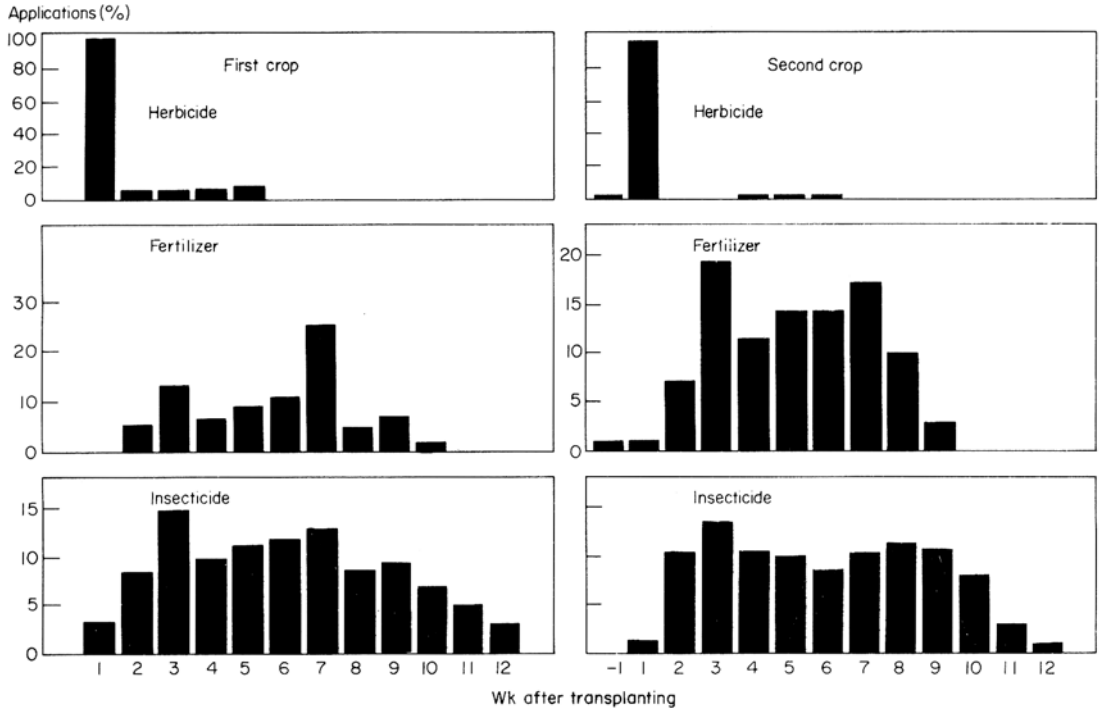
After 2 yr experience in the site where yield loss for 3 rice crops was measured, we share the farmers' concern for hoppers and virus diseases. But on resistant varieties, we place RWM, defoliators, and LF higher in importance than SB and RB. Farmers rank SB and RB high because they are conspicuous (whiteheads and RB feeding on panicles), are relatively abundant, can be seen at eye level while walking along a bund, and directly affect grain. AW also is large and conspicuously damages rice panicles, but is rare. On the other hand, damage by LF, defoliators, RWM, and CW is indirect. The greatest damage is done by vegetative stage foliar feeding insects (RWM, *Naranga*, *Rivula*, and CW) which reduce tillers per hill. This cause of yield loss is more subtle, and farmers rate it low.

In 1983, IR60 was grown on 55% of land in first crop but declined to 35% by second crop. Farmers listed susceptibility to lodging and a hard dormancy as the weaknesses of IR60, and are replacing it with other new selections from advanced lines being tested in the area.

In naming pest-resistant varieties, 40% of farmers cited IR60 and 30% correctly stated it was resistant to hoppers, but 14% could not name a pest-resistant variety. Over 20% of farmers mistakenly believe pest-resistant varieties are resistant to all pests, worms, or RB. Farmers' lack of information on pest resistance led them from "the frying pan into the fire" when they rejected IR36 because it was moderately susceptible to RTV and replaced it with SN11 and 30 other unproven lines, most of which were susceptible to BPH and GSV II. Our monthly record keeping for 60 farmers in 8 villages shows farmers continued to switch to newer cultivars. They continued to test cultivars of unproven pest resistance qualities, even though IR60 and IR62 have sufficient pest resistance qualities.

Turning to other insect-controlling mechanisms, 90% of farmers could name at least one natural enemy. Half named spiders but none knew of parasites or pathogens. They could not name practices to encourage natural enemies.

Farmers knew many cultural control practices and gave complex explanations of how each affects insect pests. Weeding, for example, encourages vigorous plant growth and a greater plant tolerance for pest damage. Planting in rows allows farmers



7. Frequency distribution of agrochemical usage on irrigated rice. Koronadal, South Cotabato, Philippines, 1983-84.

Table 5. Development of a chemical insect control recommendation for Pioneer 6181 hybrid maize planted after lowland rice.[a] Koronadal, South Cotabato, Philippines, Mar-Jun 1984.

Plant stand[b] (thousand/ha)	Thrips (no./35 plants) 21 DE	Maize borer			Yield[f] (t/ha)
		Damaged leaves[c] (%) 45 DE	Holes in stem[d] (no./50 plants) 60 DE	Tunnels[e] (no./50 plants)	
Complete protection: seed/seedling protection — 8 g ai bendiocarb 50 WP/kg seed (seed treatment); pretasseling — 1 kg ai carbofuran G/ha whorl application at 21, 31, 41 DE; posttasseling — detasseling 4 of 6 rows before pollen shed followed by 0.03 kg ai deltamethrin EC/ha at 50, 60 DE.					
51.5 a	15.4 b	3.6 a	14 a	34 a	4.02 ab
No seed/seedling protection					
55.2 a	8.8 ab	4.0 a	31 ab	56 a	4.24 a
No pretasseling protection					
48.8 a	7.4 a	11.0 ab	31 ab	46 a	3.31 b
No posttasseling protection					
50.4 a	8.6 ab	4.2 ab	121 c	174 c	2.15 c
Untreated					
58.9 a	11.8 ab	17.8 b	135 c	202 c	2.06 c
IPM: pretasseling — 0.05 kg ai carbofuran G/ha in whorl (plant by plant) 3-5 WE; posttasseling - detasseling					
53.6 a	14.4 ab	10.8 ab	45 b	113 b	3.27 b
New technology: seed/seedling protection — 4 g ai bendiocarb 50 WP/kg seed (seed treatment); pretasseling — Electrodyn cypermethrin (blue bozzel 0.10 m/s) sprayed once when active feeding is observed during tasseling stage; posttasseling — Electrodyn cypermethrin sprayed once after tassels emerged from boot.					
49.3 a	14.4 ab	14.8 ab	103 c	165 bc	2.28 c

[a]Av of 5 farms (replication). DE = d after emergence, WE = wk after crop emergence, IPM = integrated pest management. [b]No. of plants/50-m row sample. [c]Percent infested plants from 50-plant sample. [d]No. of internodes with entrance/exit holes from 50-plant sample. [e]No. of larval tunnels/50-plant sample dissected after harvest. [f]50-m^2 yield cut.

greater mobility for spraying. Removing large insects by hand was practiced by 78% of farmers and roguing by 74%. Farmers flooded (58%) or drained fields (10%) to control pests.

Because synchronous planting only began in 1983, only 38% cited it.

In 1983, more farmers used insecticides (92-97%) and herbicides (91-95%) on the first and second crops, respectively, than fertilizers (79-86%). Those who used inputs spent more for fertilizer ($17 and $21/ha) and insecticide ($16 and $15/ha) than for herbicide ($150 and $8/ha) for each crop.

Farmers reported average yields of 5.3 and 4.9 t/ha for the first and second crops. They applied a mean of 30-10-9 and 30-2-2 kg NPK/ha, respectively, for each crop. Fertilizer was broadcast into paddy water 3 and 7 wk after transplanting (WAT) (Fig. 7). Urea and ammonium chloride were preferred.

Butachlor was used in 3 of 4 herbicide applications and applied 1 WAT at 0.5 kg ai/ha.

Farmers who applied insecticide averaged 3 applications each, usually at 3 and 7 WAT, timed equally with fertilizers. Sprayables were used in 98-100% of applications. Methyl parathion was applied in 34-40% of applications, followed closely by monocrotophos (30-36%) and 8 other chemicals. Spray volume for insecticides averaged 225 litres/ha, with only knapsack sprayers used. Dosages per application averaged 0.3 kg ai/ha or less.

The choice of methyl parathion is disturbing as it is highly toxic to man and causes BPH resurgence. Farmers choose it because it is inexpensive. Continued usage of methyl parathion and continual shifting of varieties will lead to increased hopperburn and virus diseases transmitted by BPH.

Control of maize insect pests. Insects caused 49% yield loss on hybrid maize planted after lowland rice in South Cotabato in 1984 DS (Table 5). The principal pest was oriental maize borer *Ostrinia furnacalis*. Young leaves were infested by two unidentified thrips uncontrolled by bendiocarb seed treatment. Yield loss was greater (35%) during posttasseling than pretasseling (13%) period. No yield loss occurred during the seed or seedling stages when ants and seedling maggots may attack.

Maize borer egg masses were more abundant in earlier plantings and increased in number from 3 to 6 wk after crop emergence (Fig. 8). Carbofuran granules in the complete control treatment substantially reduced the pretasseling maize borer population. The IPM treatment was monitored weekly on a per-plant basis and only used carbofuran G if the youngest two leaves showed larval feeding. Only 0.05 kg ai carbofuran G was applied over a 3-wk period.

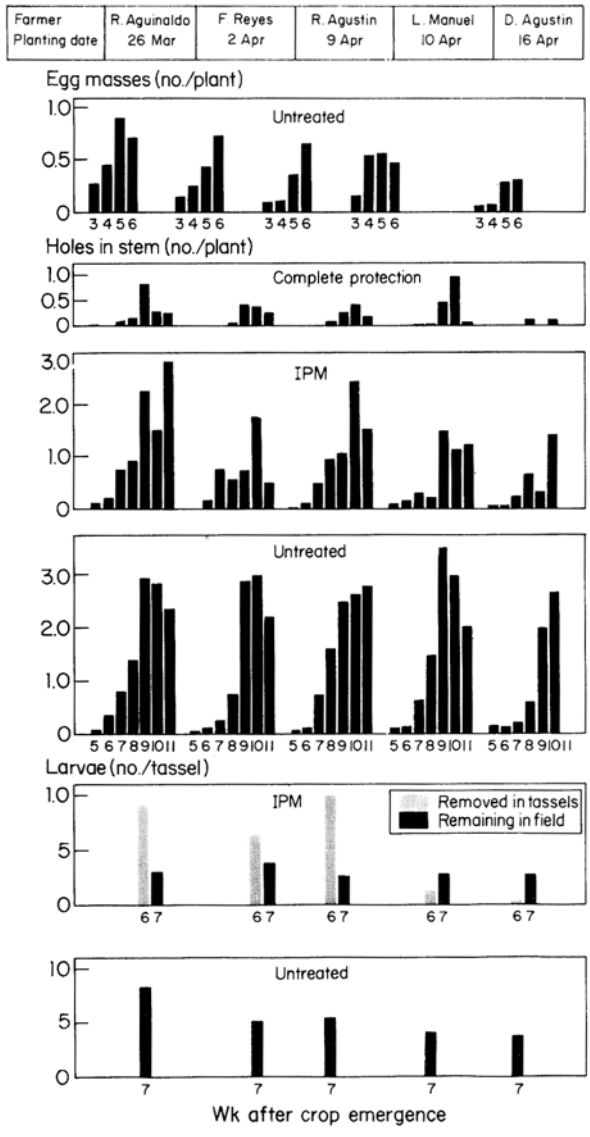
Tassels were removed before pollen shed in 4 of every 6 rows in the complete control and IPM treatments. In some fields almost 10 maize borer larvae per tassel were removed by this nonchemical method. Cypermethrin applied with the Electrodyn electrostatic sprayer (new technology) did not control *O. furnacalis*. Although the IPM treatment yielded significantly higher than the untreated, it fell short of that with complete protection. The IPM yield was equal to that without pretasseling protection. Perhaps higher dosages of carbofuran G should be applied in future trials.

Chemical control on mungbean. The lowlands of Nueva Ecija are normally planted to two irrigated rice crops, but with the long drought of 1983, the 1984 DS crop could not be planted in many tail-end regions of the Upper Pampanga River Integrated Irrigation System (UPRIIS).

Farmers planted mungbean on the residual moisture from their 1983 WS rice crop. Yields were generally very low because of drought stress, insect pests, and poor stand establishment (from farmers' inexperience with the crop and from a low supply of seed). The crop suffered 58% loss from insects — evenly distributed between preflowering (flea, beetle, bean fly, and thrips) and postflowering (pod borer) pests.

We tested our recommended practice as developed in Pangasinan and compared it with newer technology — seed treatments and electrostatic insecticide sprays. During preflowering, the new technology did not improve on the standard two monocrotophos sprays, except for cutworm and *Heliothis* control (Table 6). The furathiocarb seed treatment was inferior for bean fly control.

Deltamethrin for postflowering pod borer control effectively reduced bean lycaenid even at 0.015 kg ai/ha. Two postflowering applications of either permethrin, cypermethrin or a low dosage of deltamethrin gave inferior control of *Heliothis* pod borer compared to three deltamethrin sprays at 0.03 kg ai/ha. The complete control regime's benefit was in extending the period of grain filling, as the yield increase from the last two harvests (4th and 5th primings) made the difference between yields for complete control and for potential practices. One way to improve our standard practice would be



8. Oriental maize borer abundance in complete insecticide protection, IPM, and untreated plots of Pioneer 6181 hybrid maize replicated over 5 farmers' fields. Koronadal, South Cotabato, Philippines, Mar-Jun 1984.

Table 6. Development of a chemical insect control practice for rainfed Pagasa 1 mungbean planted after puddled rice using the yield loss method.[a] Jaen, Nueva Ecija, Philippines, Jan-Apr 1984.

Flea beetle[b] (no. holes/ plant) 15 DE	Bean fly[c] (% infested plants) 21 DE	Damaged leaflets[d] (%) 35 DE	Pod borer damaged flowers (%) 42 DE	Larvae (no./40 flower clusters) 42 DE		Damaged pods (%)		Plant stand (thousand/ha)	Yield (t/ha)	
				Bean lycaenid[e]	Bean pod borer[f]	Earworm[g] 58 DE	Bean pod borer[f] 49 DE		4th and 5th primings	Total
Complete control: preflowering – 0.5 kg ai monocrotophos EC/ha 2, 9, 16 DE; postflowering – 0.03 kg ai deltamethrin EC/ha flowering, 10 and 20 d later										
5.4 a	11 a	1 a	23 abc	1.6 a	0.8 ab	0.5 a	0.1 a	215 a	0.60 a	1.36 a
No postflowering protection										
5.6 a	13 a	6 bc	48 d	7.6 c	2.4 b	12 de	3.2 b	207 a	0.39 ab	0.95 b
No preflowering protection										
10.6 b	73 d	2 ab	14 a	4.0 abc	0 a	1 ab	0.1 a	158 bc	0.28 b	0.82 b
Untreated										
11.8 b	79 d	11 d	36 cd	2.6 ab	0.8 ab	14 e	0.8 a	142 c	0.23 b	0.57 c
Standard practice: preflowering – 0.25 kg ai monocrotophos EC/ha 2, 12 DE; postflowering – 0.04 kg ai permethrin EC/ha 30, 40 DE										
7.6 ab	30 ab	7 cd	20 abc	3.0 abc	0.2 ab	8 cd	0.4 a	190 ab	0.37 ab	1.00 b
Electrodyn sprayer: 0.02 kg ai cypermethrin EC/ha 2, 9, 16, 25, 30, 45 DE										
4.6 a	50 bc	1 a	31 bcd	6.6 cd	1.6 ab	4 abc	0.3 a	167 bc	0.25 b	1.03 b
Promising technology: seed treatment – 0.12 kg ai furathiocarb D/ha; Electrodyn 0.02 kg ai; cypermethrin EC/ha 30, 40 DE										
5.2 a	59 bcd	4 bc	16 ab	3.0 abc	0.8 ab	7 bcd	0.3 a	170 bc	0.43 ab	0.85 b
Potential practice: seed treatment – 0.12 kg ai furathiocarb D/ha; 0.015 kg ai deltamethrin EC/ha 30, 40 DE										
5.6 a	71 cd	7 cd	19 ab	1.0 a	1.4 ab	4 abc	0.1 a	192 ab	0.27 b	0.89 b

[a] Av of 5 replications (farms). DE = days after crop emergence. [b] *Medythia suturalis:* 35 plants sampled. [c] *Ophiomyia phaseoli:* 35 plants sampled. [d] *Spodoptera litura* and *Heliothis armigera:* 33 leaves sampled. [e] *Catochrysops cnejus.* [f] *Maruca testulalis.* [g] *Heliothis armigera.*

Table 7. Insecticide seed treatments for control of preflowering insects on rainfed mungbean after puddled rice.[a] Jaen, Nueva Ecija, Philippines, Jan-Feb 1984 DS.

Insecticide[b]	Flea beetle[c] (no. feeding holes/plant) 15 DE	Bean fly[d] 21 DE		Thrips[e] (no./leaf terminal) 21 DE	Plant stand (thousand/ ha)	Foliage dry wt[f] (g/100 plants) 30 DE
		Infested plants (%)	Larvae + pupae (no./35 plants)			
UC54229-S 96 D	6.2 a	80 bc	20 a	1.4 b	219 a	161 a
Carbosulfan 25 ST	4.4 a	74 abc	17 a	1.3 b	231 a	156 ab
Furathiocarb	3.2 a	72 abc	24 ab	1.6 b	207 ab	155 ab
Carbofuran 35 ST	3.8 a	59 a	18 a	1.4 b	172 ab	151 ab
Isofenfos 40 DS	4.6 a	75 bc	32 b	1.1 ab	178 ab	143 abc
Bendiocarb 50 WP	3.8 a	62 ab	18 a	1.1 ab	143 b	131 bcd
Methiocarb 50 WP	5.2 a	78 bc	26 ab	1.2 ab	179 ab	129 bcd
Untreated	10.6 b	86 c	22 ab	1.1 ab	182 ab	118 cd
Thiodicarb 34 F	6.2 a	78 bc	27 ab	0.9 a	201 ab	114 d

[a]Av of 5 replications (farms). DE = d after crop emergence. [b]Dosage = 0.12 kg ai/ha; sticker (25% gum arabic), seeds and insecticide agitated in a plastic bag. [c]*Medythia suturalis:* 35 plants sampled. [d]*Ophiomyia phaseoli:* 35 plants sampled. [e]*Thrips palmi:* 50 leaf terminals sampled. [f]100 plants cut at ground level. One field suffered drought stress.

to develop an effective seed treatment, to eliminate two early sprays, thus saving time and ensuring appropriate timing for better control.

Insecticide treatment of mungbean seed. Although seed treatments work well against upland rice and maize seedling pests, no chemical tested has worked well for grain legumes. Carbofuran ST has been a standard check (Table 7). All insecticides gave significant control (<70%) of flea beetle damage. No seed treatment gave better than 40% control of bean fly, nor did any chemical adequately control thrips. Both cereals and grain legumes were attacked by early season pests, all small insects. Being small, they should be readily controlled by low amounts of insecticide. The apparent problem with treating grain legume seeds is that the seed testa (with insecticide) emerges above the ground with the seedling. In cereals, the testa remains underground in the root zone. We will test seed coating methods so insecticide will flake off the seed coat as the seedling shoot emerges.

Cropping systems program

Design and evaluation of cropping patterns

Multiple Cropping Department

CROPPING IN A DROUGHT- AND FLOOD-PRONE ENVIRONMENT **396**
Mungbean management **396**
Relay and intercropping **396**
Rice management **397**
Direct seeding **397**
Seedling age **397**
Seedling age and varietal type **398**

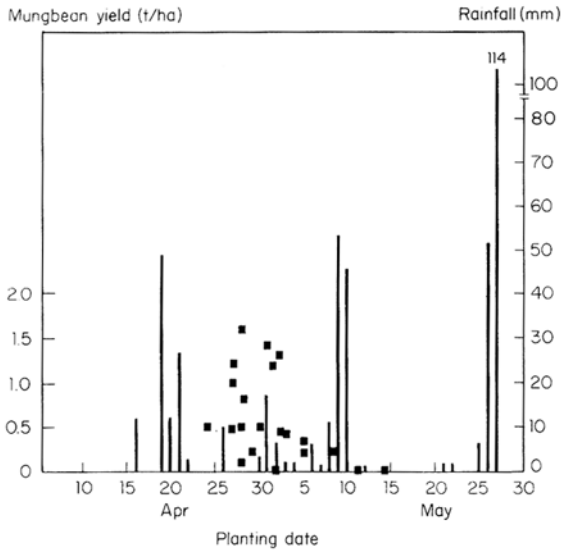
CROPPING IN A DROUGHT- AND FLOOD-PRONE ENVIRONMENT

Past management research on the first and second strata of the drought- and flood-prone areas of the Solana (Cagayan, Philippines) project had shown that cultivation of rice and mungbean from May to July was risky. Fields were often too wet for upland crops like mungbean but too dry for short-duration photoperiod-insensitive rices like IR46. Further, traditional rices are photoperiod sensitive and were not ready for harvest any earlier than if transplanted in the customary period (August to October). Regardless of species, establishment of crops early in the wet season (WS) was difficult. If modern and traditional rices were dry seeded, weeds were difficult to control during droughty periods of May-July. When mungbean was cultivated, temporary waterlogging was a hazard.

This research examined a) intercropping and relay cropping as suitable strategies for distributing risks from May to July, and b) the management of mungbean to identify practices that would increase yields and reduce risks.

Mungbean management. Trials on farmers' fields compared the effects of seeding rates, cultivars, simple surface drainage practices, and planting dates on mungbean yields. Increasing the seeding rate of Pag-asa from 12.5 to 25 kg/ha increased yields from 0.72 to 0.95 t/ha (means of 10 fields). Mean yields were 0.41 t/ha from a local mungbean cultivar and 0.79 t/ha for Pag-asa (means of 5 fields). On lower lying fields where surface drainage was tested, rains on 26 and 27 May were heavy and there was no harvest. But even on higher lying fields, surface drainage increased yields by only 0.13 t/ha.

In these experiments, 17 location-date combinations contained at least 1 common treatment, and 4 contained treatments that differed only in seeding rate (20 vs 25 kg/ha). Mean mungbean yields were plotted against planting date on a diagram showing daily rainfall. As planting was delayed, yield declined but the pattern was not regular. When planting was on 4 May or earlier, yields were variable but the mean was 0.72 t/ha. Planting after 4 May gave a mean yield of 0.14 t/ha. The yield variability from early plantings was associated with local relief features that affected waterlogging, and soil tilth differences that affected emergence. The



1. Daily rainfall and mungbean yields by planting date. Solana, Cagayan, Philippines, 1984.

rainfall-seeding date-yield data in Figure 1 show that well-established (e.g., seeds planted before 4 May) mungbean plants coped with brief periods of heavy rainfall better than later plantings. Successive rains exceeding 40 mm/d fell on 9 and 10 May and even heavier rains fell on 26 and 27 May. The 1984 and previous data indicate that for the greatest probability of high yields, an improved cultivar should be planted at seeding rates between 18 and 24 kg/ha as early in the year as first rains permit, and that fields prone to temporary waterlogging should be avoided. Simple surface drainage practices did not adequately reduce temporary waterlogging.

Relay and intercropping. One relay cropping and two intercropping experiments were conducted. In relay cropping, IR46 and a traditional cultivar (Wagwag fino) were sown into mungbean immediately after the first priming. Mungbean was sown on 4 May at one location and on 5 May at a slightly higher location. Crops at the lower location were more prone to temporary waterlogging. Mungbean was planted in 75-cm rows and 2 rows of rice were direct seeded between them on 5 and 6 Jul. Yields are summarized in Table 1. Relaying had no detectable effect on mungbean yields. IR46 yielded only slightly more than Wagwag fino, but it was harvested 52 d earlier.

Table 1. Grain yield of mungbean and 2 rice cultivars relay planted (/) with mungbean, at 2 positions. Solana, Cagayan, Philippines, 1984 WS.

Position	Crops	Yield[a] (t/ha)	
		Mungbean	Rice
High	Mungbean, no rice relay	0.65	–
	Mungbean/IR46	0.58	1.3
	Mungbean/Wagwag fino	0.68	1.1
Low	Mungbean, no rice relay	0.44	–
	Mungbean/IR46	0.59	1.5
	Mungbean/Wagwag fino	0.54	1.1
CV (%)		16	21

[a]Means of 4 replications per position.

In the second experiment, mungbean was intercropped with IR46 and Wagwag fino. The experiment was planted on 5 May on the first stratum. Mungbean and rice were seeded in alternate 30-cm rows. Yields are summarized in Table 2. Intercropping reduced mungbean yields, especially when the intercrop was traditional rice. Monocropped IR46 was affected by early drought, especially during vegetative development; therefore yield was low. When intercropped, IR46 gave almost no yield.

In the third experiment, modern and traditional rice cultivars were intercropped in stratum 1 and stratum 2. Those locations were planted on 9 and 11 Jun with modern and traditional cultivars dry seeded in alternate 30-cm rows. In stratum 1, yields of IR36 and IR46 were low and did not compensate for the lower yield from Wagwag fino. In stratum 2, modern varieties yielded higher than the traditional cultivar, and IR46 was statistically higher yielding than IR36, both as an intercrop and a monocrop.

Intercrops of dry seeded modern and traditional cultivars may increase productivity on fields lacking the drought-proneness of stratum 1. In drought-prone fields, relay planting a modern or traditional cultivar into a mungbean crop may work.

Rice management. Because strata 1 and 2 are drought prone, modern rice varieties cannot be reliably transplanted with optimum-age seedlings. Direct dry seeding can avoid the risk of modern cultivars remaining in the seedbed too long because fields are too dry to till. Another solution is to grow cultivars insensitive to seedling age. Two experiments tested these approaches. A third experiment compared the seedling age sensitivities of a comparatively well adapted modern cultivar and a traditional cultivar.

Direct seeding. The main disadvantages of direct seeding are low plant densities, poor tillering, and strong early weed competition. These disadvantages stem from drought periods early in WS. The first experiment examined the contribution that a 33% higher seeding rate (75 vs 100 kg seed/ha) would make to the yields of dry seeded IR36, IR46, and Wagwag fino. Rice was seeded in 30-cm rows between 10 and 14 Jul. The treatments were replicated across three fields in stratum 1. Severe drought delayed vegetative development of the modern varieties. Grain yields and plant densities are summarized in Table 3. The higher seeding rate increased plant density and yields. IR36 and IR46 yielded less than Wagwag fino.

Seedling age. In the second experiment, cultivars reported as photoperiod sensitive or comparatively insensitive to seedling age were transplanted on 29 Oct. Sixty-nine-day-old seedlings were transplanted in 25- × 25-cm hills. Forty kg N/ha (urea) was topdressed at 11 d after transplanting (DT). Prolonged drought prevented use of the selected rainfed field to plant 50-d-old seedlings. As the seedlings passed that age, they were transplanted in a partially irrigated field (on the fringe of a command area). Irrigation ceased in early December and crops were under severe drought stress by mid-December. Grain yields, productive tiller number, days to flowering, and plant heights are summarized in Table 4. Two Bangladesh lines (BR545-5-1-2-1 and BR236-10-2-2-1) were highest

Table 2. Grain yields of monocropped and intercropped (+) mungbean and 2 rice cultivars (IR46 and Wagwag fino). Solana, Cagayan, Philippines, 1984 WS.

Crop	Yield[a] (t/ha)	
	Mungbean	Rice
Mungbean	0.59 a	–
Mungbean + IR46	0.44 ab	0.1 d
Mungbean + Wagwag fino	0.35 b	1.5 b
IR46	–	0.8 c
Wagwag fino	–	1.8 a
CV (%)	15	17

[a]Means of 4 replications.

Table 3. Grain yields and plant densities of 3 rice cultivars dry seeded at 2 seeding rates.[a] Solana, Cagayan, Philippines, 1984 WS.

Cultivar	Grain yield (t/ha)			Plant density at emergence (10^4 plants/ha)		
	75 kg seed/ha	100 kg seed/ha	Mean	75 kg seed/ha	100 kg seed/ha	Mean
IR46	1.1	1.4	1.2 b	140	172	156 a
IR36	0.7	0.8	0.7 c	122	179	150 a
Wagwag fino	1.8	1.9	1.8 a	142	170	156 a
Mean	1.2 b	1.4 a		135 a	174 b	
CV (%)	10			13		

[a]Means across 3 locations in stratum 1.

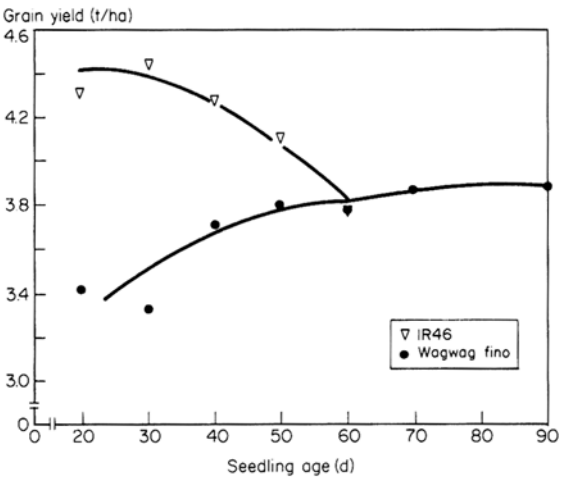
Table 4. Grain yields, productive tillers, days to flowering, and plant heights of 6 improved and 2 traditional cultivars. Solana, Cagayan, Philippines, 1984 WS.

Cultivar	Grain yield (t/ha)	Productive tillers (no./hill)	Days to flowering (DT)	Height (cm)
BR236-10-2-2-1	1.9	19	63	92
BR545-5-1-2-1	1.8	19	51	79
IR46	1.5	16	63	73
BR593-676-1-7-1	1.4	20	63	72
Wagwag faire	1.3	15	75	117
BR539-119-1-1-2	1.2	22	42	76
Wagwag fino	1.1	14	75	112
C4	0.9	16	75	74
CV (%)	11	16	–	3

yielding. They are medium height and have moderate tillering.

Seedling age and varietal type. In the third experiment, a fully irrigated field was used to compare the effects of seedling age on a moderately well-adapted modern cultivar (IR46) and a traditional photoperiod-sensitive cultivar (Wagwag fino). Seedlings of various ages were transplanted on 24 Sep in 25- × 25-cm hills. Forty kg N/ha was topdressed at 30 DT. Yields are in Figure 2.

IR46 yields declined as seedling age exceeded 40 d, but not as precipitously as reported for other modern rice varieties. Yields from the youngest (20- and 30-d-old) Wagwag fino seedlings were lowest. IR46 was harvested between 21 and 26 Dec and Wagwag fino between 22 Jan and 5 Feb. The data show the insensitivity of old Wagwag fino seedlings and suggest IR46 is comparatively insensitive to age.



2. Grain yields of IR46 and Wagwag fino as a function of seedling age on date of transplanting. Means over 4 replications, CV = 6%. Solana, Cagayan, Philippines, 1984 WS.

Cropping systems program

Selecting and testing varieties for rice-based cropping patterns

Multiple Cropping and Agronomy Departments and Rice Farming Systems Program

SCREENING AND SELECTION **400**
YIELD TRIALS **401**
Before rice **401**
Cowpea **401**
Mungbean **401**
After rice **401**
Cowpea **401**
Mungbean **401**
Soybean **401**
Peanut **401**
VARIETAL TESTING IN THE PHILIPPINES **401**
Upland crops before rice **401**
Mungbean **403**
Cowpea **403**
Bush sitao **403**
Maize **403**
Upland crops after rice **403**
Mungbean **403**
Cowpea **403**
Bush sitao **403**
Soybean **403**
Peanut **405**
Pigeonpea **405**
Sorghum **405**
Maize **405**
Upland crops in wet season **405**
Yardlong bean **405**
Sweet potato **405**
YIELDS OF 20 EARLY- AND LATE-PLANTED IMPROVED UPLAND RICES **405**
INTERCROPPING DEEP WATER RICE AND EARLY-MATURING RICE **407**
GRAIN YIELDS OF QUALITY-PROTEIN AND NORMAL-PROTEIN MAIZE **407**
EMERGENCE AND SEEDLING VIGOR OF COWPEA CULTIVARS **409**
COWPEA AND MUNGBEAN TOLERANCE FOR EXCESS MOISTURE **410**

Varietal testing and selection of various upland crops for rice-based farming systems are conducted before and after rice. The crops tested include mungbean, cowpea, bush sitao, yardlong bean, soybean, peanut, pigeonpea, maize, sorghum, and sweet potato.

We are collaborating with the Philippine Institute of Plant Breeding (IPB) to develop varieties of soybean, mungbean, and peanut and with the International Institute of Tropical Agriculture (IITA) to develop varieties of cowpea and soybean for use before and after rice. We are also screening varieties of pigeonpea and sorghum from Australia, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), and the U.S. The breeding work of IPB and IITA consists of hybridization, screening and advanced generation selection, and yield trials. Varieties are evaluated in Santa Maria (Pangasinan, Philippines) in cooperation with Pangasinan State University, and in Guimbal (Iloilo) with the Philippine Ministry of Agriculture and Food (MAF). The most promising varieties from these projects are increased in IRRI for testing in the Asian Rice Farming Systems Network.

In 1984, trials were conducted at IRRI farm; cropping systems outreach site in Solana, Cagayan; Regional Integrated Agricultural Research Systems (RIARS) Station in Ilagan, Isabela; Maligaya Rice Research and Training Center (MRRTC), Nueva Ecija; Libmanan in Camarines Sur; Guimbal; and Rainfed Agriculture Development Outreach sites (RADOs) in Santa Barbara, Pangasinan; Narvacan and Caoayan, Ilocos Sur; San Jose, Occidental Mindoro; Jamindan, Capiz; and Koronadal, South Cotabato.

SCREENING AND SELECTION

Rice Farming Systems Program

With IPB, we evaluated 272 mungbean, 67 soybean, and 97 peanut lines after rice in an observational nursery in Los Baños and in Pangasinan. Mungbean yielded 0-2.93 t/ha (mean 1.47 t/ha). Soybean yields were lower (0-1.52 t/ha) and only 4.5% yielded more than 1.2 t/ha. Peanut yields in Pangasinan ranged from 0 to 1.77 t/ha (averaging 1.05 t/ha) and 10.3% yielded more than 1.60 t/ha.

Over 1,250 soybean breeding lines and elite cultivars from IITA, the Asian Vegetable Research and Development Center (AVRDC), and the International Soybean Program (INTSOY) were screened and evaluated after rice for maturity, yield, diseases, and insects. Of 746 advanced breeding lines from IITA, 77 were promising in wet season (WS). Two high yielding lines were identified from 200 from AVRDC.

Forty-four soybean cultivars were subjected to water stress using a line source sprinkler system. At end of the moisture gradient, which did not receive water, 5 cultivars — 7024-2, 7024-3, SJ-5, 7207-1, and PM 78-6-5-13 — were found more drought tolerant than 39 others. In another study, 229 breeding lines from AVRDC were subjected to water stress using a line source sprinkler irrigation system. Top yielding lines under drought stress at end of the gradient were GSA 155, 170, 163, 154, and 156.

More than 760 cowpea varieties from IITA were screened and evaluated in dry season (DS) for maturity duration, drought, insects and diseases, and yield. The materials included F_5 to F_7 progenies. Of 282 genetically diverse germplasm, TVu 3073, TVu 3658, TVu 3906, and TVu 4694 were resistant to beanfly and are being retested in 1985.

An international cowpea disease nursery of 135 lines from IITA was planted to identify disease-resistant lines. Most lines were free from virus infection, and most also were resistant to foliar diseases except a few susceptible to powdery mildew.

Sixty-two elite lines were screened for excessive moisture and drought using the line source sprinkler system. Yields ranged from 0.42 to 2.04 t/ha under excessive moisture and 0.12 to 1.28 t/ha under drought. Cultivars TVx 2907-02D, TVx 1952-01E, TVx 2329-09D, and TVx 29492-01D consistently yielded higher under both excessive moisture and drought conditions, and were superior to All Season.

A total of 127 sorghum varieties from ICRISAT and IPB were screened. They showed wide variability in plant characters. Grain yield ranged from 0.08 to 4.74 t/ha and fodder yield from 11 to 20.66 t/ha. The most promising varieties for grain and fodder were ICSU-138, M-80214, ICSU-159, ICSU-126, and SPV-549. They have longer maturity than UPL SG-5 (check). Forty-nine varieties were selected for preliminary yield trial.

Twenty-nine pigeonpea varieties from ICRISAT

were screened after rice. The grain yield ranged from 0.03 to 1.23 t/ha. Yields were low because of waterlogging. Best entries were ICPL-189, QPL17, QPL70-1, and TC(F)5J-1.

YIELD TRIALS

Rice Farming Systems Program

Before rice. *Cowpea.* Ten early-maturing cowpeas, including All Season as a check, were evaluated before rice in three Philippine locations. IT82D-889 consistently gave the highest grain yield and shortest maturity period. It also maintained its determinate growth habit despite excessive moisture (420 mm rain) during the growing season. The entries were determinate during DS, became indeterminate in prerice environment, and had delayed maturity. IT82D-889 was resistant to brown blotch.

Thirteen lines of bush-type vegetable cowpea from IITA and the Philippines were evaluated before rice in three locations. Among entries, IT81D-1228-14, IT81D-1228-12, IT81D-1228-15, and IT81D-1228-10 were promising. They had high fresh pod yield, high fodder yields, and multiple resistance to foliage diseases.

Twenty-six early-maturing cowpea lines were evaluated in a preliminary yield trial before rice. The most promising lines yielding more than 1.5 t/ha were IT82D-892, IT82D-787, IT82D-891, and IT82D-755. Seven lines outyielded the check variety All Season.

Mungbean. Twenty mungbean lines from the observation nursery were evaluated. Bean yield ranged from 0.14 to 1.31 t/ha at Los Baños and from 0.19 to 1.36 t/ha at Pangasinan State University. The same entries were evaluated after rice in 1983-84. Data indicate high yielding varieties differ before rice and after rice.

In general yield trials, yields ranged from 0.37 to 0.98 t/ha at Los Baños, 0.68 to 1.34 t/ha at Pangasinan, and 0.58 to 1.10 t/ha at Iloilo. The most promising varieties were VC 2755A and VC 2762-B-45-2B.

After rice. *Cowpea.* Early- and synchronous-maturing cowpea varieties are highly suitable for crop intensification in rice-based cropping systems. Nine early-maturing lines of cowpea developed at IITA were evaluated under upland conditions in 1983 DS. IT82E-56 produced 1.22 t seed yield/ha in 64 d.

Twenty medium-maturing varieties were evaluated in November 1983 after lowland rice. With seed yields of 1.5-2.0 t/ha, several entries outyielded the check variety All Season. The five highest yielders were IT81D-1069, TVx 1948-012F, TVx 3871-02F, IT81D-1205-174, and TVx 4677-010E.

Nine lines of bush-type vegetable cowpea from IITA were evaluated during DS under upland conditions. Fresh pod yield over 8 t/ha was obtained from Farve 13 followed by IT81D-1228-15.

The cowpea cultivars with high grain yield and fodder yield (dual purpose types) are attractive alternatives to small farmers. Ten indeterminate cowpeas were evaluated for grain and fodder. Five varieties yielding most grain (1.56-1.89 t/ha) also gave relatively high fodder yields (12.0-19.5 t/ha). They were TVx 3671-14C-01D, TVx 2724-01F, TVx 3410-02J, TVx 1948-01F, and TVx 3381-02F.

Mungbean. In a preliminary yield trial, 81 mungbean entries yielded an average 1.32 t/ha in Los Baños and 0.62 t/ha in Pangasinan. Eighteen entries outyielded CES 87 (check). Ten promising lines were highly resistant to Cercospora leaf spot and powdery mildew. The most promising entries were IPB M 79-22-161, IPB M 79-23-73, and IPB M 79-25-153. In the general yield trial, 36 entries were evaluated in Los Baños and Pangasinan. Yields at the 2 locations averaged from 0.88 t/ha to 1.64 t/ha. Six entries consistently gave high yields in both locations.

Soybean. In a preliminary soybean yield trial, 64 entries averaged 1.35 t/ha at Los Baños and 0.54 t/ha in Pangasinan. Twenty-three entries yielded more than 1 t/ha, but only 15 were selected for the general trial.

Peanut. Of 49 peanut varieties evaluated in Pangasinan, 13 yielded better than UPL Pn-4, the check variety. Rust infection was severe. Twenty-two entries with yields more than 1.20 t/ha and rating 2 to 3 for rust were selected for the general yield trial. The most promising entries were IPB Pn 30-29, IPB Pn 42-14, and IPB Pn 48-90.

VARIETAL TESTING IN THE PHILIPPINES

Rice Farming Systems Program

Upland crops before rice. Twelve mungbean, 12 cowpea, 6 bush sitao, 7 glutinous, 9 sweet and

Table 1. Upland crop varieties better than the check or highest yielding when planted before lowland rice in cropping systems sites in the Philippines during crop year 1983-84.

Test site	Crop variety and yield[a]				
	Mungbean		Cowpea		
	Grain	Fodder	Green pod	Grain	Fodder
IRRI, Los Baños	IPB M79-13-60 (1.18) IPB M79-9-82 (1.17) IPB M79-22-117 (1.14) M350 (1.08)	IPB M79-22-62 (9.67) IPB M79-9-82 (10.1)	All Season (5.51) TVx 3236-01G (5.37) EG #2 (5.07) CP 4-2-3-1 (5.05)	CP 4-2-3-1 (0.48) TVx 3236-01G (0.46)	TVx 3629 (15.1) TVx 4577-02D (14.3)
Ilagan, Isabela	M350 (1.08) Pag-asa 1 (0.93)	IPB M79-9-82 (14.3) IPB M79-7-79 (14.2) IPB M79-22-62 (14.1)	–	IES Cowpea #3 (0.48) TVx 133-16-D2 (0.48) TVx 3236-01G (0.48) All Season (0.48)	TVx 133-16-D2 (7.97)
San Jose, Occidental Mindoro	Pag-asa 2 (1.50) IPB M79-22-117(1.25) Pag-asa 3 (1.02)	–	–	–	–

Test site	Bush sitao		Field maize	
	Green pods	Fodder	Grain	Fodder
IRRI, Los Baños	BS_1 (6-14 R X AS) (12.2) BS_3 (6-14 R X AS) (8.12) EG BS #2 (7.45)	BS_1 (6-14 R X AS) (15.5) BS_3 (6-14 R X AS) (13.0) EG BS#2 (13.1)	Ranjuna (3.32) Arun 2 (3.30) Early DMR Comp 1 (2.83)	Suwan 1 (18.5) Comayagua 8130 (15.3) CIAT 8130 (15.3)

Test site	Sweet and glutinous maize	
	Green ears	Fodder
IRRI, Los Baños	Glutinous Syn 22 (5.05) Glut Comp. Popn 41B (5.05) Los Baños Lagkitan (5.18) Bxj Sweet Comp #1 (4.76) Sweet Comp Popn 31B (4.91)	Los Baños Lagkitan (27.5) Glut Syn 22 (27.0) Bxj Sweet Comp #1 (19.2) Sweet Comp Popn 31B (22.8)
Ilagan, Isabela	Los Baños Lagkitan (3.41) Phil Supersweet #9 (2.17)	Glutinous Syn 22 (16.4) Phil Supersweet #9 (16.0)
San Jose, Occidental Mindoro	Glut Comp Popn 41A (4.83) Glutinous Syn #41 (3.01)	–
Libmanan, Camarines Sur	Glut Comp Popn 41C (2.0)	Glut Syn 22 (12.0)
Jamindan, Capiz	Glut Comp Popn 41A (7.6) Glut Syn #22 (2.1)	–

[a] Figures in parentheses are yield in t/ha.

supersweet and 10 early field maize varieties were evaluated at IRRI farm, Isabela, Capiz, Occidental Mindoro, and Camarines Sur during 1984 WS.

Table 1 lists the crop varieties that performed better than check varieties in the test before rice.

Mungbean. At IRRI, IPB M79-13-60 was the top grain yielder and IPB M79-9-82 was the top fodder producer (Table 1). In Isabela, the top grain yielders were M350 and Pag-asa 1, and fodder yield was highest in IPB M79-9-82 and IPB M79-7-79. In Mindoro, Pag-asa gave highest grain yield.

Cowpea. The top yielders of cowpea green pod at IRRI test were All Season and TVx 3236-01G with 5 t/ha (Table 1). TVx 3629 gave the highest fodder yield (15.1 t/ha) after 2 primings of dry pods. In Isabela, TVx 133-16-D2, TVx 3236-01G, and All Season were the highest grain yielders. TVx 133-16-D2 also gave the highest fodder yield (8 t/ha) after 4 primings of dry pods; however, it matured the latest (68 d).

Bush sitao. At IRRI, BS_1 (6-14 R × AS) yielded highest in green pods (12.2 t/ha) and fodder (15.5 t/ha) (Table 1). BS_1 and BS_3 matured in 74 d.

In Isabela, Los Baños Bush Sitao #1 gave the highest grain yield (1.6 t/ha) and fodder, with BS_3 and BS_1 performing well.

Maize. In field maize, the top grain yielders at IRRI were Ranjuna (Indonesia) and Arun (Nepal) (Table 1). These early-maturing varieties matured in 91 d. Stover yield after harvest was more than 15 t/ha in Suwan 1, Comayagua 8130, and CIAT 8130.

Among glutinous varieties, Los Baños Lagkitan had highest marketable ear yield (5.18 t/ha) followed by Glutinous Syn. 22 and Glutinous Composite Popn 41B (5.05 t/ha), all at IRRI. Stover yield after harvest of green ears was highest in Glutinous Syn. 22 and Los Baños Lagkitan (27.0 t/ha). In Isabela, Los Baños Lagkitan was also outstanding in marketable ears. Glutinous Syn. 22 ranked third with 3.3 t/ha, and gave the highest fodder yield (16.4 t/ha). In Camarines Sur, yield ranges were 1.1-2.0 t ears/ha and 8.0-13.0 t fodder/ha. In Mindoro, Glutinous Comp. Popn 41A and Glutinous Syn. #41 were the top yielders of marketable ears but fodder yield was low because of cutworm. In Capiz, Glutinous Comp. Popn 41A and Glutinous Syn. 22 were the highest yielders of marketable ears.

In the supersweet varieties, Bxj Comp. #1 was the top yielder of marketable ears (4.8 t/ha) and stover (19.2 t/ha) while in sweet maize, Sweet Comp. Popn 31B gave the highest marketable ear (4.9 t/ha) and stover yield (22.8 t/ha) at IRRI. In Isabela, Phil. Supersweet #9 gave the highest marketable ear yield (2.2 t/ha). Sweet Comp. Popn 31V and Phil. Supersweet #9 were the top yielders of fresh fodder.

Upland crops after rice. The trials with upland crops after rice were conducted during 1983-84 DS under two tillage levels. Zero tillage involves no land preparation; high tillage involves one or two plowings and harrowings. The zero tillage trials were conducted in IRRI, Cagayan, and Iloilo; the high tillage trials were in Nueva Ecija, Isabela, Ilocos Sur, and South Cotabato. Test varieties were 16 mungbean, 10 cowpea, 9 bush sitao, 10 soybean, 10 peanut, 10 pigeonpea, 10 sorghum, 10 field maize, 7 glutinous maize, and 9 sweet and supersweet maize.

Results of zero tillage trials are presented in Table 2 and high tillage in Table 3.

Mungbean. Under zero tillage at IRRI, mungbean grain yield ranged from 1.2 to 1.7 t/ha. The top yielders were M350, IPB M79-13-60, and IPB M79-13-29 (Table 2). Fodder yield was highest in IPB M79-13-61 and IPB M79-13-29. IPB M79-22-62 was most resistant to Cercospora leaf spot disease. Low yields at the two other sites were due to lack of moisture at Cagayan and excessive moisture at Iloilo.

Under high tillage, Pag-asa 1 yielded most grain (2.3 t/ha) in South Cotabato (Table 3). In Ilocos Sur and Nueva Ecija, CES 1T-2 was best, yielding 1.3 and 0.7 t/ha.

Cowpea. At IRRI, cowpea TVx 3671-14C-01D gave the highest grain yield (1.9 t/ha) (Table 2). TVx 4659-03E produced most fodder (23.6 t/ha) after 4 primings of dry pods. It matured in 77 d. In Cagayan, Vita 4 yielded most grain. In Iloilo, All Season and Vita 4 were best.

Bush sitao. Under zero tillage, BS_3 (6-14 R × AS) was best bush sitao variety at IRRI, yielding 1.4 t grain/ha. Other high yielding varieties were LBBS #1 and BS_7. BS_3 matured in 71 d. In Cagayan, these three were best. BS_7 yielded 3.8 t/ha and matured in 68 d.

Under high tillage (Table 3), BS_1 and BS_3 (6-14 R × AS) were best in Nueva Ecija, yielding 1.5 and 1.3 t/ha.

Soybean. Outstanding soybean lines under zero

Table 2. Crop varieties better than the check or highest yielding when planted with zero tillage after lowland rice in cropping system sites in the Philippines during crop year 1983-84.

Test site	Crop variety and yield[a]				
	Mungbean		Cowpea		Bush sitao grain
	Grain	Fodder	Grain	Fodder	
IRRI, Los Baños	M350 (1.7) IPB M79-13-60 (1.5) IPB M79-13-29 (1.4)	IPB M79-13-61 (9.6) IPB M79-13-29 (8.8)	TVx 3671-14C-01D (1.9) TVx 2724-01F (1.7) TVx 3410-02J (1.6)	TVx 4659-03E (23.6) TVx 3410-02J (19.5)	BS_3 (6-14 R X AS) (1.4) LBBS #1 (1.2) BS_7 (1.20)
Solana, Cagayan	MG50-10A (0.76) CES U-1 (0.73) CES IT-2 (0.66)	–	Vita 4 (1.4) All Season (1.0)	–	BS_7 (3.8) BS_3 (6-14 R X AS) (3.5) LBBS #1 (3.4)
Guimbal, Iloilo	CES IT-2 (0.25)	–	All Season (1.8) Vita 4 (1.7)	–	–
	Soybean	Peanut		Pigeonpea	
		Grain	Fodder	Grain	Fodder
IRRI, Los Baños	30290-11-11 (2.5) 7207-1 (2.4) 7507-38-4 (2.3)	Acc 12 (1.8) CES 2-25 (1.8) F334-33 (1.7) UPL PN-2 (1.5)	PI 118200 (12.4)	QPL 72 (2.7) TC (FC) J-1 (2.0)	TCF 6-1-1 (9.9) QPL 70-2 (8.7)
Solana, Cagayan	11-4 (0.1)	–	–	–	–
	Sorghum		Field maize		Green maize
	Grain	Fodder	Grain	Fodder	
IRRI, Los Baños	CS 137 (3.9) CS 253 (3.4)	CS 182 (13.5) CS 110 (11.6) CS 137 (11.4)	Pirsabak 7930 (3.0) Tocumen 7931 (2.8) Poza Rica 7931 (2.8)	KUC #2 F_7 (11.7) Thai Comp 1 Early (10.8)	Glutinous Syn 22 (3.8) Glut Comp Popn 41 (3.6) Phil Supersweet #1 (3.7) Sweet Comp Popn 31C (4.0)

[a] Figures in parentheses are yield in t/ha.

Table 3. Crop varieties better than the check or highest yielding when planted with high tillage after lowland rice in cropping system sites in the Philippines during crop year 1983-84.[a]

Test site	Mungbean grain	Bush sitao grain	Soybean	Peanut	Sorghum
Koronadal, South Cotabato	Pag-asa 1 (2.29) EG MG 174-3 (1.90) MG 50-10A (G) (1.88) CEC 2N-4 (1.83)	–	–	–	–
Narvacan, Ilocos Sur	CES IT-2 (1.25)	–	30050-2-17 (2.7) 7207-1 (2.6)	–	CS 110 (2.8) CS 116 (2.5)
Caoayan, Ilocos Sur	–	–	30050-2-17 (4.0) 7207-1 (3.0)	M-10 (0.7) PI 118200 (0.6)	CS 110 (5.2) CS 116 (4.3)
MRRTC, Nueva Ecija	CES IT-2 (0.70) Pag-asa 1 (0.69)	BS_1 (6-14 R X AS) (1.5) BS_3 (6-14 R X AS) (1.3)	– –	CES 101 (0.5) ACC 12 (0.4)	CS 253 (3.1) CS 268 (2.9) CS 110 (2.8)
Ilagan, Isabela	–	–	7202-1 (2.6) 50106-4-7 (2.6)	–	–

[a]Figures in parentheses are yield in t/ha.

tillage at IRRI were 30290-11-11, 7207-1, and 7507-38-4 each yielding more than 2 t/ha (Table 2). They matured in 92 d. In Cagayan, lack of moisture ruined yields.

Under high tillage, lines 7207-1 and 50106-4-7 were best grain yielders in Isabela with 2.6 t/ha (Table 3). In Ilocos Sur, lines 30050-2-17 and 7207-1 were outstanding entries yielding 4.0 and 3.0 t/ha in Caoayan.

Peanut. At IRRI, the highest yielders of shelled peanut under zero tillage were Acc 12, CES 2-25, F334-33, and UPL PN-2 (1.5-1.8 t/ha) (Table 2). PI 118200 gave the highest fodder yield (12.4 t/ha) after priming pods.

Under high tillage, yields in Nueva Ecija and Caoayan were very low.

Pigeonpea. After 2 primings of dry pods, QPL 72 (2.7 t/ha) and TC (FC) J-1 (2.0 t/ha) under zero tillage gave the highest pigeonpea yield (Table 2). TCF 6-1-1 and QPL 70-2 were best in fodder production. TC (FC) J-1 was the most resistant to fusarium root rot disease.

Sorghum. Among sorghum varieties under zero tillage at IRRI, CS 137 (3.9 t/ha) and CS 253 (3.4 t/ha) gave the most grain (Table 2). Fodder yield was highest in CS 182 (13.5 t/ha) and CS 110 (11.6 t/ha). These varieties mature in 82-84 d.

Under high tillage, CS 253, CS 268, and CS 110 were outstanding in Nueva Ecija (Table 3). In Ilocos Sur, CS 110 and CS 116 were the highest grain yielders.

Maize. Among the field maize varieties tested at IRRI, Pirsabak 7930, Tocumen 7931, and Poza Rica 7931 yielded best (Table 2) at zero tillage. Stover yield was highest (>10 t/ha) in KUC #2 F_7 and Thai Comp. 1 Early.

Of the glutinous varieties, Glutinous Syn. 22 gave the highest marketable ear yield (3.8 t/ha). In the supersweet and sweet maize types, Philippine Supersweet #1 and Sweet Comp. Popn 31C were the top yielders.

Upland crops in wet season. Under upland conditions, 15 yardlong bean selections from Thailand and IPB and 10 sweet potato varieties from IPB were evaluated at IRRI during 1984 WS. Promising varieties are listed in Table 4.

Yardlong bean. The top yielder of yardlong bean green pods after 8 primings was Red Mosaic (75), with 25.7 t/ha. First harvest was at 46 d.

Sweet potato. The top yield (22.7 t/ha) of sweet potato marketable tubers was from G113-2 B t/ha. Fodder yield was highest in G 145 r-4 (47.2 t/ha), G113-2 B (46.1 t/ha), and CI 693-9 (45.6 t/ha).

YIELDS OF 20 EARLY- AND LATE-PLANTED IMPROVED UPLAND RICES

Multiple Cropping Department

Highly productive, stable, short-duration upland rice cultivars with early vigor are central to a productive upland rice technology. In May 1984, IRRI and the Philippine Ministry of Agriculture and Food started an on-farm upland rice cropping systems research project. In anticipation of this

Table 4. Yield of promising yardlong bean and sweet potato varieties grown under upland condition. IRRI, 1984 WS.

Crop, variety	Yield (t/ha)		
	Fresh pod	Marketable tubers	Fodder
Yardlong bean			
Red Mosaic (75)	25.7		
PS #3	21.2		
PS #2	20.3		
Sweet potato			
G113-2B		22.70	46.11
Kinabakab		12.89	22.37
G 53r-17b		10.81	36.37
G 67-1a		7.70	35.00
G 145 r-4		7.22	47.21
CI 693-9		6.17	45.62

project, 20 upland rice cultivars in the 1983 International Upland Rice Yield Nursery were compared at IRRI for grain yield and general growth characteristics. Four sets of the nursery were planted on two terrain positions and on two dates within each position to expose the cultivars to different soil water regimes and weather conditions. The upper field had a free-draining profile; the lower field had soil with water table often near the surface, but unstable. Textural and chemical data for the two soils were similar. Plantings were on 10 and 11 Jun and 6 and 8 Aug 1983. The June planting enhanced chances for favorable rainfall, and the August planting improved chances for moderate drought during the late grain-filling period.

Entries were planted in 3 replications of a randomized complete block design in 3- × 5-m plots. The crops were hand-seeded at 100 kg/ha in *lithao* furrows spaced at 25 cm. Nitrogen was topdressed at 25 kg/ha 2 wk after seeding and at 50 kg/ha at panicle initiation. The crops were adequately protected from insects, diseases, and birds.

Perforated PVC pipe was installed to monitor water table depths twice weekly.

A combined analysis of variance showed that the main effect of cultivar and the interaction of cultivar and date within position were significant. In the upper position, mean yield was 4.4 t/ha in the June planting and 2.4 t/ha in August. The corresponding yields from plantings in the lower position were 3.1 and 2.6 t/ha. The June plantings received more rainfall and solar radiation. In the June planting, mean yield from the higher terrain was significantly greater than from the lower terrain. Terrain position did not significantly influence yield in the August planting. Denitrification may have been greater in the lower position where the water table was frequently within 20 cm of the surface. In the upper position, the water table was within 20 cm only once. In September, for example, mean depth of water table was 3 cm in the lower position and 140 cm in the upper. In October, mean depths were 9 and 73 cm; in November, they were 86 and 118 cm. By the end of December, water tables were deeper than 140 cm in both positions.

Factor analysis examined the patterns among cultivar grain yields from the four plantings. Yields of the local check Dagge and of IR52 were excluded because Dagge had an undesirable plant type and IR52 was heavily infected with blast (*Pyricularia oryzae*). By regarding the four grain yields from the planting date-terrain position combinations as cultivar attributes, two factors were extracted. The factor pattern matrix is presented in Table 5. Factor 1 was highly correlated with yields in the late-planted nurseries and factor 2 with yields in the early-planted nurseries. Mean yields are given by entry and planting date, and by membership in five clusters in Table 6.

Figure 1 is a scatter diagram of factor 1 and 2 scores from the 19 entries. Solid lines encircle the most similar members in a cluster. Dashed lines encompass entries corresponding less close. Factor score axes were scaled to correspond to maximum and minimum yields, and cluster means were plotted. The correspondence between cluster mean yields and mean factor scores for each cluster was close. Yields of the entries in cluster 1 were above

Table 5. Pattern matrix for 2 orthogonally rotated factors extracted from grain yields of 4 1983 IURYN plantings. IRRI, 1983.

Planting		Rotated factor pattern	
Terrain position	Month	Factor 1	Factor 2
Lower	June	−0.061	0.728
Lower	August	0.850	0.111
Upper	June	0.293	0.742
Upper	August	0.753	0.054
Variance explained		1.38	1.10

Table 6. Grain yield, mean daily productivity and maturity of 19 upland rice cultivars planted in June and August on 2 terrain positions. IRRI, 1983.

Cluster	Code		Grain yield (t/ha)			Productivity (t/ha per day)			Maturity (d)	
			Jun	Aug	Mean	Jun	Aug	Mean	Jun	Aug
1	A	BR319-1	5.0	2.8	3.9	44.1	24.7	34.4	114	114
	B	BPI Ri-6 (MRC438)	4.2	2.8	3.5	35.0	24.5	29.8	121	114
	M	IR5931-110-1	4.7	2.9	3.8	37.1	26.4	32.1	126	108
	Q	IR9782-111-2-1-2	4.7	2.9	3.8	43.8	28.5	36.1	108	100
	O	IR6115-1-1-1	4.6	2.9	3.7	42.9	28.5	35.5	107	100
	K	IR43 (international check)	4.4	3.2	3.8	33.7	28.1	30.9	131	114
	T	UPL Ri-7	4.2	3.1	3.7	34.7	27.6	31.1	121	114
		Mean	4.6	2.9						
2	E	CR156-5021-207	4.7	2.4	3.5	40.3	21.7	31.0	116	108
	G	IRAT 112	4.4	1.7	3.1	47.7	21.0	34.3	92	83
	J	IR3179-25-3-4	4.5	2.0	3.3	36.9	16.9	26.8	122	120
		Mean	4.5	2.0						
3	F	IRAT 104	3.4	2.0	2.7	30.3	18.8	24.6	112	108
	H	IR12721-24-3-1	3.1	2.4	2.7	24.3	20.0	22.2	126	130
	N	IR6023-10-1-1	3.5	2.5	3.0	27.8	20.3	24.0	126	120
		Mean	3.3	2.3						
4	C	C732-14	2.4	2.3	2.3	19.6	20.0	19.8	121	114
	I	IR13146-46-2-3	2.4	2.4	2.4	18.7	19.6	19.1	129	120
		Mean	2.4	2.3						
5	D	C894-21	3.1	2.8	3.0	25.5	24.1	24.8	123	114
	S	UPL Ri-5	3.4	2.7	3.1	27.7	24.1	25.9	124	114
	P	IR9101-124-1	3.6	2.8	3.2	27.9	22.9	25.4	128	120
	R	UPL Ri-3	3.4	3.1	3.2	26.8	27.2	27.0	126	114
		Mean	3.4	2.8						

average in both the June and August plantings.

Mean daily productivities (grain yield/ha per day) and maturities are in Table 6. Under the moderate drought stress encountered by the late-planted nurseries, daily productivity of entries did not greatly differ. The daily productivity range was greater in the early-planted nurseries. When planted in June, BR319-1, IR9782-111-2-1-2, and IR6115-1-1-1 yielded more than 40 kg grain/ha per day.

INTERCROPPING DEEP WATER RICE AND EARLY MATURING RICE

Agronomy Department

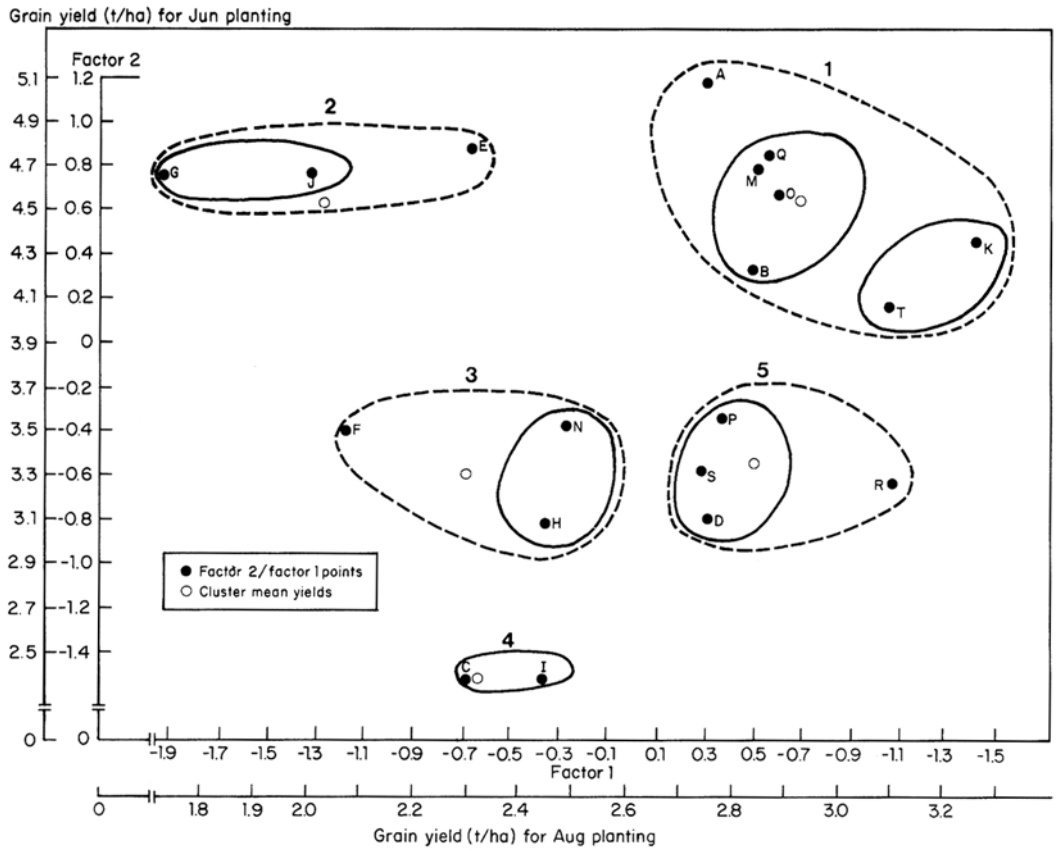
Early maturing rice RD25 was grown as a rainfed intercrop with deep water rice LMN111 for two seasons at Huntra Experiment Station, Thailand. Seed was sown into a dry seedbed at the beginning of the rainy season. Row patterns for both rices are given in Table 7. Rows were 25 cm apart. Seedlings emerged 10 May 1982 and 27 May 1983. Plots received 54 kg N and 14 kg P/ha. RD25 was harvested both years at 94 d after seedlings emerged, and LMN at 224 and 212 d. Rainfall before harvest of RD25 was 468 mm in 1982 and 655 mm in 1983.

Total yields were higher for intercrops than for monocultures. The land equivalent ratio ranged from 1.25 to 1.51. In relation to LMN as a sole crop, intercropping increased production 0.68 to 1.36 t/ha. Yield per unit area of LMN was maintained even with relatively wide spacing. At wide spacing, more LMN stems survived to maturity, increasing grain production per metre of row (Table 8).

GRAIN YIELDS OF QUALITY-PROTEIN AND NORMAL-PROTEIN MAIZE

Multiple Cropping Department

To compare the performance of 10 quality-protein maize (QPM) varieties from the International Center for Improvement of Maize and Wheat and 2



1. Factor score scatter diagram for 19 cultivars. IRRI, 1983. Grain yield ranges for June and August plantings were scaled to factor 2 and factor 1 score ranges. Mean grain yields corresponding to clusters in Table 6 are superimposed on the scatter diagram. Cultivar codes are given in Table 6.

Table 7. Grain yield of each component, total intercrop, and monocultures with land equivalent ratios (LER). Huntra Experiment Station, Thailand, 1982 and 1983 WS.

Variety and LER	Grain yield (t/ha)						LSD 0.50	CV (%)
	Intercrop[a]				Monoculture			
	1:2 (33%)	2:2 (50%)	2:3 (40%)	3:3 (50%)	LMN	RD25		
				1982				
RD25	1.44	1.37	1.54	1.43	–	2.66	0.52	20.0
LMN	2.45	2.59	2.63	2.45	2.81	–	0.23	5.8
Total	3.89	3.96	4.17	3.99	2.81	2.66	0.43	8.0
LER	1.41	1.44	1.51	1.41	–	–	–	–
				1983				
RD25	1.24	1.18	1.48	1.44	–	2.82	0.26	10.3
LMN	2.67	2.42	2.44	2.52	2.92	–	NS	11.2
Total	3.91	3.60	3.92	3.96	2.92	2.82	0.44	8.4
LER	1.35	1.25	1.37	1.36				

[a]The ratios indicate rows of LMN to rows of RD25. The percentages in parentheses indicate area of LMN.

Table 8. Grain yield for deep water rice and early maturing (modern variety) intercrop components and monocultures. Huntra Experiment Station, Thailand, 1982 and 1983 WS.

Year	Grain yield[a] (g/m of row)					LSD 0.01
	1:2	2:2	2:3	3:3	Monoculture	
			RD25			
1982	53.7	68.5	64.0	71.5	66.5	ns
1983	46.4	59.1	61.8	72.1	70.5	15.0
Mean	50.1	63.8	62.9	71.8	68.5	
			LMN			
1982	184	130	164	123	70	19
1983	201	121	152	126	73	32
Mean	192	125	158	124	72	

[a]The ratios indicate rows of LMN to rows of RD25.

normal-protein maize entries (one open-pollinated and one hybrid), a field trial was planted on a well-tilled field on 7 Mar 1984. Plots measuring 5 × 6 m each were laid out in 4 randomized complete blocks. Entries were planted at 25-cm intervals on 75-cm rows (53,333 plants/ha). One hundred kg N/ha was applied in 3 splits: 1/3 each at planting, 30 d after emergence, and tasseling. Weeds and insect pests were adequately controlled. Grain yield samples were taken from 11.25 m^2 on 11 Jun.

The yields from most QPM entries were similar (Fig. 2). Yields of the two highest yielding QPM entries (Tuxpeño, and Across 8140) and the open-pollinated variety (IPB Var 1) ranged from 6.6 to 7.0 t/ha. The hybrid (SMC 305) had the highest grain yield (7.7 t/ha).

EMERGENCE AND SEEDLING VIGOR OF COWPEA CULTIVARS

Multiple Cropping Department

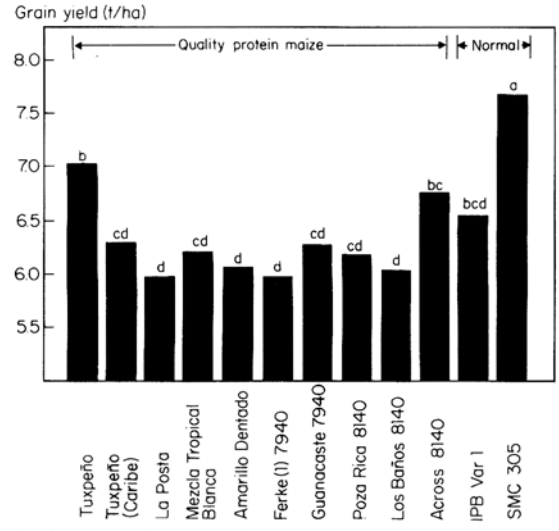
Emergence and seedling vigor of 20 cowpea cultivars were compared at adequate and low soil moisture in late 1984 DS.

The experimental area was plowed deeply and rototilled twice to obtain a dry soil in good tilth. A strip-plot design with 4 replications was laid out on 4 Apr 1984. In each subplot, seeds were planted in shallow furrows (3 m long × 0.5 m apart × 12 mm deep, 3 rows/plot). Seeds came from a variety trial harvested between 27 Feb and 9 Mar 1984. Germination percentages were determined and seeding rates adjusted for emergence of 180 seeds/plot. After planting, rice straw mulch was laid over the plots before irrigation to avoid soil crusting and rapid drying. Unrandomized strips of decreasing soil moisture gradients were established by a line-source sprinkler system. Forty-three mm of water was applied to the wettest regime, 30 mm to the intermediate, and 15 mm to the driest. Mulch was removed 4 d after irrigation. Plant counts were made 7 d after seeding (DAS) and total dry matter samples were obtained from 3.6 m^2 at 14 DAS.

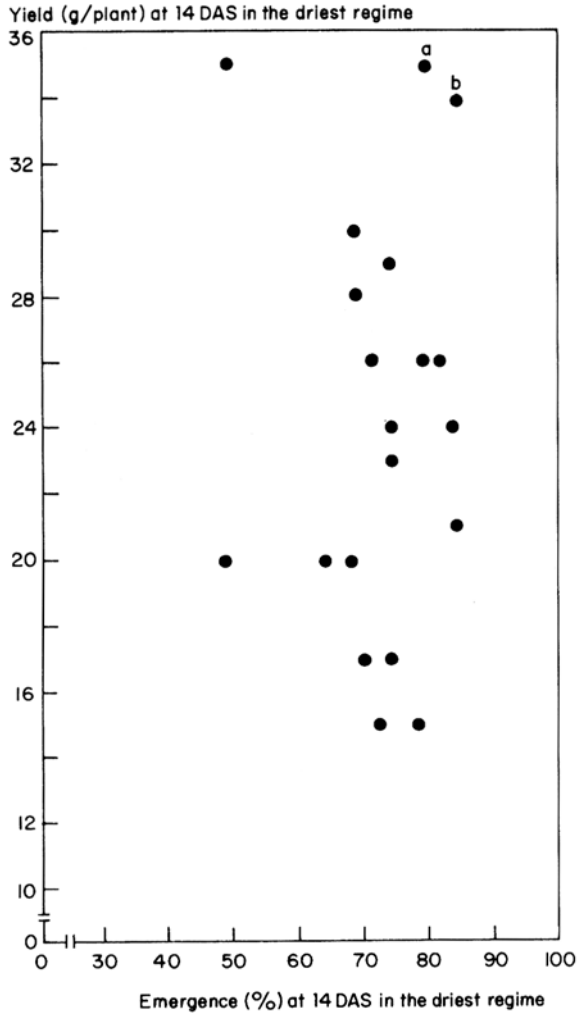
Soil temperatures below the mulch were measured at 1400 h 1 d after irrigation, on the day of mulch removal, and 4 d afterwards. Under mulch and irrigation, surface temperature was 15° C cooler than that of bare soils outside the plot for the first 2 d. Four days after mulch removal, temperatures in the driest and intermediate regimes were almost equal. Surface temperature in the wettest regime was 10° C cooler.

Emergence and total dry matter yields were significantly affected by cultivars. The cultivar-moisture regime was also significant.

Total dry matter yield of seedlings was based on two components, emergence percentage and yield per plant for 20 cultivars in the dry regime (Fig. 3). EG #1 and California Blackeye performed well in the dry regime and also in the wettest regime. In the wettest regime, only 3 cultivars did not belong to the group with the highest emergence of 88 to 97%.



2. Grain yields (at 14% moisture content) of 10 quality-protein and 2 normal-protein maize varieties. IRRI, 1984 DS.



3. Yield per plant and percent emergence, determined at 14 DAS, in the driest regime of a gradient imposed by a line source sprinkler system. IRRI, 1984 DS. Point *a* is California Blackeye and *b* is EG #1.

COWPEA AND MUNGBEAN TOLERANCE FOR EXCESS MOISTURE

Multiple Cropping Deparment

Tolerance for flooding is necessary for crops grown before or after rice. Cultivars of cowpea and mungbean were tested for shallow flooding followed by temporary waterlogging, in a sloping box constructed in the field (Annual report for 1983). In two trials, eight cowpea and eight mungbean cultivars were tested. A third trial tested 12 cowpea cultivars. Rows of cultivars were overseeded down the slope on soil at field capacity. At first-leaf stage, plants were thinned to one per seed placement position. Flooding started when plants were 3 to 4 wk old. Flooding was maintained for 2 to 3 d, and then water was drained so only the lower end of the box was waterlogged. Plants were counted by stratum, starting from I at the low end where conditions were most unfavorable (too wet), to IV where conditions were most favorable.

Table 9. Survival of 12 cowpea entries in 4 strata of excess moisture treatment. IRRI, 1984 WS.

Entry	Survival (%)			
	I	II	III	IV
All Season	25	80	100	100
CP2-3-1	60	95	95	95
CP4-2-3-1	80	80	95	100
EG #2	40	50	95	95
IT 82D-889	95	100	100	100
Pelungga	0	45	70	85
TVU 2931	5	60	85	60
TVX 7-5H	5	30	45	5
TVX 1836-19E	10	90	95	95
TVX 3236-01G	65	90	100	85
Vita 3	80	100	85	100
Vita 4	30	35	70	30

Results show mungbean was less tolerant of excess moisture than cowpea. Mungbean cultivars reacted similarly to excess moisture. Among cowpea cultivars, however, CP4-2-3-1 showed the greatest and Pelungga the least tolerance for excess moisture.

In the third trial, the box was enlarged, mungbean was excluded, and 12 cowpea entries were tested. Plants per entry per stratum increased from 15 to 20. Percentages of surviving plants are in Table 9.

Survival of entries differed and the entry stratum interaction was significant. CP4-2-3-1 again was tolerant of the strong excess moisture pressures in stratum IV, where soil moisture was maintained at a high level after flooding. Vita 3 and IT 82D-889 also showed tolerance, but Pelungga did not. TVx 7-5H and Vita 4 recovered poorly from flooding in all strata. In strata III and IV, survival of other cultivars was high once flooding was withdrawn. Damping-off contributed to plant losses in these strata after flooding ended.

Cropping systems program

Agronomic management in rice-based cropping systems

Multiple Cropping, Plant Pathology, and Soil Chemistry/ Physics Departments

GREEN MANURING **412**
- Contribution of a short-duration green manure cowpea crop to rice yields and nitrogen uptake **412**
- Evaluation of green manures for wet season rice **412**
- Performance of three *Sesbania* species **413**
  - Rice response to incorporation age and cultivation with and without flooding **413**
  - Flowering responses to planting dates **416**
- Effect of green manure incorporation-transplanting interval, and of incorporation and surface application **416**
- Soil physical effects of green manures and crop residues in rainfed lowland cropping sequences **417**
- Maize response to green manure and inorganic N **417**

FERTILIZATION AND CULTURAL MANAGEMENT **418**
- N management in rice-based cropping systems **418**
- Mycorrhizae in rice-based cropping systems **419**
- Mycorrhizal association on maize and soybean after lowland rice **419**
- Effects of rhizobium inoculation on mungbean **420**
- Effects of cultural management on upland rices **420**

INTERCROPPING AND RELAY PLANTING **421**
- Upland rice + cowpea **421**
  - Crop proportions at high and low soil fertility **421**
  - Effect of seeding rate on yield and N uptake **422**
  - Cowpea cultivar performance **423**
- Rice + maize response to excess soil moisture **424**
- Upland rice + maize response to nitrogen fertilizer **424**
- Relay planting maize with two upland rices **425**

CROP ESTABLISHMENT **426**
- Emergence of RIP-seeded mungbean and maize at various soil moisture levels **426**
- Drainage methods to control early flood damage to mungbean **427**

SORGHUM MANAGEMENT **427**
- Crop performance at two terrain positions and planting dates **427**
  - Main crop **427**
  - Ratoon crop **427**
- Time and rate of N application **428**

WHEAT MANAGEMENT **429**
- Nitrogen management **429**
- Cultural management at Cagayan Valley **429**
  - Effect of planting date **430**
  - Response to fertilizer **430**

GREEN MANURING

Multiple Cropping and Soil Chemistry/ Physics Departments

Contribution of a short-duration green manure cowpea crop to rice yields and nitrogen uptake (*Multiple Cropping*). Cowpea (All Season), substituted for mungbean in the fourth year of this green manure experiment, was planted on 26 Apr and 16 May 1984. Because plantings were 10 d late and the wet season (WS) started earlier than in the past 3 yr, the green manure was exposed to periods of waterlogging, as it would if a farmer waited for early rains before green manure establishment. The green manures were incorporated on 14 Jun when they were 25, 35, and 45 d old. Twenty-day-old IR54 seedlings were transplanted on 16 Jun. To half of the plots, 80 kg inorganic N/ha was split-applied (1/3 at planting and 2/3 at panicle initiation [PI]). Rice was harvested on 26 Sep. On 26 Oct, 20-d-old IR54 seedlings were transplanted to test for residual N responses from the green manure and inorganic fertilizer treatments.

Total dry matter yields (TDMY) and N accumulations in the green manures are shown in Table 1. The 45-d-old cowpea accumulated 74 kg N/ha, 12 kg/ha less than the mungbean average in prior years. Rice yield responses to applied green manure and inorganic N and to N uptake are shown in Figure 1, together with apparent N recovery as a function of applied N. Rice yield response from the 45-d-old green manuring alone was 1.1 t/ha. Figure 1 shows responses to N sources were similar.

N efficiency was high where N application was low, but diminished as N applications increased. For example, the first kg N/ha increased grain yield by 17 kg/ha. When the combined N application was 100 kg/ha, response was only 8 kg/ha per additional kg N. Furthermore, yields of the control have risen steadily in 4 yr, from 1.0 t/ha in 1981 to 3.2 t/ha in 1984.

Table 1. Total dry matter yield and N accumulated by cowpea incorporated as green manure at 3 ages. IRRI, 1984 WS.

Age at incorporation[a]	TDMY[b] (kg/ha)	N accumulation (kg/ha)
25 DE	385	7
35 DE	1517	36
45 DE	3370	74
CV (%)	15	7

[a]DE = days after emergence. [b]Total dry matter yield.

The response to inorganic and green manure N was not additive. For example, the response to a 45-d-old cowpea crop was only 0.5 t/ha in the presence of 80 kg inorganic N/ha but 1.1 t/ha in its absence. The response curve in Figure 1 suggests that the yield plateau was approached when both the combined inorganic and green manure N levels were high. Grain yield per kg N/ha taken up from both sources showed similar diminishing responses. However, apparent N recovery was linear over the N range.

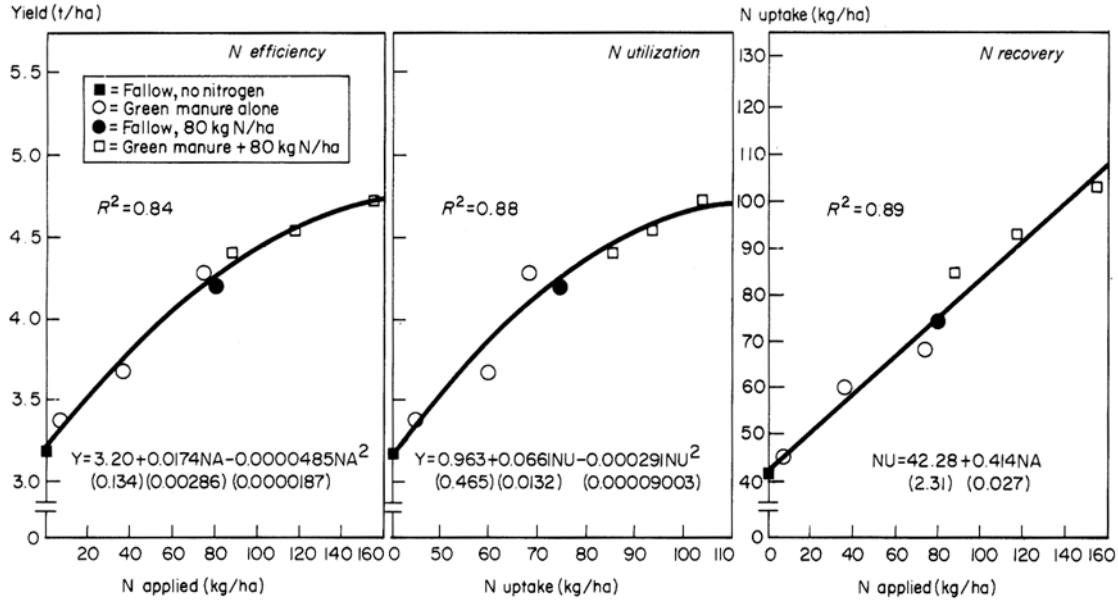
Although first crop yield response diminished as N level increased, second crop yields did not show residual response to N. Mean yield from the second planting was 3.4 t/ha and CV was 8%. Differential residual responses should not be expected.

Evaluation of green manures for wet season rice (*Multiple Cropping*). At IRRI, eight green manure crops were evaluated for biomass production, N accumulation, and as substitute for fertilizer N in rice. The Maahas clay (mixed non-acid, isohyperthermic Aeric Tropaquept) soil had pH 6.3, 1.02% organic C, 0.123% total N, and 15 ppm available P (Olsen).

The green manure crops were sown 16 Apr 1984 without fertilizer application. Biomass production was determined at 30 and 60 d after emergence (DE) and plants analyzed for N concentration. Also determined was weed biomass production on fallow plots that received a series of N fertilizer treatments when rice was cultivated.

Green manures and weeds were incorporated into the soil a week before IR54 was transplanted on 26 Jun. Four N levels (0, 50, 100, and 150 kg/ha) were applied to fallow plots. Half of each green manure plot received 50 kg N/ha, and half was unfertilized. Inorganic N was split applied: 1/3 at transplanting and 2/3 at 38 d after transplanting (DT).

Green matter and dry matter production and N accumulation at 30 and 60 DE in the green manure crops and weeds (Table 2) show that fresh weights of the green manure crops at 60 DE varied from 46.3 t/ha in *Sesbania aculeata* to 12.2 t/ha in mungbean (excluding harvested pods). The corresponding dry weights were 9.9 and 2.5 t/ha. The



1. Efficiency, utilization, and recovery of N from cowpea green manure incorporated at 3 ages, with or without 80 kg inorganic N/ha. IRRI, 1984 WS.

Table 2. Fresh and dry weights and N accumulation in green manures at 30 and 60 DE.[a] IRRI, 1984 WS.

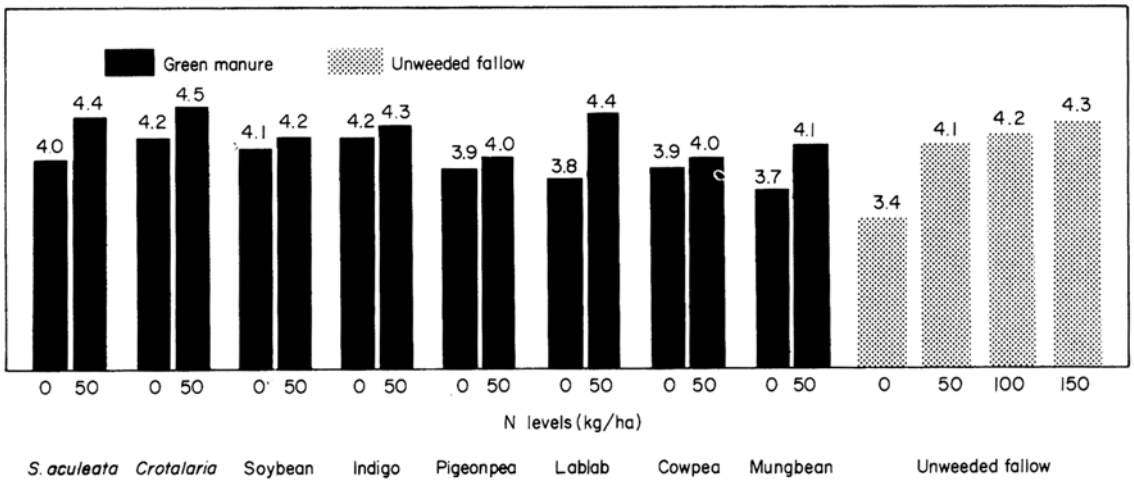
Green manure crop	Fresh wt (t/ha)		Dry matter (t/ha)		N accumulation (kg/ha)	
	30 DE	60 DE	30 DE	60 DE	30 DE	60 DE
S. aculeata	21.0	46.3	2.8	9.9	86	224
Crotalaria	18.1	45.8	2.4	8.5	69	141
Soybean	9.7	28.3	1.4	7.9	42	141
Mungbean	9.0	12.2	1.1	2.5 + 0.9[b]	32	50[d]
Lablab	6.4	22.6	0.9	4.5	25	84
Cowpea	4.9	15.2	0.6	3.0 + 0.4[c]	18	69[d]
Indigo	2.6	19.1	0.4	4.7	14	110
Pigeonpea	2.6	14.2	0.5	3.6	12	76
Unweeded fallow	–	16.3	–	1.6	–	25
CV (%)						

[a] Days after emergence. [b] Grain. [c] Dry pods. [d] Excluding harvested portions.

N incorporated from the green manures varied from 50 kg to 224 kg/ha. Figure 2 shows that in the inorganic N series, rice responded significantly to 50 kg N/ha. Rice yield with green manure alone was comparable to rice yield obtained with 50 kg N/ha in a weedy fallow, indicating a substitution of 50 kg N/ha irrespective of green manure species.

The marginal yield response to N at 25 kg N/ha, the N content in the incorporated weeds, was only 17 kg grain per kg N added. At 141 kg N/ha, the N level supplied by *Crotalaria* and soybean, the marginal response was less than 4 kg grain per kg N added. Thus abundant quantities of N from green manure were not effectively used.

Performance of three *Sesbania* species (*Multiple Cropping*). *Rice response to incorporation age and cultivation with and without flooding*. Green manuring potentials of 3 *Sesbania* species were



2. Rice yields from green manures and inorganic N fertilizer. IRRI, 1984 WS. Numbers over the bars are grain yield in t/ha.

Table 3. Total dry matter yields (TDMY) and N accumulations in 3 *Sesbania* species planted on 2 dates, grown under 2 water regimes, and incorporated on 18 Jul. Means of 4 replications and analyses of variance. IRRI, 1984 WS.

Treatment		TDMY (t/ha)		N accumulation (kg/ha)	
Green manure	Planting date	Unflooded	Flooded	Unflooded	Flooded
S. rostrata	19 May	7.7	6.9	176	148
S. rostrata	1 Jun	2.6	2.3	89	68
S. aculeata	19 May	7.2	6.3	144	121
S. aculeata	1 Jun	2.5	2.1	64	62
S. "china type"	19 May	6.9	4.9	131	98
S. "china type"	1 Jun	2.7	1.8	58	43

Source of variation	*df*	*Mean squares*	
Growth duration (D)	1	221.34**	62496**
Species (S)	2	2.66*	5808**
D X S	2	1.40	446
Flooding (F) X D	1	1.59	675*
F X S	2	0.84	201
F X D X S	2	0.12	53
CV (a) %		23	35
(b) %		20	21

compared under unflooded and partially flooded conditions. The experiment involved *Sesbania* species (control [without *Sesbania*], *S. rostrata*, *S. aculeata*, and *S. "china type"*), growth duration (incorporated 49 and 61 d after seeding [DAS]), and green manure water management (unflooded, continuously flooded 25 d before incorporation). One control had inorganic N applied in splits at planting (20 kg N/ha) and at PI (40 kg N/ha). The other control had no N fertilizer. The water management treatments were applied to main plots containing eight subplots.

Sesbania species were planted (50 kg seed/ha) in rows 40 cm apart on 19 May and 1 Jun 1984.

On 18 Jul, the green manures were chopped, all plots flooded, and material was incorporated by plowing and harrowing. Eighteen-day-old IR58 seedlings were transplanted on 23 Jul in 20- × 20-cm hills, 3-4 seedlings per hill. Pests were adequately controlled.

Among the *Sesbanias*, N accumulation and TDMY were highest in *S. rostrata*, regardless of water management or growth duration (Table 3). N accumulation and TDMY were higher when crops were 12 d older, regardless of species and water management treatments. Mean N accumulation across species and water treatments was 6.1 kg N/ha per day during the 12 d. Flooding reduced N accumulation by 20%, irrespective of growth duration. However, the shorter duration reduced N accumulation by 80 kg N/ha without flooding vs only 64 kg N/ha with flooding.

Rice grain yields were affected by green manure growth duration and species (Table 4). The interaction between water management on green manure and unfertilized control-green manure treatments was significant. TDMY, N uptake, and productive tillers were most strongly influenced by green manure growth duration. *Sesbania* species, water management, and their interaction with duration were either not significant or of lesser significance. The interaction between water management on *Sesbania* and unfertilized control vs green manure treatments was significant and agronomically important. The grain yield response from green manuring was lower where the soil was flooded the last 25 d of green manure growth.

The longer duration (12-d) green manure produced 114% higher N accumulation. To explore the effects of species, growth duration, and flooding, grain yield - N application - N uptake relations were examined.

Results show yield responses to green manure were primarily due to N accumulated at incorporation time, but responses also depended on whether green manures had or had not been flooded. N uptake did not differ in flooded and unflooded treatments. However, N uptake in an unflooded control plot without applied inorganic N was more effectively used than N derived from green manures or soil that had been flooded. N taken from unflooded, no-green-manure soil was approximately 10 kg/ha lower than from flooded, no-green-manure soil.

Table 4. Grain yield, N uptake, TDMY, and productive tillers of IR58 after green manure incorporation.[a] IRRI, 1984 WS.

Treatment		Grain yield (t/ha)		N uptake (kg/ha)		TDMY (t/ha)		Productive tillers (no./m^2)	
Green manure, N rates (kg/ha)	Green manure planting date	Unflooded	Flooded	Unflooded	Flooded	Unflooded	Flooded	Unflooded	Flooded
Fallow, 0 N		1.8	2.4	29.5	41.0	3.6	4.7	218	259
Fallow, 60 N		3.5	3.7	53.2	57.8	6.2	7.0	378	395
S. rostrata	19 May	3.9	3.3	78.5	69.3	7.7	7.2	429	420
S. rostrata	1 Jun	3.1	2.8	45.4	44.4	4.8	4.8	389	376
S. aculeata	19 May	3.5	3.2	81.2	68.5	7.7	7.4	415	406
S. aculeata	1 Jun	3.1	2.8	54.0	51.3	5.9	6.6	364	346
S. "china type"	19 May	3.2	3.2	81.1	74.9	7.9	7.7	424	420
S. "china type"	1 Jun	2.8	2.7	56.2	52.0	6.8	6.6	366	361
Source of variation[b]	*df*	*Mean squares*							
N_0 vs N_1	1	9.12**		1634.2**		24.40**		87370**	
N_0 vs green manure treatments (GM)	1	7.61**		5302.3**		46.42**		1634	
Growth duration (D)	1	3.32**		7517.5**		33.52**		32344**	
Species (S)	2	0.45**		184.6*		5.45**		1692	
D X S	2	0.06		50.3		2.70**		331	
Flooding (F) X D	1	0.04		133.7		0.70		56	
F X S	2	0.14		8.8		0.30		86	
F X D X S	2	0.04		17.8		0.26		26	
F X (N_0 vs GM)	1	1.22**		522.1**		2.46*		4517	
Remainder	1	0.18		115.3		0.96		666	
CV (a) %		10		10		7		12	
(b) %		9		12		11		10	

[a] Means of 4 replications. [b] N_0 = no fertilizer control, N_1 = 60 kg N/ha.

N recovery from unflooded *S. rostrata* was lower than from unflooded *S. aculeata* or *S. "china type."*

Flowering responses to planting dates. The three *Sesbania* species were planted at monthly intervals starting 28 Dec 1983 and ending 28 May 1984. This planting interval covered most of the daylength range at Los Baños (11 h 20 min to 12 h 45 min). Plants were thinned to 300,000 plants/ha 14 DAS. Plots were irrigated regularly, and plants protected from insects, diseases, and weeds.

Mean maximum and minimum temperatures varied only slightly during the growth period. With all species, duration between seeding and flowering lengthened when daylength at planting was about 12 h. Height at flowering also increased sharply as daylength increased, being highest for March and April planting but dropping for the 28 May planting. Changes in duration to flowering and plant height were most pronounced in *S. rostrata*. The short vegetative duration and plant stature have implications for the insertion of these green manure species in sequences with rice.

Effect of green manure incorporation-transplanting interval, and of incorporation and surface application (*Multiple Cropping*). In 1984 DS, research examined the effect of delays between cowpea incorporation and transplanting on grain yields and N recovery. Another experiment compared surface and soil incorporation. In both experiments, cowpea (TVx 1839-19E) planted in an upland field was harvested, chopped, and carried to the experimental field.

Green manures were applied at equally spaced rates to determine efficiency trends. IR58 was transplanted at 20- × 20-cm spacing on well-puddled fields, and plant protection practices were applied. The experiments were adjacent.

In the first experiment, cowpea was planted on 9, 15, 21, and 27 Nov 1983. Two green manure rates (6 and 12 t/ha, fresh matter basis) and 4 intervals between incorporation and transplanting (0, 6, 12, and 18 d) were used. No-green-manure was the control. This schedule enabled rice seedlings to be transplanted on the same day with green manure of same age (50 d). The final harrowing was 1 d before transplanting. Because green manure plantings and incorporations were staggered, the N content of incorporated materials differed: the 6 t/ha treatments incorporated on days 0, 6, 12, and 18 contained 27, 33, 26, and 24 kg N/ha, and twice those for the 12 t/ha treatments.

Duration between time of green manure incorporation and transplanting did not influence grain yield, TDMY, and N uptake (Table 5). Moreover, the interaction between rate and duration was not significant. Apparent N recovery was 54% and the soil supplied 73 kg N/ha. The response to 1 kg of green manure N was 15 kg rice. Grain yield increase was a linear function of N uptake.

In the second experiment, cowpea was planted on 9 Nov 1983. Three green manure rates (4, 8, and 12 t/ha containing 16, 32, and 48 kg N/ha) and 2 application methods (soil incorporated at final harrowing and surface broadcast at 15 DT) were applied, as were inorganic N treatments (0, 40, and 80 kg N/ha). Inorganic N was applied at transplanting (1/3) and 35 DT (2/3). On 14 Jan, seedlings were transplanted in 20- × 20-cm hills on well-puddled fields.

ANOVA results for grain yields and N uptake appear in Table 6. Single degrees of freedom for a linear inorganic N response and a linear organic N response accounted for 90% of the treatment sum of

Table 5. Analysis of variance for grain yield, TDMY, and N uptake of rice. IRRI, 1984.

Source of variation	df	Mean squares		
		Grain yield	TDYM	N uptake
Control vs others	1	1.83**	6.24**	1144**
Rate (R)	1	1.42**	3.44**	787**
Duration (D)	3	0.07	1.90	252
D × R	3	0.17	1.53	263
Error	24	0.06	0.65	112
CV (%)		6	10	12

Table 6. Analysis of variance for N uptake and grain yield of IR58. IRRI, 1984.

Source of variation	df	Mean squares	
		N uptake	Grain yield
Replication	3		
Inorganic N (linear)	1	1213**	0.340**
Organic N (linear)	1	298**	0.127**
Remainder	6	34	0.092
Error	24	14	0.054
CV (%)		(10)	(10)

squares for grain yield and 88% for N uptake by the rice crop.

Topdressed green manure was as effective as material incorporated at transplanting, although its response coefficient was numerically lower. Inorganic N was recovered more efficiently than organic N, but the sources were equally used for grain production. The difference in efficiency (kg grain/kg N applied) was due to difference in apparent N recovery. However, N recovery from green manure was only 18%, irrespective of application method; this is much lower than the 30-50% in other experiments. The soil supplied only 28 kg N/ha to the crop. No reason is evident for the large difference between soil-supplied N and apparent N recovery.

Soil physical effects of green manures and crop residues in rainfed lowland cropping sequences (*Soil Chemistry/Physics and Multiple Cropping*). To puddle a rice soil requires water equivalent to about 200 mm rainfall. In some monsoonal rainfed lowland rice-based cropping systems, to accumulate 200 mm at onset of WS may take several weeks. Previous studies showed that during these weeks it may be profitable to grow a legume crop as green manure to provide 80 to 100 kg N/ha for a following rice crop. Typical sequences including a green manure crop are legume - rice -rice, legume - maize - rice - rice, legume - rice - legume - maize. The manures and residues from each crop, and residues in sequences where there are no green manures are incorporated by rototillage to a maximum of 15-cm depth. Incorporated residues and manures may change soil-physical properties — particularly porosity and, hence, the soil hydraulic and mechanical properties — and possibly crop rooting.

In 2 experiments, both on silty clay loam soils of 1.3% initial organic matter content, and with legumes immediately before rice, we measured in 1984 the effects of 4 yr green manures and, separately, of 1 yr incorporated residues, on soil hydraulic and mechanical properties.

After 4 yr of legume green manures and crop residues, the slight increase in total porosity of the 0-20 cm layer was not statistically significant. Mean infiltration rate was possibly higher on manured plots, but the effects were small. Infiltration rates measured before manure incorporation at WS start were high (20 mm/h) enough on both manured and unmanured plots to imply a need for intensive puddling to impound water for a rice crop.

In the second experiment (after 1 yr incorporation of crop residues), site elevation differences influenced bulk density and porosity more than did the incorporated residues. Bulk density generally was low, and porosity correspondingly high. Soil strength was measured both by cone penetrometer and by shear vane. Penetrometer measurements showed 1 yr's residues had not decreased soil strength. In both topsoil and subsoil, effects of soil structural variation exceeded those of residues. One year's residues affected neither soil cohesion nor friction angle.

Both vane and penetrometer data suggest that at the prevailing volumetric soil-water content of 0.5, soil strength is approximately constant at depths from 20 to 50 cm. Saturated hydraulic conductivity was determined in the laboratory on undisturbed cores taken from both higher and lower regions of the site. Results showed no effect of crop residues, but values were higher in the upper area, where porosity also was higher.

Maize response to green manure and inorganic N (*Multiple Cropping*). *Sesbania aculeata* was planted on 15 Dec 1983 to determine its contribution to maize grain yield and N uptake, and the efficiency of inorganic N application with and without green manure. Treatments included 4 inorganic N rates (30, 60, 90, 120 kg N/ha) split applied, 1/2 at planting and 1/2 at 25 DE, or applied all at 25 DE. Two control treatments (with and without green manure) were not fertilized with inorganic N. The *Sesbania* was chopped and incorporated at 60 DE. Maize was planted on a well-tilled soil on 16 Feb 1984. Seeds were oversown on 50-cm rows and emerged plants were thinned to 300,000/ha. Weeds were adequately controlled, but not maize borer *Ostrinia furnacalis*. Maize suffered moderate but frequent periods of drought stress between irrigations.

The aboveground *Sesbania* dry matter yield averaged 9.4 t/ha and N accumulation was 233 kg/ha.

Table 7 shows that maize grain yield and N uptake were affected by green manuring, fertilizer N, and time of N application. Interactions were not significant. Grain yield from the control treatment with no inorganic N or green manure application

Table 7. Analysis of variance for grain yield and N uptake at 4 N levels, 2 application timings, and with or without green manure. IRRI, 1984.

Source of variation	df	Sum of squares	
		Grain yield	N uptake
Controls vs others	1	13.34**	4627**
Among controls	1	2.44**	703*
Green manure (GM)	1	2.94**	3191**
N rate (N)	3	12.96**	16734**
GM X N	3	0.66	642
Method (M)	1	0.91*	1053*
M X GM	1	00.21	61
M X N	3	0.72	1032
M X N X GM	3	0.18	252
Error	51	10.20	9129
CV (%)		13	15

was significantly lower than yields from other treatments.

Green manure increased the unfertilized control yield response by 1.2 t/ha (Fig. 3). Without green manure, single N applications appeared more efficient than split applications over most of the N range tested. With green manure, efficiencies were similar.

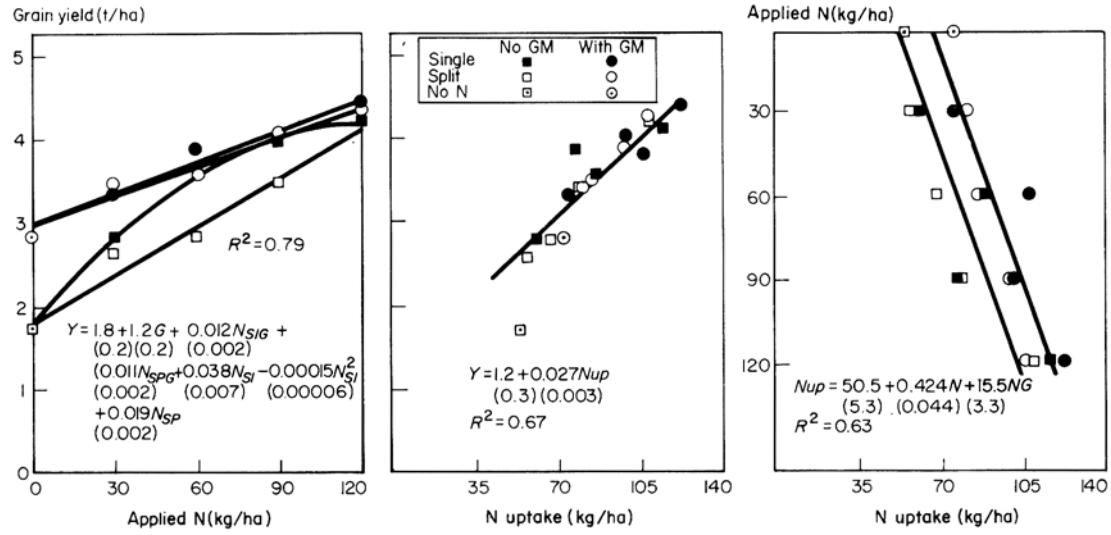
Maize absorbed 42% of the applied inorganic N with or without green manure. The green manure increased N uptake by 15.5 kg/ha, only 7% of the N incorporated. Where inorganic and green manure N were applied, N uptake was transformed to grain yield at a constant rate of 27 kg/kg N taken up. The higher efficiency of single delayed N applications without green manure was associated with higher than average N recovery at 60 kg and 120 kg N/ha and higher than average utilization at 90 kg N/ha. Higher recovery and higher utilization of recovered N contributed to the higher inorganic N efficiency.

On 29 Jun 1984, 29-d-old IR54 seedlings were transplanted on these plots after maize harvest. The rice was not fertilized. Neither residual green manuring nor inorganic N fertilizer significantly changed grain yields. Mean grain yield was 2.9 t/ha and CV was 12%. Thus, while maize recovered only 7% of the green manure N, little residual N was available for the following WS rice.

FERTILIZATION AND CULTURAL MANAGEMENT

Multiple Cropping and Plant Pathology Departments

N management in rice-based cropping systems (*Multiple Cropping*). An experiment at IRRI measured responses of WS irrigated rice to fertilizer N application following maize fodder, mungbean, unweeded fallow, unweeded fallow + farmyard manure (FYM), and *Sesbania aculeata* green manure. The Maahas clay soil had pH 6.2, 1.1% organic C, 0.121% total N, and 23 ppm available P (Olsen).

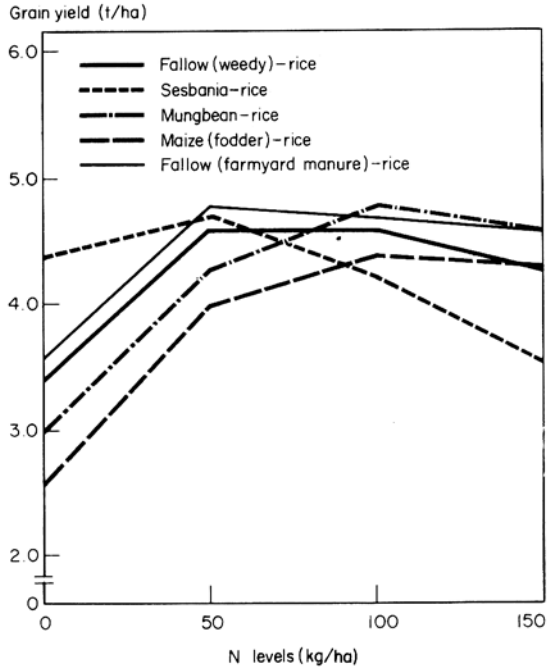


3. Maize grain yield-N uptake-N applied relations after 4 N rates were applied with or without green manure (GM) incorporation. IRRI, 1984.

Maize fodder, mungbean, and *S. aculeata* were sown on 17 Apr 1984. Maize fodder received 50 kg N/ha at sowing while mungbean and *S. aculeata* received no fertilizer. Maize fodder harvested on 4 Jun produced 50 t green matter/ha. Mungbean (0.67 t grain/ha) was harvested and 2.1 t residue/ha removed on 18 Jun. *S. aculeata* (5.8 t dry matter/ha) and weeds (4.3 t dry matter/ha) were incorporated on 18-22 Jun. Fifteen t FYM/ha (1.37% N, 0.55% P, and 1.01% K) and 1/3 of 4 levels of N (0, 50, 100, and 150 kg N/ha) were applied on 28 Jun. IR54 was transplanted on 29 Jun. The remaining 2/3 N was applied on 6 Aug.

Rice yield data (Fig. 4) show that without inorganic N application, 1.8, 1.4, 1.0, and 0.8 t/ha more grain was obtained when rice followed the green manure than when it followed maize fodder, mungbean, unweeded fallow, and unweeded fallow + FYM, respectively.

Rice yield with green manure application was comparable to rice yields obtained with 100 kg N/ha after maize fodder and 50 kg N/ha following the remaining 3 treatments. Therefore, an input of 50-100 kg N/ha can be saved by adopting a green manure - rice cropping pattern, without reducing rice yield.



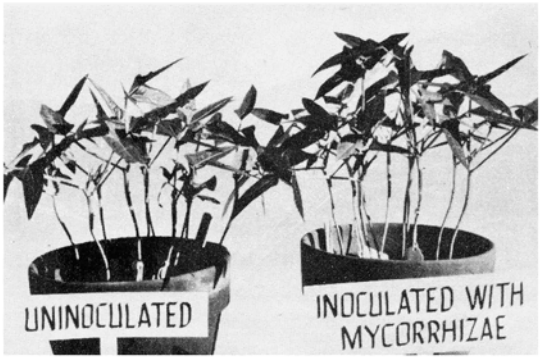
4. Grain yields at 4 N rates applied to rice cultivated after a weedy fallow, green manure *Sesbania aculeata*, mungbean, maize for fodder, and weedy fallow plus farmyard manure. IRRI, 1984 WS.

Mycorrhizae in rice-based cropping systems (*Multiple Cropping and Plant Pathology*). Mycorrhizae are mutually beneficial associations between plant roots and certain fungi. Research on mycorrhizal formation in various crops at cropping systems sites showed that lowland ricefields had lesser vesicular-arbuscular mycorrhizal (VAM) fungal spores than upland areas. Species belonging to the genera *Glomus, Gigaspora,* and *Sclerocystis* were observed.

Inoculation with mycorrhizal fungi produced significantly taller cowpea (Fig. 5), peanut, and rice plants at 44 DAS (Table 8). The roots of inoculated rice and peanut were heavier than the uninoculated. In maize and soybean planted after rice, roots from either crop grown at zero tillage were extensively colonized by VAM fungi. Application of P in either the first (rice) or the second crop (maize or soybean) reduced VAM colonization of roots.

Mycorrhizal associations on maize and soybean after lowland rice (*Multiple Cropping and Plant Pathology*). P availability increases with soil submergence and decreases as soil dries. Thus, dryland crops grown after lowland rice often suffer P deficiency. The deficiency may be more pronounced in untilled soil, because root density will be low and P uptake limited.

This exploratory field experiment examined the effects of P fertilizer and tillage on early growth of and P uptake by maize and soybean. Roots were also examined for mycorrhizae (*Glomus* spp.).



5. Inoculation of cowpea with mycorrihizal fungi produced significantly taller plants at 44 DAS. IRRI, 1984.

Table 8. Effect of inoculation with mycorrhizal fungi on growth parameters of mungbean, maize, peanut, cowpea, and rice.[a] IRRI, 1984.

Treatment	Growth parameters		
	Plant ht[b] (cm)	Shoot dry wt[c] (mg/plant)	Root dry wt[c] (mg/plant)
Mungbean			
Inoculated	23.58	780	200
Not inoculated	22.55	560	110
Maize			
Inoculated	62.83	3150	1020
Not inoculated	60.58	2470	1030
Peanut			
Inoculated	22.95	1470	430
Not inoculated	20.46	960	180
Cowpea			
Inoculated	32.62	1060	210
Not inoculated	27.52	620	200
Rice			
Inoculated	38.44	780	930
Not inoculated	34.28	1120	450

[a]Mean of 5 replications. To compare means for plant height (between inoculated and uninoculated): $LSD_{.01}$ = 3.40 cm, $LSD_{.05}$ = 2.32 cm; for shoot weight: $LSD_{.01}$ = 1253 mg/plant, $LSD_{.05}$ = 851 mg/plant; for root weight: $LSD_{.01}$ = 138 mg/plant, $LSD_{.05}$ = 94 mg/plant. [b]Plant heights were measured 44 DAS. [c]Shoot and root weights were taken 50 DAS.

Treatments were 0 and 17.5 kg P/ha to the rice crop (residual P), 11.0 kg P/ha to the maize and soybean crops, and zero (seed furrow opened) and conventional tillage for maize and soybean. P on maize and soybean was placed directly in the seed furrow. Rice (IR58) transplanted on 19 Oct 1983 and harvested on 31 Jan 1984 did not respond to P fertilizer. Mean grain yield was 4.5 t/ha.

Maize and soybean were planted on 2 Mar and harvested 35 DE. Neither P applied to rice or directly to maize or soybean increased dry matter yields. Tillage increased maize dry matter yield from 29 to 33 g/m^2. Soybean dry matter yield was 46 g/m^2.

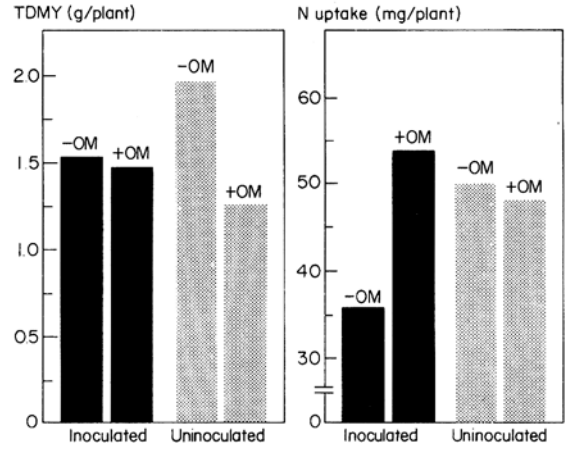
Direct application of P fertilizer reduced mycorrhizal vesicles from 3.8/cm to 2.0/cm on soybean roots. Tillage and the application of P to rice did not affect vesicle number on soybean.

P applied to rice and tillage depressed vesicle number on maize. Moreover, tillage-residual P and direct P-residual P interactions were significant.

Effects of rhizobium inoculation on mungbean (*Multiple Cropping*). A greenhouse experiment used soil taken from a field on which rice had been cultivated in both seasons for 21 yr. Treatments were applied to 7 kg air-dried soil in earthen pots. Rice straw (chopped to about 5 cm) was incorporated into soil in one set of pots. Ground maize cobs (to pass 2-cm sieve) in another set were incorporated. In a third set, a mixture of 1/3 rice straw, 1/3 ground maize cobs, and 1/3 sucrose was incorporated. All sets contained the equivalent of 10 t organic matter/ha. Mungbean (CES55) seeds were inoculated, oversown, and thinned to 3 plants/pot. Plants were harvested at first flowering.

Inoculation significantly increased nodule number from 18 to 39 per plant, but nodule weight per plant did not increase. Inoculation increased dry matter yields and N uptake only in the presence of organic matter (Fig. 6). Highest yield was from the uninoculated plants without organic matter added, suggesting that the high organic matter levels effectively depressed net N mineralization. Although rhizobium persisted after many years of rice cultivation, either the numbers were insufficient to fix enough N for maximum mungbean growth or the naturally occurring strain was less effective than the inoculated strain.

Effects of cultural management on upland rices (*Multiple Cropping*). Three 1983 experiments compared responses of contrasting upland cultivars to N fertilization, tillage intensity, and postemergence weed control measures. Except when fertilizer N was a variable, all treatments received 30 kg N/ha at 25 and 50 DE. For all experiments, seeding rate



6. TDMY and N uptake by mungbean grown on soils double-cropped with rice for 21 yr. Means minus OM (organic matter) are for 4 replications and 3 OM sources. IRRI, 1984.

was 90 kg/ha. Insect protection was adequate.

In one experiment, IR43 and Dagge (a tall traditional cultivar) were planted 20 Aug 1983. Three N application timings (all at 25 DE; all at 50 DE; 1/2 at 25 DE, 1/2 at 50 DE) were compared at 30 and 60 kg N/ha.

Cultivar and N effects and the cultivar-N interaction were significant. Time of application was also significant. Dagge yielded much less than IR43 at all N levels. Results suggest that if N is to be applied to Dagge, the rate should be low (30 kg N/ha) and it should be applied late (50 DE). The 60 kg N/ha rate applied entirely at 25 DE caused Dagge to lodge (visually estimated at 32%). Time of application was not important when 30 kg N/ha was applied to IR43, but split applications were more efficient at 60 kg N/ha.

In a second experiment, tillage and planting combinations were applied to IR6115-1-1-1 and Dagge. The experiment, seeded 21 Aug 1983, involved two tillage intensities (one plowing followed by [fb] harrowing, vs two plowings fb two harrowings) and three planting techniques (broadcast fb harrowing, rolling injection planter, *lithao* furrowing fb harrowing). The more intense tillage decreased weeds and increased grain yields, but not significantly. Dagge yielded significantly less than IR6115-1-1-1 (1.4 vs 3.8 t/ha).

In the third experiment, Dagge, IR43, and UPL Ri-5 were planted 20 Aug 1983. Cultivation practices compared were control (no postemergence cultivation), 2 or 4 passings with a native spike-tooth harrow (passings on 17 and 26 DAS; passings on 17, 26, 35, and 47 DAS), 1 *lithao* interrow cultivation fb passing with a native spike-tooth harrow on 17 and 26 DAS, and 1 *lithao* interrow cultivation on 17 DAS. These common native practices reduced both weed competition and rice plant density. Grain yield differences were not detected among cultivation methods regardless of cultivar. Weed yields were suppressed as postemergence harrowing intensity increased, but differences were not significant. UPL Ri-5 yielded 3.8 t/ha; IR43, 4.3 t; and Dagge, 0.9 t.

In 1984, two experiments compared upland rice management options. Upland rices IR6115-1-1-1, UPL Ri-5, and Dagge were compared at two levels of tillage (one or two plowings fb one harrowing with a *lithao*) and two planting methods (seeds were placed in shallow furrows, covered by foot, and compressed; and seeds were placed in shallow furrows and covered by harrowing across rows). Seeding rate was 100 kg/ha. N fertilizer (60 kg/ha) was applied in equal splits 25 and 50 DE. Insects were controlled but weeds were not.

Grain yields differed significantly among varieties but not among tillage or planting levels, or the interactions among factors. IR6115-1-1-1 yielded 0.8 t/ha; UPL Ri-5, 1.5 t; and Dagge, 0.3 t. Although not statistically significant, yields from plots plowed twice were 0.3 t/ha more than from plots plowed only once.

Treatments plowed twice had less weed growth than treatments plowed once (0.9 vs 1.2 kg/m^2).

In the second experiment, UPL Ri-5 and Dagge were planted on 5 Jun 1984 on a well-prepared field. Two N rates (30 and 60 kg N/ha) and 3 application timings (all at 40 DE, all at 65 DE, and 1/2 at 40 DE fb 1/2 at 65 DE) were applied. Control was no-fertilizer treatment. Dagge was harvested on 25 Sep and UPL Ri-5 on 8 Oct 1984.

Neither cultivar responded positively to fertilizer treatments. Dagge yielded 1.3 t/ha. Sixty percent of the unfertilized and 90% of the fertilized crop lodged.

Mean yield from UPL Ri-5 receiving 0 and 30 kg N/ha was 4.3 t/ha. Less than 5% of plants in these treatments lodged. Fertilization with 60 kg N/ha significantly depressed yield (3.8 t/ha); 12% of the plants lodged.

INTERCROPPING AND RELAY PLANTING

Multiple Cropping Department

Upland rice + cowpea. In many upland environments, farmers regard rice as a subsistence crop and do not apply fertilizer N. Thus, yield potentials are not reached.

Diets in these environments are often protein deficient. In 1984, a series of experiments tested upland rice + cowpea intercrops for N economies and crude protein yields.

Crop proportions at high and low soil fertility. To examine N contribution from cowpea and responses of intercrops to changing rice + cowpea proportions at two N fertility levels, an experiment was planted on 31 Jan 1984. To simulate a naturally high N fertility level, ipil-ipil leaves and chicken manure containing 75 kg N/ha were incorporated and compared to no N applied. Nine crop propor-

Table 9. F-ratios for grain and crude protein yields and N uptake for intercropped upland rice (R) and cowpea (C) corresponding to tests of significance on changing rice and cowpea proportion and crop proportion – N level interaction. IRRI, 1984 DS.

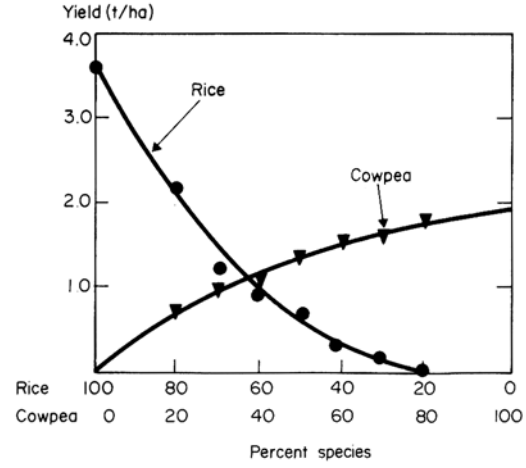
Source of variation	df	Mean squares							
		Grain yield		Crude protein yield			N uptake		
		R	C	R	C	R + C	R	C	R + C
Crop proportion (P)	7	10.97**	1.33**	26331.2**	84159.5**	75107.8**	3709.3**	9451.6**	4788.0**
N level X P	7	0.05 ns	0.01 ns	207.2 ns	1016.8 ns	1062.1 ns	113.3*	52.4 ns	136.3 ns

tions (area) of rice UPL Ri-5 and cowpea EG #2 were planted (100% rice, 80% rice + 20% cowpea, 70% rice + 30% cowpea, 60% rice + 40% cowpea, 50% rice + 50% cowpea, 40% rice + 60% cowpea, 30% rice + 70% cowpea, 20% rice + 80% cowpea, and 100% cowpea). All plots received 13 kg P/ha. Crop protection was adequate. The experiment was heavily sprinkler irrigated to simulate WS rainfall. The final priming for cowpea grain yield was 25 Apr (85 d after planting [DAP]) and rice harvested 4 Jun (125 DAP). Analyses of variance for grain yield, crude protein yield, and N uptake are summarized in Table 9.

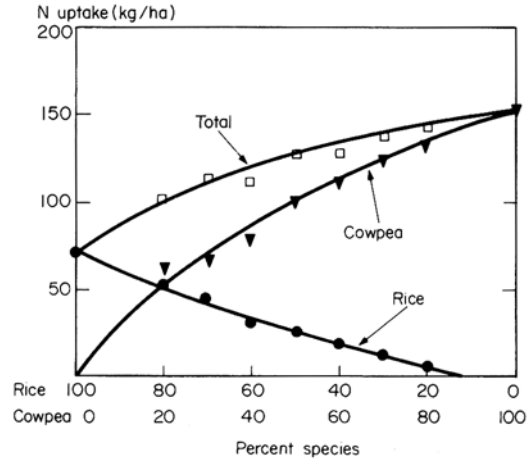
Rice yield in the monocrop was higher where chicken manure and ipil-ipil were applied, but not significantly so (3.6 vs 3.4 t/ha). Grain yield from the monocropped cowpea was not affected by N application.

Figure 7 shows the cowpea cultivar EG #2 was aggressive and rice yields were more than proportionally reduced as cowpea area increased. Figure 8 shows N uptake as crop proportion changed. Cowpea did not affect N uptake by rice as adversely as it did rice grain yield. However, with 80% rice and 20% cowpea, crude protein almost doubled, although rice yields declined 35%. Although most protein increase came from cowpea, protein in milled rice increased from 6.3 to 9.1%. Percent N in milled rice and straw increased linearly as cowpea proportion increased.

Effect of seeding rate on yield and N uptake. To determine the influence of populations of rice UPL Ri-5 and cowpea EG #3 on grain and protein yields in a 50% rice + 50% cowpea intercrop (area), an experiment was planted on 2 Mar 1984. Seeding rates were 70, 90, 110, and 130 kg rice seeds/ha and 15, 17, 19, and 21 cowpea seeds/ha. Plots received



7. Grain yields of rice + cowpea in which rice was progressively replaced by cowpea. Means of 4 replications and 2 N levels. IRRI, 1984 DS.



8. N uptake by rice + cowpea in which rice was progressively replaced by cowpea. Means of 4 replications and 2 N levels. IRRI, 1984 DS.

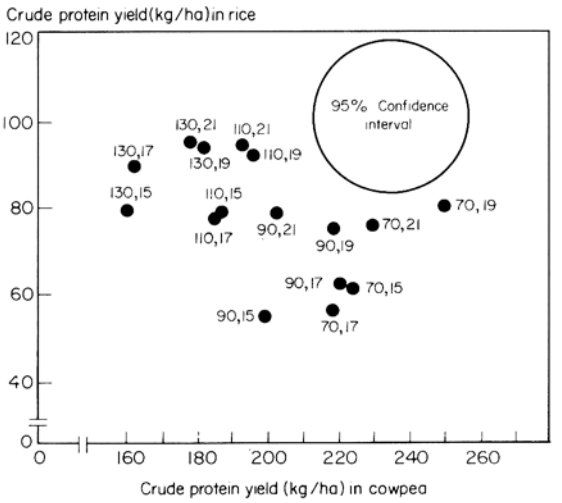
13 kg P/ha, but no N. Crop protection was adequate. The experiment was sprinkler irrigated to simulate WS rainfall. The last cowpea priming was 22 May (80 DAP); rice was harvested 6 Jul (125 DAP).

Higher seeding rate increased grain yield, protein yield, and N uptake of rice and cowpea. The rice + cowpea seeding rate pairs 70-19 and 70-21 kg/ha produced 1.2 t rice/ha and 0.90 t cowpea/ha. The rates 110-19 and 110-21 kg rice + cowpea/ha produced 1.6 t rice/ha and 0.75 t cowpea/ha.

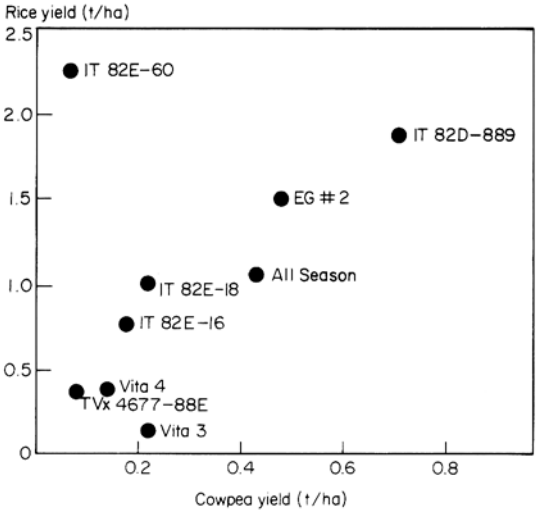
N uptake ranged from 78 to 110 kg/ha, lowest with low seeding rates of both species, and highest where both were high. More than 100 kg N/ha was accumulated at seeding rates of 110-21 and 130-21 kg rice + cowpea seeds/ha.

Figure 9 shows crude protein components from rice and cowpea in the combinations. Contributions from rice were highest where rice and cowpea seeding rates were both high. However, the highest total crude protein occurred with low rice seeding rates and high cowpea.

Cowpea cultivar performance. To test cowpea competitiveness and rice vegetative development and yield, nine cowpea cultivars of contrasting growth habits were intercropped with upland rice UPL Ri-5 in an experiment planted on 19 May 1984. Three cowpea cultivars (TVx 4677-88E, IT 82D-889, IT 82E-16) were classified as early-maturing, three as intermediate-maturing (IT 82E-60, IT 82E-18, All Season), and three as late-maturing (Vita 4, Vita 3, and EG #2). Two rice rows (20 cm apart) alternated with one cowpea row (30 cm from adjacent rice rows). No N was applied, but P was 13 kg/ha. Crop protection was adequate. The experiment was sprinkler irrigated to prevent severe drought stress.



9. Mean crude protein yields of rice and cowpea corresponding to 16 rice + cowpea seeding rates (kg rice and cowpea seed/ha). IRRI, 1984 DS.



10. Mean grain yields of rice and 9 cowpea cultivars when intercropped 50:50 (area basis). IRRI, 1984 WS.

Bivariate analyses of variance showed cowpea cultivars highly significantly affected grain yields ($F = 42.2^{**}$), N yields ($F = 10.9^{*}$), and crude protein yields ($F = 121.7^{**}$) [df = 8, 24]. Grain yields of five cowpea cultivars were low because the plant types were poor (Fig. 10). Three, however, accumulated N exceeding 95 kg/ha. Grain yield of IT 82E-60 was low and it accumulated only 60 kg N/ha, apparently competing poorly with rice.

Regardless of initial classification, most cowpea cultivars had long growth durations and were viny. The viny cultivars grew over the rice plants and sharply depressed rice yields. Although N and protein percentages of rice increased, total grain and crude protein yields were low when rice was intercropped with aggressive cowpea cultivars. However, one cowpea cultivar (IT 82D-889), with a 60-d duration and determinate growth habit, intercropped well with rice. Although IT 82D-889

accumulated only 67 kg N/ha, it yielded 0.71 t grain/ha and 187 kg crude protein/ha; rice yielded 1.86 t grain/ha and 108 kg crude protein/ha.

Rice + maize response to excess soil moisture. A rice + maize intercrop experiment in 1984 WS used a line source sprinkler to apply an irrigation gradient across intercrops and monocrops. The objective was to determine if excessive water at the wet end would increase rice competitiveness relative to maize.

The experiment involved three moisture regimes (regime 1 heavy sprinkler watering, regime 3 purely rainfed, and regime 2 intermediate) and three cropping schemes (monocrops of rice and maize and a rice + maize intercrop). Cropping schemes were randomized within the moisture gradient. Each 6- × 7-m subplot was bunded to prevent water flow.

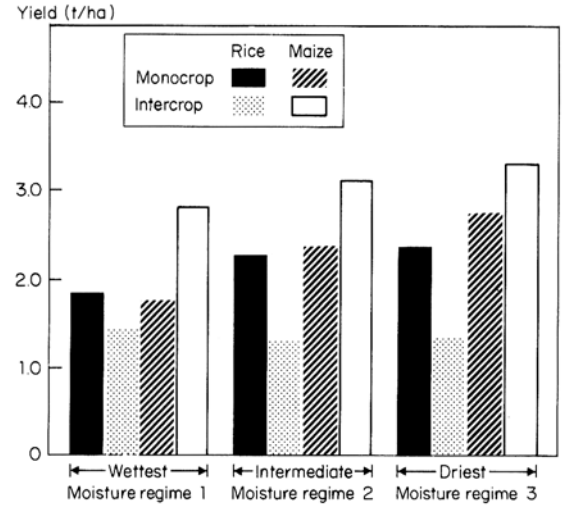
The monocropped and intercropped UPL Ri-5 was planted (90 kg seed/ha) on well-prepared soil in 25-cm rows. Monocropped maize IPB-1 was planted with a maize jabber at 0.75- × 0.25-m spacing (53,333 plants/ha). The maize intercrop was spaced at 1.5 × 0.25 cm (26,667 plants/ha). The rice received 60 kg N/ha (1/3 applied at planting and 2/3 topdressed at PI). The intercropped and monocropped maize received 40 and 80 kg N/ha, respectively (1/3 at planting, 1/3 sidedressed at 34 DE, and 1/3 at tasseling). For uniform emergence, the experiment was evenly irrigated with 40 mm water the day after planting.

Rains were heavy the first month after planting. Irrigation started 10 Jul, with 40 mm water applied to regime 1 every 3 to 4 d.

In the wettest regime, maize received 1,144 mm from rainfall plus irrigation, and rice received 1,486 mm. In the driest regime, maize received 715 mm and rice 950 mm.

Mean maturity was 88 d for maize and 124 d for rice. Intercropping and moisture treatments had little influence on phasic development of rice and maize. Intercropping shortened the duration from emergence to PI and PI to heading in rice.

Yields of monocropped maize are expressed in t/0.5 ha for easier comparison with yields from intercropped maize (Fig. 11). Analyses of variance showed that irrigation treatments and intercropping significantly influenced maize grain yield, but their interaction was not significant. Intercropping significantly influenced rice yields, and the moisture gradient-intercropping interaction was significant. The coefficient of variation was 25% for rice and 14% for maize. The high variability of rice yields may have been due to differences in infiltration and/or redistribution of water in the soil profile and its effects on denitrification and/or nitrate leaching. Maize and rice in the wettest regime appeared N deficient. Increases in monocropped rice and monocropped-intercropped maize yields from the wettest to the driest regime may not have been direct effects of soil moisture on root aeration but indirect effects of moisture on N availability.



11. Yields of monocropped and intercropped rice and maize under a line sprinkler irrigation gradient. Monocropped maize yields are expressed in t/0.5 ha. IRRI, 1984 WS.

More N was available to maize when intercropped because rice was less competitive. Intercropped maize yields were not as depressed by excess water as were monocropped maize yields. The rice may have withdrawn water from the profile to improve root aeration for intercropped maize.

Upland rice + maize response to nitrogen fertilizer. Low maize populations are often planted with upland rice seeded at optimal rates. Because maize has a tall broadleaved canopy, it competes with rice for light; it also competes for water and nutrients. This experiment tested whether N applied directly to only one crop in an intercrop would increase its competitiveness.

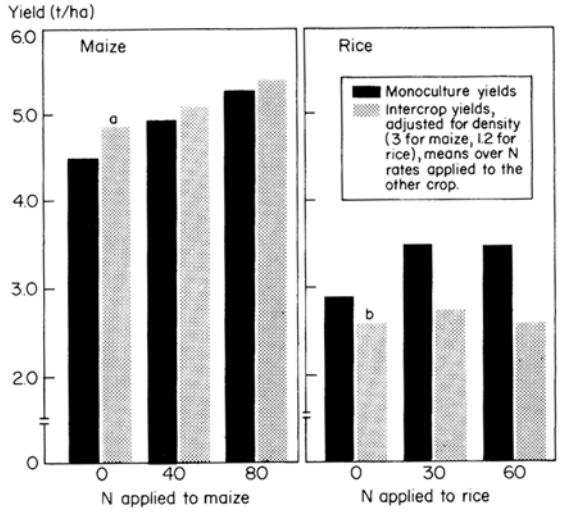
The experiment was planted on a well-tilled

upland field. Pests and diseases were adequately controlled. Monocropped maize (IPB Var 1) was planted at 53,333 plants/ha in 75-cm rows. Monocropped rice (UPL Ri-5) was seeded at 90 kg/ha in 25-cm rows. For the intercrop, every sixth rice row was replaced by maize. The rice seeding rate was 75 kg/ha (5/6 of monocropped rice) and maize was planted directly at 17,777 plants/ha (1/3 of monocropped maize).

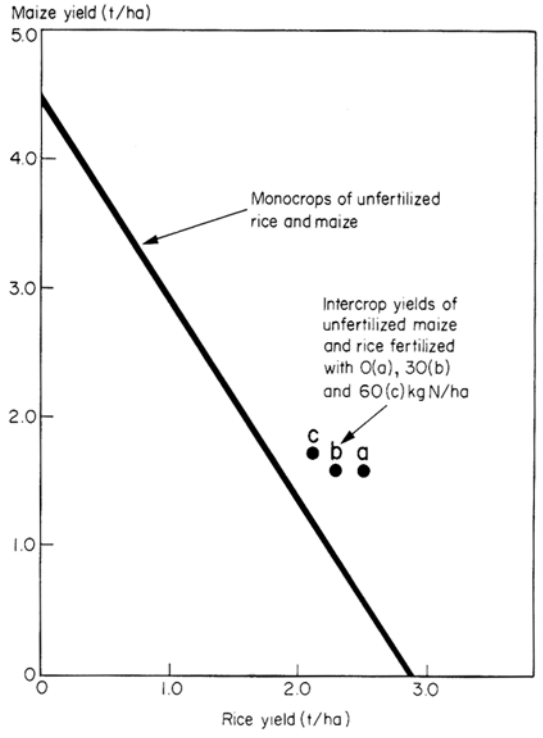
Analyses of variance showed that rice monocrop yields were significantly higher than intercropped yields, but neither rice crop responded to N. Monocropped maize yields were significantly higher than intercropped maize yields. Monocropped maize responded to N, but intercropped maize did not. Leaf equivalent ratios were comparatively low and differences among them were not significant.

In Figure 12, intercropped rice and maize yields were adjusted to monocropped plant density equivalents by multiplying rice yields by 1.2 and maize yields by 3. At all N levels of intercropped maize, maize yields were similar to monocropped yields. For rice, however, intercropping depressed yields. Furthermore, higher N rates on rice did not increase its competitiveness.

Figure 13 shows monocropped rice and maize yields that would have been obtained by equally



12. Grain yields of monocropped and intercropped maize and rice with increasing N rates. a = means over N treatments on rice, b = means over N treatments on maize. IRRI, 1983 WS.



13. Monocropped and intercropped rice and maize yields. IRRI, 1983 WS.

dividing a 1-ha field into unfertilized monocropped rice and unfertilized monocropped maize. The points corresponding to 0, 30, and 60 kg N/ha applied to rice intercropped with unfertilized maize suggest that, for rice yields not to be sacrificed to maize yields when the two species are intercropped, N fertilizer should not be applied to either rice or maize. If economics is considered, this conclusion is even more significant.

Relay planting maize with two upland rices. An experiment evaluated the effect of relay planting maize with two upland rice cultivars differing in height. IR6115-1-1-1 (85 cm) and UPL Ri-5 (115 cm) were drilled (80 kg seeds/ha) in 25-cm rows on well-pulverized soil on 25 Jul 1983. Sixty kg N/ha was split-applied to rice (1/3 at planting and 2/3 at PI).

In the skipped-row treatment, every fourth row of rice was left unplanted during rice establishment. In the lodged-row treatment, every fourth and fifth row pairs were slightly lodged 15 d after heading. Control treatments had unmanipulated complete

rice rows, and skipped and lodged rice with no maize relay.

Maize IPB 1 was relay seeded with a rolling injection planter (RIP) into untilled soils in the rows 15 d after rice heading (94 DE in UPL Ri-5 and 97 DE in IR6115-1-1-1). Maize was planted on 4 Nov in UPL Ri-5 and 7 Nov in IR6115-1-1-1. Both plantings were harvested on 5 Mar 1984. The final maize population was 40,000 plants/ha. Maize received 80 kg N/ha, sidedressed 1/3 at 7 DE, 29 DE, and tasseling. Because rice maturities differed, rice and maize growth overlapped for 12 d in IR6115-1-1-1 and 16 d in UPL Ri-5. Insect pests, diseases, and weeds were adequately controlled. Both crops received irrigation as needed.

Grain yield from the complete rice rows was not significantly affected by cultivar. Whether maize was or was not relay planted with rice, skipping every fourth rice row resulted in significant yield loss in both selections. Lodging paired rows of rice had no effect on IR6115-1-1-1 yield but significantly reduced UPL Ri-5 yield.

Rice cultivars did not significantly affect maize grain yield. Yields from maize seeded on skipped or lodged rows were similar but were significantly lower than yields from control plots, indicating that maize was sensitive to early shading.

CROP ESTABLISHMENT

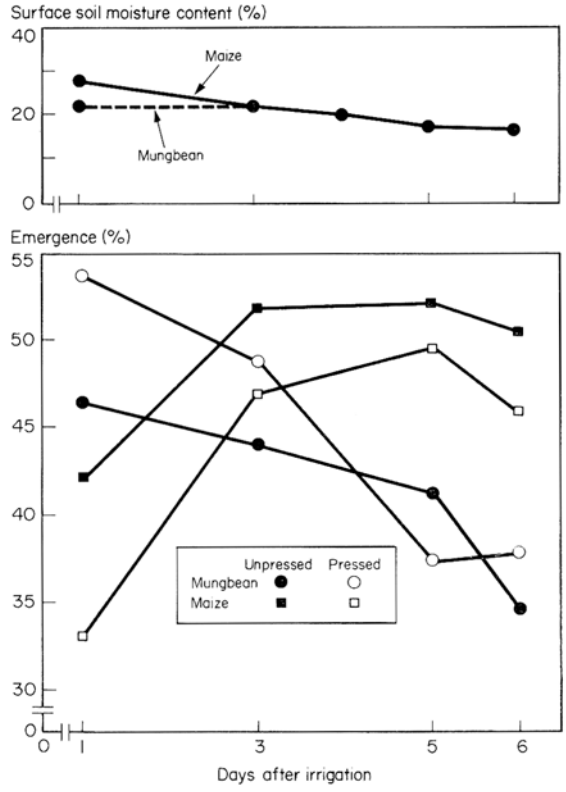
Multiple Cropping Department

Emergence of RIP-seeded mungbean and maize at various soil moisture levels. Establishing upland crops after rice is often difficult. The soil is normally left in a cloddy condition. When crops are seeded immediately after rice harvest, flooding and temporary waterlogging are risks; when seeded after the threat of rains, the soil surface may be too dry for germination. In 1984, the sensitivity of late planted crops to decreasing surface soil moisture and planting methods and sensitivity of early planted crops to surface drainage and field elevation were tested in separate experiments.

In early DS 1984, three experiments in an upland field evaluated the effects of placing mungbean and maize seeds by an RIP, covering them using a small disk covering device, and compressing the seed row with a roller.

In the first two experiments, land was prepared to a fine tilth and irrigated so surface soil was suitable for emergence. In one study, maize seeds were planted 1, 3, 5, and 6 d after irrigation; in the other, mungbean seeds were planted on the same day. Emerged maize seeds were counted 7 DAS and emerged mungbean seeds, 6 DAS, and values were expressed as percent of planted seed. Surface soil moisture (0-5 cm) was determined on each planting date.

Pressing significantly reduced maize emergence regardless of planting date or soil moisture (Fig. 14). Excess moisture may have caused lower emergence on the first maize planting date. For mungbean emergence, the date of planting was significant but pressing was not. Emergence declined steadily as planting was delayed. The interaction of pressing



14. Surface soil (0-5 cm) moisture content on date of planting, and emergence percentages from mungbean and maize planted 1, 3, 5, and 6 d after irrigation. Mungbean emergence was determined 6 DAS and that of maize, 7 DAS. Means over covered and uncovered treatments and 4 replications. IRRI, 1984 DS.

and date approached significance.

In the third experiment, the RIP seeder was compared at zero and moderate tillage levels (2 rototillings with a 5-hp hand tiller) with and without a 10-kg weight on the seeder, with and without a covering device, and with and without a press wheel. The press wheel (18 cm wide, weighing 67 kg) was rolled over the seed rows to increase seed-soil contact. The 10-kg weight on the RIP seeder increases depth of seed placement and the covering device placed behind the seeder at a 30° angle from the row improves seed covering. The experiment was planted on 75-cm rows with 15 cm between hills 6 d after 30 mm irrigation was uniformly applied to the field. Assuming one seed placed per hill and 100% emergence, the potential population was 89,000 plants/ha. Emerged plants were counted 11 DAS.

Neither press wheel nor weight affected emergence, but the interaction between tillage and the covering device was significant. Without tillage, the covering device increased plant density from 57,000 to 61,000 plants/ha. Rototilling reduced density from a mean of 59,000 to 54,000 plants/ha. Covering did not promote emergence on rototilled soil.

The contrasting results between the first two experiments and the third are not explainable.

Drainage methods to control early flood damage to mungbean. Mungbean CES 1D-21 was planted on 20 Jul 1984 in 40-cm rows on 3 fields along a toposequence. Plots were 8×5 m^2 and bunded. Two surface drainage treatments were imposed: opened bund and closed bund.

Heavy rains in late August caused natural waterlogging and shallow flooding during flowering. Shallow flooding was maintained by irrigation on all plots for 3 d. Subsequent rains kept treatments under some degree of shallow flooding or waterlogging until pod-filling stage.

Crop stand was not significantly affected by drainage treatment. Grain yield which averaged 0.71 t/ha in the 2 upper fields was least in the lowest field (0.25 t/ha).

SORGHUM MANAGEMENT

Multiple Cropping Department

Sorghum ratoons easily and can use water remaining in the soil profile during DS. Ratoon yields, however, have not been consistently high. In 1983-84, an experiment at IRRI determined the sensitivity of sorghum main and ratoon yields to planting date and terrain position. A second experiment examined responsiveness of main and ratoon yields to N applied to the main crop.

Crop performance at two terrain positions and planting dates. Sorghum Cosor 3 was planted on 21 Nov and 16 Dec 1983 and 10 Jan 1984 on well- and poorly-drained upland fields.

The crops were seeded on well-tilled soil and lightly irrigated to obtain uniform emergence. Neither the main nor ratoon crops received further irrigation. The main crop was thinned to 200,000 plants/ha. Thirty kg N/ha was broadcast and incorporated before main crop planting and 60 kg N/ha topdressed before hilling (27 DAS). N treatments on the ratoon crop were 0 and 50 kg N/ha. topdressed immediately after main crop harvesting. Weeds and insects were adequately controlled; however, the ratoon crop was affected by *Phyllachora* leaf spot (*P. sorghi*). The main crop was cut at the first node aboveground.

Main crop. A combined analysis of variance showed that grain and total dry matter yields (TDMY) were affected by terrain position, planting date, and planting date-terrain position interaction. Main-crop sorghum yields were higher on the upper position, and were only slightly affected by planting date (Table 10). Dry matter yields increased with later planting dates and with increased solar radiation.

Ratoon crop. Ratoon crop grain yield and TDMY were affected by terrain position, planting date, and planting date-terrain interaction (Table 10). Ratoon plant density was affected by planting date. N fertilizer did not affect ratoon grain yield, TDMY, or plant density. Grain yields were higher on the poorly drained field. WS started before ratoons from the second and third plantings were harvested. During the ratooning period from the second planting, a 330-mm rainfall was concentrated during the grain filling phase. The 510-mm rainfall during the ratooning period from the third planting was well distributed. Ratoon yield depressions on the well-drained field were apparently caused by heavy *Phyllachora* leaf spot infection.

Table 10. Grain and TDMY of main and ratoon sorghum planted on 3 dates, main and ratoon durations, and mean daily solar radiation during the main and ratoon crops. IRRI, 1983-84 DS.

Planting date	Grain yield (t/ha)				TDMY (t/ha)				Mean growth duration (d)		Mean daily radiation (mWh/cm^2)	
	Upper field		Lower field		Upper field		Lower field					
	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon	Main	Ratoon
21 Nov	4.35	2.79	3.84	3.54	6.52	8.47	6.62	8.20	96	62	368	540
16 Dec	5.32	3.33	4.17	4.10	9.09	7.93	6.73	12.59	92	83	405	538
10 Jan	5.01	2.27	3.10	4.16	9.82	12.98	7.82	18.53	88	87	467	480
CV (%)	10	20	10	20	16	24	16	24	–	–	–	–

In both terrain positions, ratoon plant counts from the first and third plantings were significantly reduced relative to the second planting (150,000, 220,000, and 148,000 plants/ha).

Differences in crop duration between terrain positions were small (Table 10). The duration of the main crop decreased with planting date, but that of the ratoon crop increased. The 10 Jan planting shortened the main crop duration by 8%, but lengthened the ratoon crop's by 40% relative to the 21 Nov planting.

As DS progressed, mean soil water content of the well-drained field declined slightly more than that of the poorly drained field but increased sharply when rains fell in May.

Time and rate of N application. An experiment planted on 23 Nov 1983 compared time and rate of inorganic N on sorghum main and ratoon crop grain yields. Main crops were harvested between 1 and 6 Mar 1984 and ratoon crops between 19 May and 12 Jun. Sorghum (Cosor 3) was overseeded in 60-cm rows on a well-prepared field and thinned to 200,000 plants/ha after emergence. The crop was irrigated and weeds, birds, and insects were adequately controlled.

The experiment contained all factorial treatment combinations of 6 N rates (25 to 150 kg N/ha in increments of 25 kg N/ha) and 2 application timings (1/3 applied at planting fb 2/3 sidedressed at 25 DE and all applied at 25 DE) plus a zero N control. The treatments were arranged in three replications of a randomized complete block.

The time and rate of N application affected grain yields of both the main and ratoon crops (Table 11). Time and rate of application affected N taken up by the main crop, but only N rate affected N taken up by the ratoon crop. For the main crop, split applications more efficiently increased grain yields than single delayed applications. Regardless of application time, 1 kg N taken up/ha was used by the main crop to produce 33 kg grain/ha. Below 60 kg N/ha, the apparent N recovery by the main sorghum crop was 50%. The recovery of N applied in excess of 60 kg/ha was variable.

Ratoon crop yields responded to N beyond the point where apparent N recovery by the main crop

Table 11. Summary of analyses of variance of main and ratoon crop grain yields and N uptake at given N rates and time of application. IRRI, 1983-84 DS.

Source	df	Mean squares					
		Grain yield			N uptake		
		Main	Ratoon	Combined	Main	Ratoon	Combined
Control vs others	1	2.476**	0.832**	6.178**	1966**	42	2730**
N rates (N)	5	0.812**	1.637**	21.539**	362**	172**	5552**
Method (M)	1	0.588*	0.697*	2.564**	1047**	5	0
N X M	5	0.094	0.078	0.146	113	85	122
Error	24	0.119	0.112	0.235	80	17	109
CV (%)		7	15	7	11	22	11

departed from the trend observed below 60 kg N/ha. The time of application had no apparent effect on N efficiency, N utilization, or apparent N recovery. For each kg of N taken up/ha, the ratoon crop produced 34 kg grain/ha, similar to main crop utilization. N recovery by ratoon crop complemented that by main crop. An increase in N uptake above that contributed by the soil was observed only in rates exceeding 82 kg N/ha.

Analysis of variance results for combined main and ratoon grain yields were similar to those for main crop (Table 11). Split N applications more efficiently promoted grain yields than single delayed applications, but N uptake was unaffected by time of application. The relationship between N applied and N uptake was linear, but variability associated with the single delayed N application and apparent N recovery was higher than that with split N application and apparent N recovery. However, the mean apparent recovery in both crops was only 30%. Seventy-three kg N/ha was derived from the soil.

Although results are limited because control yield of the main crop was high and the maximum yield response was only 1.7 t/ha, data demonstrate that split N application produced slightly higher yield. The ratoon crop will recover N not taken up by the main crop and produce about the same grain yield increase per kg N/ha taken up by the main crop.

Although sorghum ratoon yields can equal main crop yields, ratoon yields are not stable because they can be influenced by weather and diseases. The first experiment demonstrated that N applied to the ratoon immediately after main crop harvest did not increase grain yields. The second study, however, showed that where N was deficient, the ratoon responded to N residual from the main crop, though not efficiently. Therefore overfertilization of the main crop would not be a reasonable production practice.

WHEAT MANAGEMENT

Multiple Cropping Department

Nitrogen management. Wheat has seldom been grown at latitudes less than 25° N or S. Two IRRI experiments, one irrigated and the other unirrigated, during DS (Dec to Mar) examined the response of wheat UPLW-1 to N split-applied (1/2 at planting, 1/2 at PI) or all at planting. Wheat was seeded at 120 kg ha. The irrigated experiment received water at 34, 54, and 74 DAP. The experiments were planted on 3 Dec 1982 and harvested on 14 and 15 Mar 1983.

The control yield in the irrigated experiment was higher than that in the rainfed (Table 12). In the irrigated experiment, 80 and 120 kg N/ha depressed yields perhaps because of excessive vegetative growth. In both experiments, wheat responded to the first 40 kg N/ha increment, but not to higher N levels. Yields did not differ between N application timings.

On 15 Dec 1983, a second experiment was established on a well-tilled upland field to examine time of N application. Three N fertilizer levels (33, 66, and 99 kg/ha) and 6 timing treatments were applied to UPLW-1. An unfertilized treatment (control) was included. The experiment received sprinkler irrigation on 6 Jan, 2 Feb, and 20 Feb. Unlike in 1983, the crop did not respond to N, irrespective of application time. Mean yield was 1.9 t/ha and CV was 10%.

In both years, yields were rather low in spite of a high level of management, perhaps because of temperatures higher in February and March than optimum for wheat.

Cultural management at Cagayan Valley. Cultural management studies at IRRI in 1983 indicated wheat yields exceeding 3 t/ha can be obtained from early DS plantings. Yields, however, were very sensitive to planting date and high temperatures during grain-filling. A comparatively well-drained field in a slightly cooler location of the Philippines

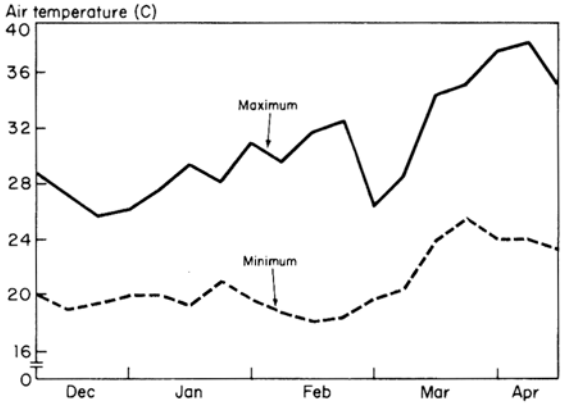
Table 12. Grain yield of wheat as affected by rate and time of N application. IRRI, 1983.

N (kg/ha)	Time of application[a]	Main yield (t/ha)	
		Irrigated	Rainfed
0	Control	1.0 d	0.7 c
40	FO	2.1 a	2.0 a
	SP	1.9 ab	1.9 ab
80	FO	1.7 bc	1.7 ab
	SP	1.7 bc	2.0 a
120	FO	1.6 bc	2.0 a
	SP	1.5 c	2.0 a
	CV (%)	11	13

[a] FO = all at planting, SP = split (1/2 at planting and 1/2 at PI).

than Los Baños was chosen to compare the sensitivity of four wheat cultivars to planting dates, fertilizer, and seeding rates. Three experiments were conducted in Cagayan Province, 17° 46' N.

Effect of planting date. Four wheat cultivars (2 lines C169-6 and C220-5; a Mexican cultivar, INIA 66; and a Philippine Seed Board-released cultivar, UPLW-1) were planted on 23 Dec, 7 Jan, and 20 Jan. Using local carabao-drawn implements, a field used for lowland rice cultivation the previous season was plowed twice and harrowed three times. Seeds were planted by hand at 125 kg/ha in plots of 2 rows 30 cm apart and 6 m long. Before seeding, 80 kg N/ha (from urea) was applied in the furrow and covered with a thin layer of soil. The field was flush irrigated lightly on 14 Jan and 10 Feb. On 20 Feb, the field was soaked thoroughly and water allowed to recede naturally. Weeds, insects, and diseases were adequately controlled.



15. Weekly mean maximum and minimum temperature at the Cagayan Integrated Agricultural Development Project pilot center, Iguig, Cagayan, Philippines, 1983-84.

Flowering date was recorded when 50% of plants had flowered. Plots were harvested when plants were dry and spikes brittle. Grain yields were adjusted to 12% moisture content.

Growing season minimum and maximum temperatures are summarized in Figure 15. A few light showers, totaling less than 5 mm, fell in March.

Delaying planting from 23 Dec to 20 Jan hastened harvest by 6 to 10 d. Cultivar, planting date, and the cultivar-planting date interaction significantly influenced days to flower. Delayed planting hastened flowering of UPLW-1 and C220-5 by 5 to 6 d, but had little effect on C169-6 and INIA 66.

Summary analyses of variance for grain yield, yield components, and days to flower are in Table 13. Cultivars differed significantly in all attributes except number of spikelets per spike. Significant planting date-cultivar interactions were found for grain yield, 1000-grain weight, and plant height. Grain yields declined as planting was delayed. Both the number of grains per spike and 1,000-grain weight were adversely affected by delayed planting. Thousand-grain weight, however, was the only yield component with a significant planting date-cultivar interaction.

C169-6 yielded higher than other cultivars. It had shorter vegetative growth phase than UPLW-1 and C220-5. Furthermore, delayed planting did not shorten its preflowering duration nor affect its height. The other cultivars were tallest when planted on 7 Jan.

Response to fertilizer. Two fertilizer experiments were conducted. The first measured response of early planted irrigated wheat to applied N. UPLW-1 was planted on 23 Dec and harvested on 19 Mar.

Table 13. Summary analyses of variance for grain yield, plant height, and yield components. Cagayan, Philippines, 1984.

Factor	df	Mean squares					
		Grain yield	Plant ht	Yield components			
				Spikes/m^2	Spikelets/spike	Grains/spike	1,000-grain wt
Planting date (P)	2	285.2	10.2*	3.7	2.5	5.4*	56.0**
Cultivar (C)	3	37.0**	44.0**	3.7*	0.8	12.8**	309.6**
P x C	6	3.1*	5.1**	0.8	0.9	0.4	7.0**
CV (a), %		6	8	18	9	16	5
CV (b), %		13	5	13	10	16	4

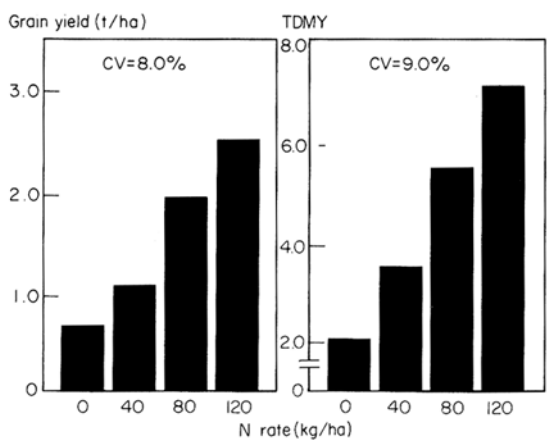
Four N treatments (control, 40, 80, and 120 kg N/ha) were applied at planting. Cultural practices were similar to those of the planting date experiment.

N fertilizer significantly increased grain and TDMY, all yield components except 1,000-grain weight, and plant height. Grain and TDMY are in Figure 16.

Grain yield efficiency was only 17 kg grain/kg N fertilizer. The grain yield responses were generated by increasing the number of grains per spike and number of spikes per m^2. Relative to yield components from unfertilized plants, 120 kg N/ha increased number of grains per spike by 172% and number of spikes per m^2 by 39%.

The second experiment determined the sensitivity of irrigated wheat to N and P fertilizer and to seeding rates when the crop was planted late UPLW-1 was planted on 8 Jan and harvested on 10 Apr.

Two N rates (40 and 80 kg N/ha) and 3 P rates (0, 13, and 26 kg P/ha) and an unfertilized control treatment were compared at 3 seeding rates (100, 150, and 250 kg/ha). N and P were incorporated in seed rows and covered with a thin layer of soil before sowing.



16. Grain and TDMY of wheat at 4 N rates. Cagayan, Philippines, 1984.

Table 14. Grain and TDMY, and plant heights at 7 N and P fertilizer combinations. Cagayan, Philippines, 1984.

N rate (kg/ha)	Grain yield (t/ha)	TDMY (t/ha)	Plant ht (cm)
		0 kg P/ha	
0	0.95 d	2.87 d	82 c
40	1.39 bc	4.17 abc	96 ab
80	1.55 ab	4.14 abc	98 ab
		13 kg P/ha	
40	1.15 cd	3.91 bcd	94 ab
80	1.77 a	5.00 ab	103 a
		26 kg P/ha	
40	1.18 bcd	3.66 bc	92 b
80	1.46 abc	5.84 a	97 ab
CV (%)	28	29	4

[a] Means over 3 seeding rates.

Fertilizer treatments increased grain yield, TDMY, and plant height (Table 14). Seeding rates did not affect any of those three agronomic characteristics.

P fertilizer did not significantly alter any characteristic. N response was significant, but its efficiency was only 8 kg grain/kg N fertilizer. Delayed planting, and therefore higher temperatures, probably contributed to lower efficiency, as may also have wetter field conditions.

Although spikes per m^2 increased as seeding rate increased, the increase was not adequate to compensate for the apparent influence of temperature. N fertilizer increased spikes per m^2 and grains per spike, but not the two other yield components.

Cropping systems program

Preproduction testing and technology transfer

Training and Technology Transfer, and Agronomy Departments

TESTING OF NITROGEN-PLACEMENT MACHINES **434**
Multilocation yield responses to machine-placed N **434**
Yield response and N loss to floodwater with machine-placed PU and USG **435**

TESTING OF NITROGEN-PLACEMENT MACHINES

Training and Technology Transfer and Agronomy Departments

Multilocation yield responses to machine-placed N (*Training and Technology Transfer*). During 1983-84 dry season (DS), the curved spring auger was tested with other methods of applying N fertilizer in trials in Cagayan, Nueva Ecija, Iloilo, and South Cotabato.

With 60 kg N/ha treatments (Table 1), the researcher split yielded significantly higher than farmer practice in only 2 of 22 locations. In 3 of 22 trials, the spring auger gave significantly higher yield than researcher split. In 18 of 22 sites, the 60 kg N/ha researcher split gave yield similar to that of 90 kg N/ha; in 21 of 22 sites, 60 kg N/ha with the spring auger gave yield similar to that of 90 kg N/ha; in 18 of 22 sites, 60 kg N/ha hand placed as urea supergranules (USG) gave yield equivalent to that of 90 kg N/ha; and in 17 of 22 locations, yields were similar to those with 60 kg N/ha farmer practice.

Generally, 60 kg N/ha, regardless of application method, gave yields comparable to that of 90 kg N/ha researcher split. Some control plots yielded as

Table 1. Methods and rates of N application at 22 Philippine locations, 1984 DS.

Location	Yield[a] (t/ha)					
	No N	60 kg N/ha				90 kg N/ha
		Farmer practice	Researcher split	Spring auger	Hand-placed urea supergranules	Researcher split
Luzon						
Amulung, Cagayan	3.78 c	3.04 c	4.50 ab	3.53 abc	3.49 bc	4.62 a
(IR36)	2.84 b	3.36 ab	3.98 a	4.00 a	4.07 a	4.23 a
	3.08 e	4.63 d	5.28 cd	5.86 bc	5.99 b	6.99 a
	4.64 b	5.18 ab	5.60 a	5.60 a	5.44 a	5.89 a
	2.60 c	3.80 bc	3.87 bc	4.49 ab	4.45 ab	5.56 a
	3.43 b	4.91 ab	5.28 a	5.08 a	5.88 a	6.28 a
Mean	3.40	4.15	4.75	4.76	4.90	5.60
Talavera, Nueva Ecija	3.81 b	4.67 a	5.12 a	4.84 a	5.10 a	5.16 a
	2.36 b	4.17 a	4.30 a	4.17 a	4.45 a	4.56 a
	3.91 b	4.68 ab	4.84 a	4.88 a	5.07 a	5.15 a
	2.69 b	3.71 a	3.84 a	3.86 a	3.96 a	4.19 a
Mean	3.19	4.31	4.53	4.77	4.44	4.65
Visayas (IR36)						
Ajuy, Iloilo	3.10 b	3.79 a	3.59 ab	3.32 ab	3.59 ab	3.28 ab
	2.54 b	4.67 a	3.58 ab	4.14 a	4.54 a	3.78 a
	3.24 b	4.73 a	4.76 a	4.72 a	3.95 ab	4.25 ab
	3.29 c	4.91 ab	3.70 bc	4.40 a	3.98 ab	4.20 ab
Mean	3.04	4.53	3.91	4.15	4.05	3.88
Barotac, Nuevo, Iloilo	4.11 a	4.75 a	4.09 a	4.22 a	3.60 a	2.54 a
	4.38 a	4.81 a	4.24 a	4.71 a	4.80 a	4.38 a
	4.51 b	4.45 b	4.86 ab	5.34 a	4.63 b	4.97 ab
Mean	4.33	4.67	4.40	4.77	4.34	4.30
Mindanao (IR60)						
Koronadal, South Cotabato	4.74 c	4.75 c	5.26 b	5.75 a	4.93 c	5.74 a
	3.90 b	4.53 ab	4.44 ab	5.50 a	4.55 ab	4.31 ab
Tantangan, South Cotabato	2.76 b	3.04 ab	3.44 ab	3.59 a	3.27 ab	3.47 ab
Surallah, South Cotabato	3.52 bcd	3.78 abc	3.21 d	3.86 ab	3.29 ab	4.20 a
Norala, South Cotabato	4.46 c	5.96 b	5.94 b	6.71 a	5.45 b	6.96 a
Mean	3.89	4.46	4.46	5.08	4.30	4.94

[a]Separation of means in a row by Duncan's multiple range test at the 5% level.

high as did 90 kg N/ha because of high soil N, particularly in Barotac Nuevo, Visayas (0.24-0.36% N).

In 1983 DS, farmers in various Philippine locations volunteered to test and evaluate machines on 500-m^2 plots. In three of four locations, the deep plunger gave the highest average grain yield (Table 2). However, even though machines were calibrated, application rates were inconsistent because of faulty metering.

In 1984 wet season (WS), we compared the spring auger and the press wedge with researcher split using two levels of N (Table 3). Yields were similar for the 3 application methods, and 30 kg N/ha produced yields similar to those with 60 kg N/ha.

Most results indicate that, with improved management including better weed control, we can lower fertilization from 90 to 60 kg N/ha and still produce more than 4 t/ha in lowland irrigated areas.

Although deep-placement machines show potential in improving the efficiency of fertilizer use, only further refinement will give consistent performance and increase efficiency, making them economical for farmer use.

Yield response and N loss to floodwater with machine-placed PU and USG (*Agronomy*). In testing of prototype, IRRI-designed fertilizer placement machines, two machines applied prilled urea (PU) in band and two point-placed USG.

Hand point-placed USG produced significantly higher yield than machine-placed fertilizers at IRRI in DS (Table 4). The improved method and timing of N gave yields comparable to or significantly higher than deep-placed N by machine. On the other hand, farmer practice yielded significantly less. With machines, fertilizer delivery varied by

Table 2. Yield with 4 deep-placement machine in 500-m^2 farmers' fields at various Philippine sites, 1983 WS.

Location	Variety	Yield (t/ha)			
		Prilled urea		Urea supergranules	
		Spring auger	Oscillating plunger	Press wedge	Deep plunger
Luzon					
Cagayan (n = 5)	IR36	4.6	4.8	4.8	5.0
Visayas					
Leyte (n = 3)	IR56	4.0	3.8	3.9	4.4
Iloilo (n = 7)	IR36	4.7	4.7	4.4[a]	4.1[b]
Mindanao					
South Cotabato (n = 2)	IR60	4.2	3.5	4.5	4.8
Av		4.3	4.1	4.3	4.6
Range (kg N/ha)		37-108	7-89	36-63	43-73

[a] n = 5. [b] n = 3.

Table 3. Mean rice yield with 30 and 60 kg N/ha applied with fertilizer applicators in lowland irrigated areas at various Philippine locations, 1984 WS.

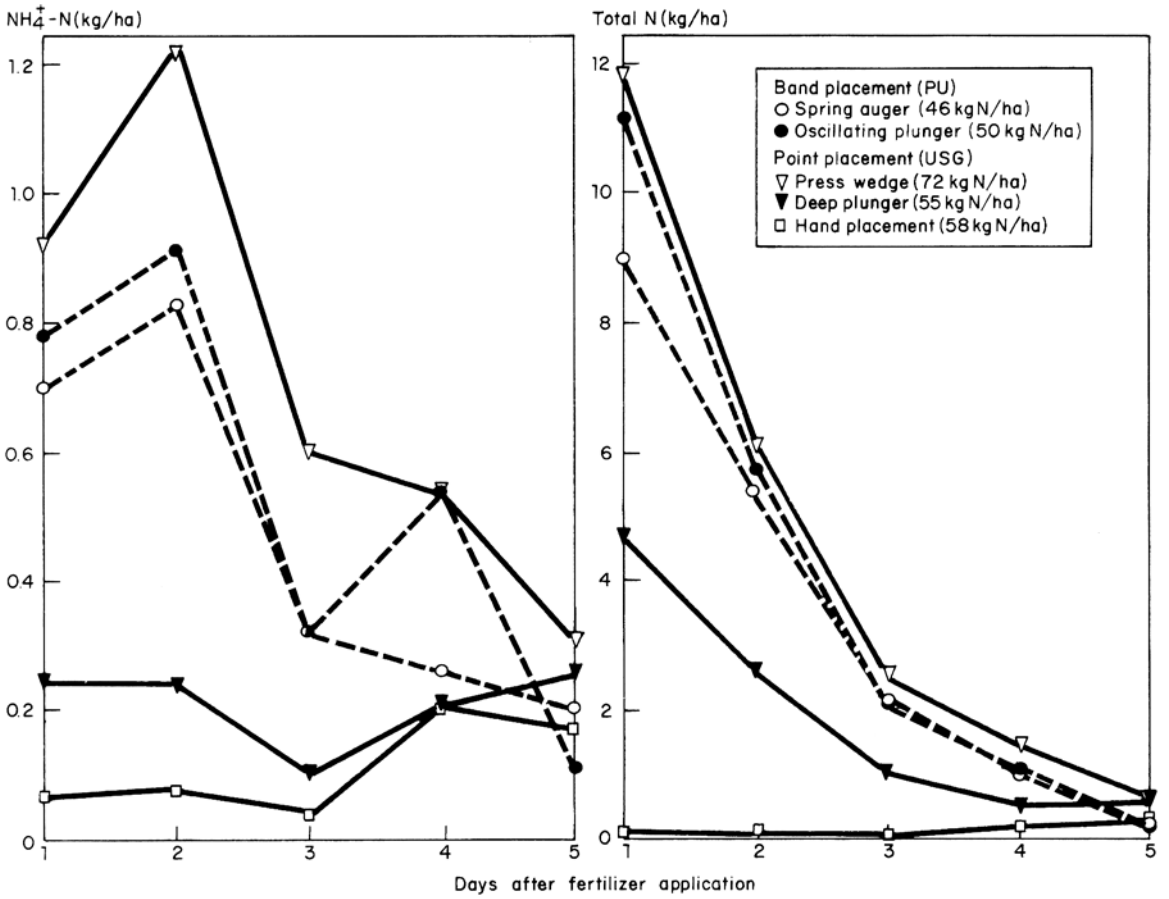
Location		Rice yield (t/ha)					
		Spring auger		Press wedge		Researcher split	
		30	60	30	60	30	60
Central Luzon[a]	(n = 8)	3.20	3.96	3.35	3.85	3.41	3.81
Iloilo[b]	(n = 3)	1.86	1.84	2.35	2.09	1.41	2.38
South Cotabato[c]	(n = 4)	5.99	5.74	5.69	5.98	5.59	5.88

[a] Variety used was IR36. [b] Variety used, IR36, suffered severe tungro virus infection. [c] Variety used was IR60.

Table 4. N applied, grain yield of IR58 rice, and fertilizer efficiency as affected by application techniques using hand and machine.[a] IRRI and Maligaya Rice Research and Training Center (MRRTC), Nueva Ecija, Philippines, 1984 DS.[b]

Urea source[c]	Application method	N applied (kg/ha)		Grain yield (t/ha)		Fertilizer efficiency (kg rough rice/kg N)	
		IRRI	MRRTC	IRRI	MRRTC	IRRI	MRRTC
PU	Band placement by spring auger	65	77	3.6 d	6.2 a	26	37
PU	Band placement by oscillating plunger	68	63	3.8 cd	5.6 ab	28	38
USG	Point placement by deep plunger	67	64	4.6 b	5.7 ab	40	39
USG	Point placement by press wedge	82	67	4.2 bc	5.2 bc	28	29
USG	Point placement by hand	73	73	5.2 a	5.8 ab	46	35
PU	Researcher split	73	73	4.4 b	5.3 bc	34	28
PU	Farmer split	73	73	3.4 d	4.8 c	21	21
–	No fertilizer N	0	0	1.9 e	3.3 d	–	–

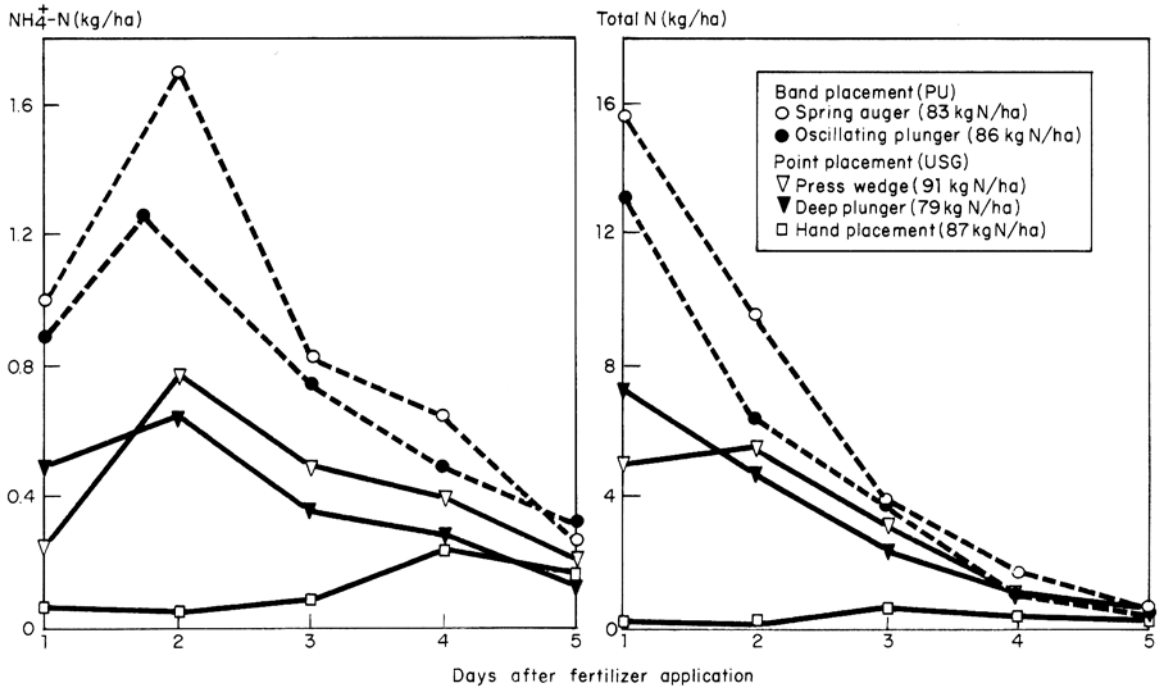
[a] Av of 4 replications and 2 N rates. [b] On Maahas clay at IRRI and Maligaya silty clay loam at MRRTC. [c] PU = prilled urea, USG = urea supergranules.



1. Floodwater NH_4^+-N and total N (urea + NH_4) at 1300-1400 h as affected by machine and hand placement of fertilizers at the intended rate of 58 kg N/ha. IRRI, 1984 DS.

−21% to +24% from the intended N rate of 58 kg/ha and by −9% to +5% from 87 kg/ha.

In Nueva Ecija, machine delivery varied by −19% to +5% from 58 kg/ha and by −13% to +6% from the intended rate of 87 kg/ha. Although band placement of PU by spring auger produced the



2. Floodwater NH_4^+-N and total N (urea + NH_4) at 1300-1400 h as affected by machine and hand placement of fertilizers at the intended rated of 87 kg N/ha. IRRI, 1984 DS.

Table 5. N applied, grain yield of IR58 rice, and fertilizer efficiency as affected by fertilizer application techniques using hand and machine.[a] IRRI and Maligaya Rice Research and Training Center (MRRTC), Nueva Ecija, Philippines, 1984 WS.[b]

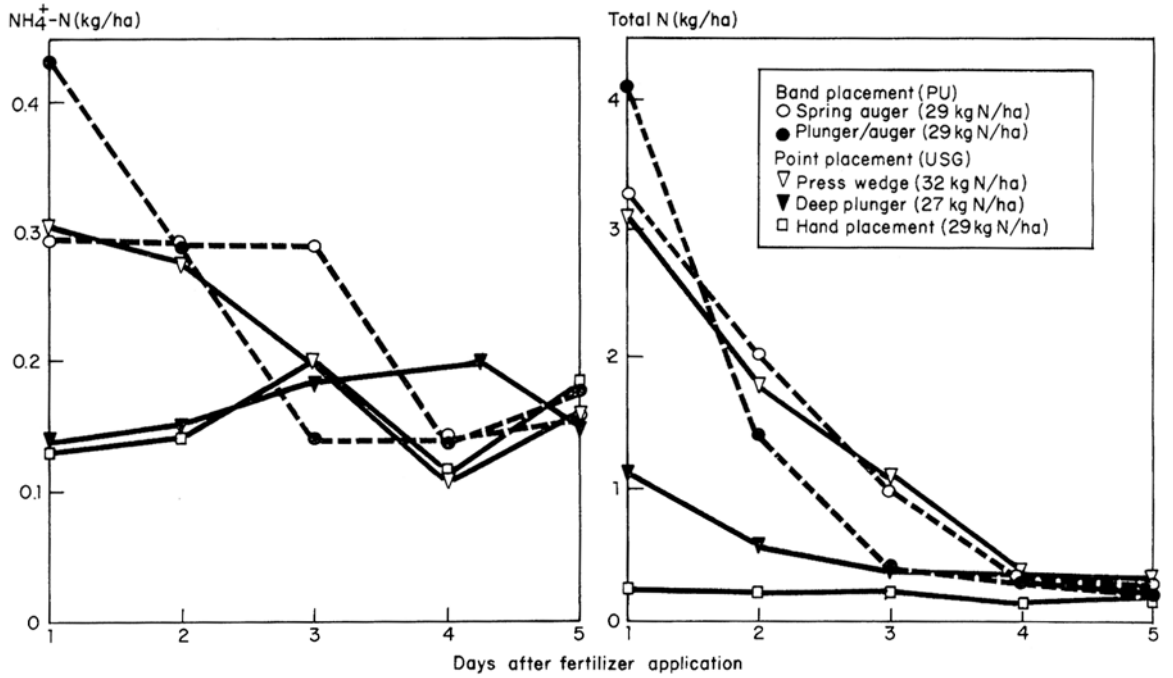
Urea source[c]	Application method	N applied (kg/ha)		Grain yield (t/ha)		Fertilizer efficiency (kg rough rice/kg N)	
		IRRI	MRRTC	IRRI	MRRTC	IRRI	MRRTC
PU	Band placement by spring auger	44	46	3.8 ab	3.9 a	34	15
PU	Band placement by plunger/auger	44	46	4.0 a	3.8 a	39	13
USG	Point placement by deep plunger	40	41	3.9 a	3.7 a	41	12
USG	Point placement by press wedge	42	39	4.0 a	3.8 a	41	15
USG	Point placement by hand	44	44	4.2 a	4.0 a	44	18
PU	Researcher split	44	44	3.8 ab	3.8 a	33	14
PU	Farmer split	44	44	3.5 b	3.6 a	27	9
—	No fertilizer N	0	0	2.3 c	3.2 b	—	—

[a] Av of 4 replications and 2 N rates. [b] On Maahas clay at IRRI and Maligaya silty clay loam at MRRTC. [c] PU = prilled urea, USG = urea supergranules.

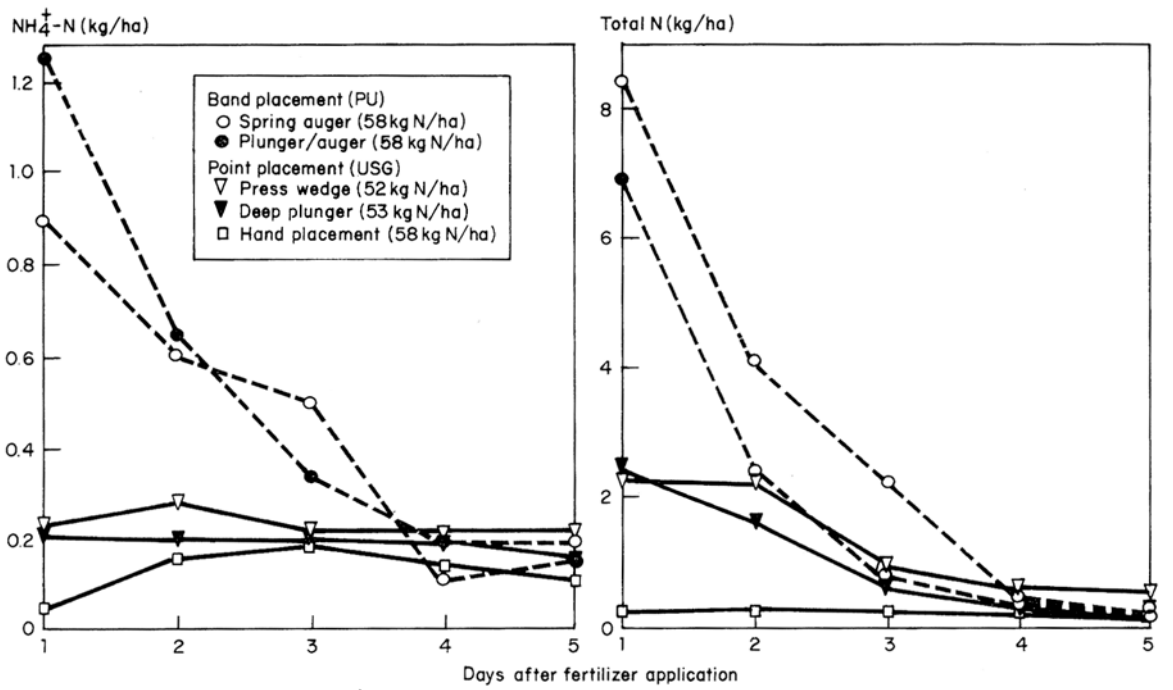
highest yield (Table 4), the machine delivered 5% more than intended. Among machines, the deep plunger was most efficient. Yields with the researcher split treatment were comparable to those with the hand- or machine-placed methods, but higher than with farmer practice.

The lower yields at IRRI were probably due to higher N losses in floodwater. Among machines, the deep plunger produced the lowest floodwater N at the intended N rate of 58 kg/ha (Fig. 1) and 87 kg/ha (Fig. 2). The two machines for PU produced high floodwater N, probably because of repeated applications on the same spot.

At IRRI in WS, hand-placed USG and machine-placed fertilizers gave yields comparable to those with the improved method and timing of applying PU in split doses (Table 5). The farmer practice of PU application in equal split doses at 10 d after



3. Floodwater NH_4^+-N and total N (urea + NH_4) at 1300-1400 h as affected by machine and hand placement of fertilizers at the intended rate of 29 kg N/ha. IRRI, 1984 WS.



4. Floodwater NH_4^+-N and total N (urea + NH_4) at 1300-1400 h as affected by machine and hand placement of fertilizers at the intended rate of 58 kg N/ha. IRRI, 1984 WS.

transplanting and 10 d after panicle initiation was significantly inferior to deep-placed USG either by hand or machine, and inferior to band-placed PU by plunger/auger machine.

Among deep placement methods, hand point-placement of USG produced negligible floodwater N, followed by point placement of USG by the deep plunger (Fig. 3, 4).

In Maligaya, yields with different N application methods were comparable, and significantly higher than yields without added N.

In both sites, fertilizer efficiency was highest with hand point-placement of USG and lowest with farmer split (Table 5).

Cropping systems program

Asian Rice Farming Systems Network

Rice Farming Systems Program

NATIONAL PROGRAMS **442**
CROPPING PATTERN TESTING **442**
VARIETAL TESTING **442**
LONG-TERM CROPPING PATTERN AND FERTILIZER STUDIES **444**
RICE - WHEAT CROPPING SYSTEMS **444**
- Cropping pattern testing **444**
  - Nepal **444**
  - Bangladesh **445**
  - Pakistan **445**
  - China **445**
- International Rice - Wheat Integrated Trials (IRWIT) **445**

CROP-LIVESTOCK SYSTEMS RESEARCH **446**
- On-farm research **446**
- Experiment station research **448**
  - Establishing nutritive values **448**
  - Pesticide residues in rice and straw **448**
  - Evaluation of forage grasses grown on levees **448**
  - Herbage yield and quality of five leucaena cultivars grown in hedgerows **449**
  - Cowpea as green pod, dry pod, and fodder **449**
  - Maize + soybean intercropping **449**
  - Pigeonpea intercropping with mungbean, cowpea, and peanut **449**
  - Insect pests on forage and green manure crops **450**

Asian Rice Farming Systems Network scientists continued collaborative research on many regional problems encountered in intensive rice farming systems. Collaboration emphasized cropping pattern testing, varietal testing of upland crops, rice - wheat systems, and long-term fertilizer and cropping pattern trials. Crop-livestock research started in the Philippines, Thailand, and Nepal.

Collaboration on using the rolling injection planter to establish upland crops was discontinued in some countries; the implement should be used only in light- or medium-textured soils.

Collaboration in 1985 will include green manuring, especially short-duration green manure crops and dual-purpose grain crops such as cowpea, mungbean, and pigeonpea. Grain crop can be harvested and crop residues used as green manure.

NATIONAL PROGRAMS

All network countries are doing cropping/farming systems research, modifying methodology developed by IRRI and network scientists to suit their organizations, power, and financial conditions. New systems are based on maize (Philippines, Thailand, Indonesia), coconut (Philippines and Malaysia), cassava (Indonesia and Thailand), and sugarcane (Philippines and Bangladesh). Some national programs include livestock and fisheries. The Philippines, Thailand, and Nepal implemented crop-livestock research, and Indonesia, Bangladesh, and Sri Lanka plan such work. Thailand began integrated farming systems with rice, livestock, and fish.

Rice-based cropping/farming systems research sites in 12 countries collaborating with the network increased from 173 in 1983 to 194 in 1984. These include 126 rainfed, 23 partially irrigated, 42 irrigated, 47 upland, and 92 deep water sites. Countries involved are the Philippines, Burma, Indonesia, Korea, China, Pakistan, Sri Lanka, Bangladesh, Thailand, Malaysia, Taiwan, and Nepal. Bhutan collaborates in rice - wheat cropping systems and Vietnam in varietal testing.

Each site's main focus is increasing production and cropping intensity, using early-maturing varieties. In sites with high intensity, research focused on increasing crop productivity.

National programs have implemented the preproduction (multilocation testing and pilot production) and production phases of the methodology. Bangladesh, the Philippines, Nepal, Sri Lanka, and Indonesia continued to expand multilocation testing and pilot production programs. In the Philippines, the six rainfed agricultural development outreach sites (RADOS) have multilocation testing and pilot production programs in 1984. Multilocation testing of mungbean - rice began in northern Thailand. Bangladesh expanded multilocation testing and pilot production in rainfed rice areas, using modern rice varieties (MVs) in a rice (MV) - rice (MV) cropping pattern. Production programs were expanded to 36,000 ha in Iloilo, Philippines, and to 17,000 ha in 6 districts of the terai and inner terai in Nepal.

CROPPING PATTERN TESTING

In 1984, cropping pattern testing involved 44 sites in 13 countries (Table 1). Most experiments were in farmers' fields. We monitored the environment, crop performance, and economic performance of patterns. In most cases, the focus is to increase production, net income, and cropping intensity.

The experimental patterns are always compared with the dominant farmer pattern in each site. Table 1 indicates number of crops in predominant farmer patterns, in experimental patterns, and the promising patterns. Usually, experimental patterns produce more yield and income than farmers' patterns.

VARIETAL TESTING

Varieties are tested in collaboration with the Philippine Institute of Plant Breeding (IPB), the Thailand Field Crops Research Institute, Indonesia's Central Research Institute for Food Crops, International Institute of Tropical Agriculture (IITA), and other national programs. See the section "Selecting and testing varieties for rice-based cropping patterns" for information on IPB and IRRI-IITA breeding projects and IRRI screening activities. Seeds of promising entries are increased in the IRRI farm for network distribution.

We received and increased at IRRI 12 maize varieties from the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Indonesia, Thailand, and IPB; 10 pigeonpea from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT); 18 mungbean from the Asian

Table 1. Crops in farmers' predominant patterns and the experimental pattern, and promising cropping patterns 1984.

Site	Crops (no.) in pattern		Promising cropping pattern[a]
	Farmers'	Tested	
Rainfed lowland			
Carmen, Philippines[b]	2	3	Rice – rice – mungbean
Abuyog, Philippines[b]	2	2-3	Rice – rice – watermelon
Wakema, Burma	1-2	2	Jute – rice Rice – tobacco
Kota Bharu, Malaysia	1-2	2	Rice – peanut
Vigan, Philippines[b]	2-3	3	Rice – rice – onions
Bantoa, Indonesia[c]	1	2	Rice – rice[c]
Katupotha, Sri Lanka[c]	1-2	2	Rice – peanut Rice – bush sitao
Bireun Aceh, Indonesia	1	2	Rice – soybean
Ratna Nagar, Nepal[b]	1-2	2-3	Rice – maize
Guimbal, Iloilo, Philippines[c]	1-2	2-3	DSR – green maize DSR – mungbean
Khon Kaen, Thailand	1	2	Peanut – rice Cowpea – rice
Nakhonsri Thammarat, Thailand	1-2	2-3	Mungbean – rice – mungbean
Rainfed lowland (with cooler temperature)			
Pumdi Bhumdi, Nepal[b]	2-3	2-3	Rice – wheat – maize Rice – maize
Sukchaina, Nepal[b]	2	2	Rice – chickpea Rice – wheat
Hathazari, Bangladesh	2-3	3	Rice – rice Rice – rice – cowpea
Partially irrigated			
North Nawin, Burma	1	2	Rice – sunflower
Bandarawela, Sri Lanka[c]	2	2-3	Rice – potato – bean
Patheingyi, Burma	1	2	Cotton – rice
Yezin, Burma	1-2	2-3	DSR – peanut
Phrae, Thailand	1-2	2-3	Mungbean – rice – soybean
Hathazari, Bangladesh	2-3	3	Rice – rice – wheat Rice – rice – peanut
Rainfed upland			
Antique, Philippines	2	2-3	Rice – maize + peanut
Bukidnon, Philippines	2	2-4	Rice + maize – maize + peanut
Batumarta, Indonesia	2-3	4	Rice + maize/cassava/ peanut or soybean
Manito, Albay, Philippines	2	2-3	Rice – sweet potato – mung-bean
Irrigated			
Beijing, China	1-2	2	Wheat – DSR
Mahaweli H, Sri Lanka	2	2-3	Rice – onion/chilies Rice – peanut
Changsha, China	2-3	2-3	Rape – rice – rice
Parsa, Nepal[b]	2-3	3	Rice – maize – maize Rice – wheat – rice
Shoaxing, China	2-3	2-3	Barley – rice – maize Barley – rice – rice
Ratna Nagar, Nepal[b]	2	3	Rice – wheat – mungbean Rice – wheat – maize
Kyeongbuk, South Korea	2	2	Rice – vegetables (pea, garlic) Wheat – rice
Candelaria, Zambales, Philippines	2	2-3	(new)
Kaoshiung, China	2-3	2-3	Rice – soybean – maize
Deep water and tidal swamp			
Daudkandi, Bangladesh	2	2-3	DW rice – fallow – potato DW rice – potato – sesame
Barambi, Indonesia[b]	1-3	4-6	Rice – rice in paddy and maize + peanut/ cassava + sorghum in bunds

[a]DSR = dry seeded rice, DW = deep water. [b]Used for multilocation and pilot production program. [c]Used for multilocation testing

Vegetable Research and Development Center (AVRDC) and IPB; 22 soybean from AVRDC and IPB; 20 cowpea from IITA; 9 peanut from IPB; and 10 sorghum from ICRISAT and IPB. A total of 107 trials before rice (23 mungbean, 20 cowpea, 13 bush sitao, 13 soybean, 13 peanut, and 18 maize) and 171 trials after rice (24 mungbean, 28 cowpea, 17 bush sitao, 33 soybean, 22 peanut, 20 sorghum, and 27 maize) were also distributed to Burma, Nepal, Thailand, Indonesia, China, Bangladesh, Sri Lanka, Malaysia, Vietnam, and the Philippines.

The most promising varieties of mungbean, soybean, cowpea, bush sitao, maize (green and field), peanut, pigeonpea, and sorghum were distributed in the network for testing before and after rice. Most trials had 10 entries and 2 checks (recommended varieties). Testing was done in experiment stations or cropping/farming systems sites.

For cropping pattern year 1984-85, we are distributing 157 trials before rice: 35 mungbean, 31 cowpea, 24 bush sitao, 7 soybean, 9 peanut, 5 field maize, 24 glutinous maize, and 22 sweet maize. The 261 trials after rice consist of 51 mungbean, 31 cowpea, 31 bush sitao, 35 soybean, 38 peanut, 15 sorghum, 29 field maize, 19 green maize, and 12 pigeonpea.

LONG-TERM CROPPING PATTERN AND FERTILIZER STUDIES

Intensive cropping presents danger of rapid fertility loss, lowering productivity. In late 1982, network scientists agreed to conduct studies on long-term fertilizer use and cropping patterns. Studies are examining effects of using different crop rotations on soil and crop performance, and determining residual effects of fertilization and other soil amendments on cropping pattern performance.

The Bangladesh Rice Research Institute is studying four cropping patterns (rice - rice, rice - green manure - rice, chickpea - rice - rice, wheat - rice - rice) with irrigation in Comilla and Joydebpur, and three rainfed lowland rice cropping patterns (rice - rice, legume - rice - rice, and rice - rice).

In Burma, the long-term fertilizer management trials used rice - wheat - sesamum, mungbean - rice - sunflower, and maize - transplanted rice - soybean.

Nepal started with four cropping patterns and three fertilizer rates in 1983 in Khumaltar.

Indonesia established four experiments in lowland and upland fields: 1) effectiveness of partially acidulated phosphate rock in year-round cropping patterns in four research sites, 2) crop and soil response to time and P treatment in cropping patterns in four research sites, 3) controlled-release N fertilizers in upland cropping in five research sites, and 4) evaluation of effects of crop residue management on soil and production of rice and soybean in year-round cropping patterns in three experiment stations.

Most China trials are long-term with pattern rotation. The Shaoxing trial includes six cropping patterns: barley - rice - maize, green manure - rice - rice, barley - rice - rice, rape seed - rice - soybean, barley/soybean - rice, and barley/maize - rice. The highest yielder has been barley - rice - rice.

The Pintung, Taiwan, trials involved three cropping patterns: rice - rice - soybean, soybean - rice - maize, and rice - soybean - maize with fertilizer treatments.

RICE - WHEAT CROPPING SYSTEMS

Collaborating with national programs, IRRI and CIMMYT are researching rice - wheat cropping systems in 14 countries: temperate countries (China and Korea), subtropical countries (Bangladesh, Nepal, Bhutan, Pakistan, and China), and tropical countries (Philippines, Thailand, Indonesia, Burma, Sri Lanka, Vietnam, and Malaysia).

The first two projects are cropping pattern testing and rice - wheat integrated trials.

Cropping pattern testing. Patterns with rice, wheat, and other crops are being tested in the cropping systems sites and experiment stations in Nepal, Bangladesh, Pakistan, and China.

Nepal. At Ratna Nagar in Nepal, patterns were tested in irrigated and rainfed lowland. Rice - wheat - mungbean and rice - wheat - maize gave higher production and net returns than the farmers' rice - wheat in irrigated fields. Lumbani and UP 262 wheat yields were 65 to 91% higher than farmers' wheat (RR 21) yield, and yields of Laxmi and Malaka Janaki rice were 0 to 63% higher than the yield of farmers' Masuli variety. In rainfed lowland, rice - maize with improved management and rice - wheat patterns showed higher production and net returns than farmers' rice - maize practice.

In the Bahuwari tubewell site, seven cropping

patterns were tested. Rice - maize - maize showed higher production and net returns than rice - wheat - rice. The farmers' practice of rice - rice - wheat was comparable to the improved rice - rice - wheat because farmers have used improved varieties and better management in the past 3 yr.

The Pumdi Bhumdi site is rainfed lowland with two categories: high production potential and medium production potential. The rice - wheat - maize pattern under good agronomic management was tested in 1982-83 in the high-production potential areas. Production was 12.8% higher than the farmers' rice - wheat - maize pattern, but net incomes did not differ. Several tests led to farmers' adoption of improved agronomic management and high yielding varieties. In the medium production potential areas, four cropping patterns were tested (rice - wheat, rice - maize, rice - broad bean - maize, rice - oats). Net return was highest for rice - maize ($899), 25% higher than for rice -wheat.

Bangladesh. In Bangladesh, most sites are looking at rice - wheat systems. Farmers in Hathazari traditionally grow only 2 rice crops and leave the field fallow for 180 d. The team introduced a third crop, wheat, coupled with improved rice. The 2 rice crops under improved management yielded 7.5 t/ha, 32% better than farmers' practice. The net returns of rice - rice - wheat were 59% better than farmers' rice - rice pattern.

In the rainfed areas of Trishal Thana, the Bangladesh Agricultural University tested rice - rice - wheat and jute - rice - wheat. Predominant patterns were rice (local) - rice (local), and jute (local) - rice (local). With wheat as a new crop, rice and jute yields were much higher than those of local varieties, and the wheat crop was excellent. Net return was much higher with wheat in the rice - rice pattern (318-510% better) and in the jute - rice (383%).

In Thakurgaon, the Bangladesh Water Development Board tested several patterns using improved varieties and medium levels of fertilizer. Yields and net returns of new patterns (rice - rice - wheat, millet - rice - wheat, mungbean - rice - wheat) were higher than the farmers' rice - rice - wheat. Mungbean and millet are good alternatives for improving the system. Rice - rice - wheat gave highest net returns. Jupateco, Balaka, and Pavon increased production and net returns, especially Pavon.

Pakistan. In Pakistan, common patterns are rice - wheat and rice - clover in Punjab Province, and rice - wheat and rice - peas in Sind. New cropping patterns were tested in Kala Shah Kaku: rice - wheat, rice - clover, rice - mustard - mungbean, rice - mustard - sunflower. Rice yielded 3.7 t/ha and wheat 3.2 t/ha. Compared to the rice - wheat total net return, that of rice - clover was 29% better; rice - mustard - mungbean, 33%; and rice - mustard - sunflower, 19%. For patterns tested in Dokri Rice Research Institute in Sind Province under rainfed conditions, winter crops were not irrigated and fertilized. Wheat yielded only 0.95 t/ha. Highest net income was obtained in rice - chickpea ($893/ha), 22% better than that in rice - wheat.

China. Testing at Tongxian, Beijing, China, involved rice - wheat. Green manure - DSR (direct-seeded rice), barley - DSR, silage crops - DSR, and wheat - DSR were tested. Yield was highest in wheat - DSR (9.01 t/ha) and lowest in silage crops - DSR (3.70 t/ha). Of patterns tested in Chang-Hwa in Taiwan, rice - soybean - wheat gave highest net return. Other patterns such as rice - rice - wheat and rice - sorghum - wheat were better than rice - rice.

International Rice - Wheat Integrated Trials (IRWIT). IRWIT aims to identify better varieties of rice and wheat with multiple resistance to pests and diseases that fit the rice - wheat system. After trials in experiment stations, materials will be tested in cropping system sites. Rice entries come from the IRRI IRTP, and wheat from the CIMMYT wheat program. National breeding programs contribute 50% of trial entries.

In 1983-84, we distributed 31 sets of rice trials to 15 countries: 8 early sets to temperate and high elevation countries (China, Korea, Bhutan, Nepal, and Egypt) and 23 sets of early- and medium-maturing varieties to subtropical and tropical countries (Burma, Philippines, Thailand, Vietnam, Bangladesh, Nepal, Pakistan, Sri Lanka, Indonesia, and Malaysia). These countries also received 31 sets of early- and medium-maturing wheat varieties.

Yields of highest yielding rice and wheat varieties and local checks are presented in Tables 2-4.

Table 2 shows the top yielding rices in Burma, Philippines, Thailand, Bangladesh, and Nepal.

Table 3 shows the most promising early-maturing wheats. Of CIMMYT entries, UP262 was best in Joydebpur and Jamalpur, Bangladesh; Muang Prae, Thailand; Milyang, Korea; and Isabela,

Table 2. Yield and days to flower of the highest yielding early- and medium-maturing rice varieties and local checks in 5 Asian countries, 1983-84.

Site	Variety[a]	Yield (t/ha)	Days to flower
Burma			
Patheingyi	Milyang 54	4.8	105
	(Pelita 1-1)	5.4	106
Wakema	IR42	4.4	107
	(Shewewalay)	4.2	67
Yezin	IR42	0.7	105
	(Sintheingyi)	0.6	106
Philippines			
Isabela	BR 51-282-8	3.7	126
	(UPLR1-4)	0.7	118
Los Baños	IR36	4.1	78
	(IR60)	4.2	80
Nueva Ecija	RP825-45-1-3	5.9	94
	(IR36)	5.2	75
Thailand			
Chiang Mai	IR54	4.5	101
	(RD7)	3.6	85
Chieng Rai	RP825-45-1-3	1.3	103
	(RD10)	1.1	110
Chumpae	RP825-45-1-3	3.0	81
	(RD6)	1.9	101
Muang Prae	IR54	3.6	109
	(RD15)	3.5	114
Bangladesh			
Jessore	IR54	5.7	75
	(BR11)	5.2	84
Joydebpur	IR13540-56-3-2-1	5.1	103
	(BR11)	5.0	109
Nepal			
Bairawaha	RP825-45-1-3	2.8	103
	(Saryu 49)	3.0	93

[a]Local check varieties are in parentheses.

Table 3. Yield and duration of the highest yielding, early-maturing wheat varieties and local checks in 7 Asian countries, 1983-84.

Site	Variety[a]	Yield (t/ha)	Duration (d)
Bangladesh			
Joydebpur	UP262	2.70	111
	(Balaka)	2.82	109
Jamalpur	UP262	5.30	94
	(Akbar)	5.68	91
Jessore	Nacozari 76	3.33	98
	(Balaka)	3.19	96
Nepal			
Rupandehi	Nacozari 76	2.21	108
	(Vaskar)	2.54	109
Thailand			
Muang	UP262	0.44	86
	(Sonora 64)	0.30	79
Khon Kaen	Sonka Inia	1.06	79
	Sonora 64	0.73	79
China			
Changsha, Hunan	Sonalika	1.95	174
	(Xiang 1675)	2.27	183
Korea			
Milyang	UP262	2.74	203
	(Olmil)	4.51	199
Pakistan			
Dokri	Sonalika	1.79	107
	(Punjab 81)	1.87	113
Philippines			
Los Baños	C213-15	1.89	76
	(C214-1)	1.86	83
	(Trigo 1)	1.80	90
Isabela	UP262	1.82	83
	(C169-6)	1.75	74
	(Trigo 1)	1.48	87

[a]Local check varieties are in parenthesses.

Philippines. However, it was outyielded by local varieties in Bangladesh and Korea.

In the medium-maturing group, the highest yield (4.6 t/ha) was obtained in Bangladesh (Table 4). In 1984-85, we distributed 9 early-maturing rices, 28 early-maturing and medium-maturing rices, 28 early-maturing, and 22 medium-maturing wheats.

CROP-LIVESTOCK SYSTEMS RESEARCH

The Philippines, Thailand, Nepal, Sri Lanka, and Indonesia are testing crop-livestock combinations. The Philippine project started 6 Apr 1984 as an International Development Research Center project, and involves the Ministry of Agriculture and Food (MAF) in Santa Barbara in Pangasinan, IRRI, and the Institute of Animal Science at the University of the Philippines at Los Baños (UPLB-IAS). At Ban Phai, Khon Kaen, a rainfed rice area typical of northeast Thailand, the project focuses on cattle. At the Pumdi Bhumdi, Nepal site, representing the mid-hills rainfed lowland rice area, research will involve dairy cattle and buffalo. The projects in Sri Lanka and Indonesia will start in 1985.

On-farm research. The Philippine on-farm site in Santa Barbara, Pangasinan, 262 km north of Manila, is composed of 29 barrios or barangays involving 5,800 ha. In barangay Carosucan, a rainfed site, average landholding is 1.6 ha with 1.4 head of cattle or buffalo per farm. In barangay Malanay, irrigated lowland with an upland area, landholdings average 1.3 ha, with 1.1 head of livestock per household. Livestock carrying capacity is 1 and 0.92 animal units per ha in the 2

barangays. Rainfall starts in May or early June, peaks in August, then ends in October. Soil is clay loam to sandy loam with pH 6.7-7.9.

Twenty farmers in Malanay and 18 in Carosucan were selected based on survey results and willingness to collaborate. Assignment to treatment was based on size of landholding and involvement in animal raising. In Malanay, treatments I and II had farmers with 0.5-2 ha and 1 draft + 1 fattener animal. Treatments III and IV were farmers with 2.1-3.5 ha and 1 draft + 2 fatteners. In Carosucan, treatments I and III farmers had 0.5-1 ha and 1 draft animal each; treatments II and IV had 1.1-2 ha and 1 draft + 1 farm animal each. At both locations, treatments I and II were provided with technology and III and IV served as control.

Farmers lacking required animals were provided with fattening cattle, on a *paiwi* sharing system to equalize animal holdings within treatments.

In this traditional livestock rearing-sharing scheme, the lender gives the animal to the caretaker. Incremental profit is split 50:50 upon sale, and initial animal value goes to the lender.

Interventions in livestock management include daily feeding with 2 kg Leucaena or other legume forages, provision of urea-molasses-mineral blocks, establishment of improved forages in their lots, and animal health care. Use of fibrous crop residues, especially rice straw, is recorded and related to farm grain and residue output.

Animals were weighed at experiment start, and every 1.5 mo thereafter. After 110 d feeding, liveweight gains of cattle did not differ because of farm size or interventions. In Carosucan, animals in treatment I gained the least (0.1 kg/d). Gains were 0.49 kg/d in treatment II, 0.37 in III, and 0.14 in IV. In Malanay, performance was more uniform. Control animals (treatment III, 0.38 kg/d; and IV, 0.47 kg/d), however, gained as much as or more than intervention animals (I, 0.23 kg/d; and II, 0.47 kg/d). Animals were slaughtered after 6-8 mo fattening.

Animals had serological and fecal examinations. In the experimental group, animals were dewormed a month after farm adaptation. Semen samples were collected from bulls. All animals owned by farmer cooperators were vaccinated for foot-and-mouth disease and hemorrhagic septicemia.

From fecal examinations, internal parasite loads in eggs per gram were high at project start. Administration of a broad-spectrum dewormer in September controlled them. Animals were tested for brucellosis and leptospirosis. One Carosucan animal was positive for leptospirosis and several Malanay animals tested positive for both diseases.

In the irrigated and upland test sites in Malanay, whole farm research examined the stability of the rice - rice pattern. Between rice crops, the 75 d turnaround time could accommodate a mungbean crop to increase cropping intensity and fodder yield. Component technology trials on variety and fertilizer rates were conducted to reduce farmers' inputs. In the upland portion, cropping pattern trials were in a 1,000-m^2 lot with component technology trials superimposed in the cropping pattern fields.

The 60-d mungbean grew well. Proper row

Table 4. Yield and duration of the highest yielding, medium-maturing wheat varieties and local checks in 7 Asian countries, 1983-84.

Site	Variety[a]	Yield (t/ha)	Duration (d)
Bangladesh			
Joydebpur	Pavon 76	6.51	110
	(Akbar)	6.10	108
Jamalpur	Ciano 79	5.37	105
	(Barkat)	5.33	105
Jessore	Tyrant S	3.81	112
	(Barkat)	3.97	109
Nepal			
Patun, Kathmandu	Ciano 79	1.57	167
	(HS94)	1.89	165
China			
Changsha, Hunan	Glennson 81	1.91	181
	(Xiang 1629)	2.34	181
Sichuan	Glennson 81	2.80	194
	(Sichuan Wheat)	4.16	184
Pakistan			
Dokri	Pavon 76	1.87	125
	(Zerhad 82)	1.83	125
Burma			
Wakema, Irrawaddy	Glennson 81	0.36	74
	(C214-1)	0.23	83
Pyinmana, Ari Yezin	Tyrant S	1.09	83
	(C214-1)	1.02	83
Philippines			
Los Baños	C213-15	1.02	80
	(C169-6)	0.81	82
	(Trigo 1)	0.67	93
Thailand			
Pan, Chiang Rai	Pavon 76	1.40	88
	(Inia 66)	1.20	87

[a] Local check varieties are in parentheses.

arrangement between peanut and maize would probably give more yield than farmers' mixed cropping. Most component technology tests on rice failed because of severe flooding.

In irrigated Malanay, 92% of farms were planted to high yielding varieties. The most prominent MVs with grain yield in t/ha were IR42, 4.9; IR36, 3.2; IR32, 3.8; and IR54, 3.1. The farmers' local variety yielded as well as did IR42 (4.1 t/ha). Fresh fodder yield after harvest showed that the farmers' variety yielded highest (15.5 t/ha) followed by IR32 (15.5), IR36 (13.3), IR42 (11.4), and IR54 (11.1). In the upland portion, field maize intercropped with cowpea followed by field maize plus peanut is being compared to farmers' pattern of field maize followed by peanut or vegetables.

At Carosucan, trials were intensifying the rice crop and fitting in upland crop (mostly legumes) to take advantage of the residual soil moisture. Upland crops after early-maturing rice could be well established. The research team worked on two soil types: a medium-light but drought-prone soil and a heavy, poorly drained and flood-prone soil. Farmers planted early-maturing MVs (IR36) in lighter soils where water stress is expected, and taller and late-maturing varieties (IR42, IR48 and local) on heavier soils.

The 1984 WS rice crop gave grain yields of 3.6 t/ha (IR42), 3.3 (IR48), 3.0 (IR36), and 2.7 (IR52). These MVs occupied 76% of the area. Farmers' varieties — IR36 and IR42 — averaged 3.1 t/ha with a fresh fodder yield of 12.3 t/ha.

Early- (IR36) and late-maturing (IR42) varieties were tested for cropping pattern trials at Carosucan followed by field maize, peanut, mungbean, and cowpea. In the experimental pattern, IR36 yielded slightly higher than the farmers' practice (2.8 vs 2.6 t/ha), but farmers' practice produced at least 6% higher net income because for the experimental pattern, inputs, particularly insecticide and herbicide, were expensive. IR42 yields in the experimental pattern equaled those of farmers' practice (2.9 t/ha). The experimental pattern had lower fertilizer expenses, 53% less than farmers' practice; however, it also used herbicide while the farmers did no weeding. Net returns were similar.

Superimposed trials on fertilizer rates in rainfed areas showed that an added return of $42/ha for IR36 and $163/ha for IR42 can be obtained by using 60 kg N/ha, and not the 40 or 30 kg N/ha recommended for cropping pattern testing.

The Agronomy Department identified and monitored weeds for animal feed. Of 20 species collected by farmers, *Panicum repens* L. contributed the most in WS. The farmers also identified these preferred by animals: *Brachiaria mutica*, (Forsk.) Stapf., *Cynodon dactylon*, *Echinochloa colona*, *Ipomoea aquatica*, and *Alysicarpus vaginalis* (L.) DC. Sedges such as *Cyperus rotundus* and *Fimbristylis miliacea* (L.) Vahl. were often uneaten. Researchers reported *A. vaginalis* was an outstanding forage legume.

Experiment station research. *Establishing nutritive values.* Nutritive and feeding values of rice straw and crop residues are being determined to formulate rations adaptable to farmers' conditions. Digestion trials are using cattle and carabao at UPLB-IAS.

In digestion trials of guinea and para grass, carabao showed higher coefficient of digestion (COD) for energy and various nutrients than did cattle. That showed carabao efficiency in digesting roughage, especially that of poorer quality. Guinea grass had higher dry matter and crude fiber than para grass, and twice as much cell wall fiber.

Pesticide residues in rice and straw. The Philippine National Crop Protection Center collaborated with IRRI in measuring pesticide residues in rice and straw. At IRRI, medium-maturing UPL-Ri5 was planted and 10 pesticides were applied. No residues were found in plants treated with monocrotophos, diazinon, gusathion, benomyl, and butachlor. Residues of BPMC + chlorpyrifos found in grains, leaves, and stalks, ranged from 0.01 to 0.08 mg/kg. The provisional maximum residues limit (MRL) for the compound is 0.05 mg/kg body weight in cattle (FAO/WHO Joint Meeting on Pesticide Residue, 1979). No MRL level is given for rice. Carbofuran was detected at 0.03 to 0.04 mg/kg, within the MRL for treated rice and maize (FAO/WHO).

Evaluation of forage grasses grown on levees. Sixteen forage grasses were evaluated at IRRI. To simulate farm levees, bunds 0.3 m wide and 0.35 m high were made 1 m apart. Grass was planted on weed-free strips. Thereafter, weeds were allowed to compete and were later harvested. No insecticides and fertilizers were applied.

First clipping was done when species were well-established. After 2 clippings every 30 d, dry matter (DM) yield and competition with weeds were satisfactory for 5 grasses. Two clippings of para grass *Brachiaria mutica* gave 1.14 kg DM/6-m-long bunds. Star grass *Cynodon plectostachyum* yielded 0.31 kg DM/6-m-bund, and plicatulum *Paspalum plicatulum* produced 0.30 kg. Alabang *Dichanthium aristatum* and Setaria cv. Nandi and Kazungula *Setaria sphacelata* yielded 0.26 kg DM.

Herbage yield and quality of five leucaena cultivars grown in hedgerows. Under smallholders rice-based farming conditions, Leucaena could be planted in fencelines or field borders to provide fodder, especially through DS. At IRRI, cultivars Peru, K28, K6, and Cunningham were established in hedgerows 0.5 × 0.5 m apart, 4 rows each. Cutting intervals were 30, 45, and 60 d. Cutting heights were 30 and 150 cm. Two cuttings of K28 at 60-d intervals gave 3.2 kg DM/10-m hedgerow, or roughly 0.32 kg/linear metre during WS.

Cowpea as green pod, dry pod, and fodder. During 1983-84, we evaluated eight cowpea varieties as a vegetable, grain, and fodder crop under different fodder harvest times and two growing seasons at IRRI.

Harvesting time of fodder significantly influenced grain yield in WS but not in DS. Harvesting time significantly influenced fodder yield both seasons. The variation in green pod yield was primarily due to variety in both seasons. No entry was found to be a triple-purpose variety for both seasons. For DS, TVx 3381-02F could be recommended as a triple-purpose variety producing the highest green pod (3.72 t/ha), grain (1.30 t/ha), and fodder (17.75 t/ha) yields when harvested at third priming of dry pods. For WS, TVx 2939-09D and again TVx 3381-02F were promising.

During WS, TVx 3381-02F gave highest protein content at 13.8%, while Vita 7 gave the highest crude protein yield at 479.6 kg/ha. TVx 1836-19E and TVx 3381-02F produced the lowest crude fiber at 32.3 and 32.9% and also the highest DM digestibility with 63.6 and 62.4%, respectively. In DS, the highest crude protein content was obtained from TVx 3671-7C-02D (16.5%) and the highest crude protein yield from TVx 3381-02F (473.0 kg/ha). Crude fiber content was lowest in TVx 289-4G (29.9%), and DM digestibility was highest in Vita 7 (66.9%). As regards to pod, grain, and fodder yield quality, TVx 3381-02F was best among the eight entries for both seasons.

Maize + soybean intercropping. An experiment examined integrating fodder production into a maize + soybean intercropping at IRRI in WS and DS. Maize hybrid SM 301, variety Phil. DMR 2 and soybean Acc. 2120 were used. There were 3 treatments (2 thinnings [20, 30 d after emergence (DE)], 3 thinnings [20, 30, 40 DE], and 4 thinnings [20, 30, 40, and 50 DE]) and 2 harvest dates of soybean (35 and 55 DE) for fodder.

Highest mean fodder yields of thinned (26.4 t/ha) maize were obtained under 4 thinnings. Maize hybrid gave higher fresh herbage yields over the local variety in both seasons. Grain (4.6 t/ha) and stover yields (10.8 t/ha) at maize harvest were not affected in both seasons, but maize hybrid declined in both grain and stover yields in DS. However, maize grain and stover yields were not hurt by varying fodder harvest dates.

Herbage yields of soybean were considerably higher (4.5 t/ha) at 55 DE than at 35 DE. Grain (1.2 t/ha) and stover yields at harvest (4.8 t/ha) were drastically reduced due to intercropping. Yield reduction of 60-80% was associated with fewer pods per plant and seeds per pod.

Pigeonpea intercropping with mungbean, cowpea, and peanut. In June 1984, we intercropped pigeonpea + mungbean, pigeonpea + cowpea, and pigeonpea + peanut at IRRI to identify superior legume combinations for grain and fodder. We also measured grain, fodder, and DM yields of pigeonpea, mungbean, cowpea, and peanut varieties as affected by thinning dates of pigeonpea and harvest dates of intercrops for fodder.

The most promising system was pigeonpea + cowpea followed by pigeonpea + mungbean; pigeonpea + peanut was least favorable. The land equivalent ratio of pigeonpea + cowpea was 1.48 and that of pigeonpea + peanut, only 0.99. The pigeonpea + cowpea system produced the highest fodder (39.9 t/ha) and DM yields (4.6 t/ha). The peanut monocrop plots yielded no fodder. Thinning pigeonpea in excess of the normal plant population and harvesting intercrops at different growth stages for fodder did not significantly affect the grain, fodder, and DM yields of main crops and intercrops. Treatments did affect pods per plant in

mungbean, branches per plant, branch length, pods per plant, pod length, and hundred-seed weight in pigeonpea. Pigeonpea varieties and intercrops significantly differed.

Insect pests on forage and green manure crops. In IRRI tests, pigeonpea and Crotalaria were most attacked by insects. Pigeonpea was infested mainly with pod and seed pests (bollworm *Heliothis armigera*, bean pod borer *Maruca testulalis*, lima bean pod borer *Etiella zinckenella*), although leaf-folder *Hedylepta indicata* and aphid *Aphis craccivora* attacked the foliage. Hyacinth bean was attacked mainly by pod borer *Catochrysops cnejus* and also by *Aphis craccivora* and a stem-feeding bug *Coptosoma*. Stylosanthes harbored the plant-hopper *Machaerota ensifora* and Sesbania harbored thrips. Although a typhoon eliminated yield loss measurement, insects will be a problem on pigeonpea and Crotalaria, less a problem on hyacinth bean, and not a problem on stylosanthes and Sesbania. The latter crops are therefore preferred for low-input forage and green manure.

Machinery development and testing

Agricultural Engineering Department

TILLING **452**
Rotary tiller **452**
Wheel float attachment **452**
Intermediate drive **452**
Cable-powered subsoiler for strip tillage **453**
SEEDING AND TRANSPLANTING **453**
Direct seeder for lowland paddies **453**
Rice transplanter adoption **454**
PUMPING **455**
Axial-flow pump **455**
FERTILIZER PLACEMENT **456**
Wire and sheet augers for metering and injection **456**
Laboratory study **456**
Field study **457**
Performance summary **457**
The plunger-auger fertilizer injector **458**
Roller auger applicator for prilled urea **458**
Field testing of deep placement applicators **459**
Embedding depth and N transfer to floodwater **460**
GRAIN DRYING **460**
Warehouse dryer design changes **460**
Drying trays **460**
Warehouse **460**
Furnace **460**
INDUSTRIAL EXTENSION **460**
Philippines **460**
Burma **462**
Indonesia **462**
Thailand **462**
India **462**

Agricultural Machinery Development is a cooperative program involving Agricultural Engineering, Physics, Multiple Cropping, Agronomy, and Training and Technology Transfer Departments. A committee of staff from these departments sets research priorities.

The committee establishes design criteria using results of farmer surveys. When criteria are met, machines are field tested by the Test and Evaluation Section. When a machine is ready for production, the Industrial Liaison Section of each country takes the blueprints to cooperating manufacturers and assists them in fabricating prototypes and in introducing machines to farmers.

Agricultural Engineering collaborates with the Regional Network for Agricultural Machinery (RNAM) in introducing machines to cooperating countries, and with the Agricultural Machinery Testing and Evaluation Center (AMTEC) in testing prototype models. RNAM and AMTEC are based at the University of the Philippines at Los Baños.

Priorities for 1984 were development of deep placement fertilizer applicators and direct seeders. Work continued on grain drying and on improving the rotary tiller. A two-stage axial-flow pump was tested. The transplanter was improved, and a program to introduce the machine to farmers was implemented.

TILLING

Rotary tiller. *Wheel float attachment.* On wet soil, rotary tillage is more economical than conventional tillage (plowing and harrowing) despite the higher power required. Rototilling is about three times as fast as plowing and harrowing.

On freshly harvested fields and recently flooded fallowed fields, rotary blades are more effective than puddling wheels; they cut and penetrate soil more efficiently. However, lightweight power tillers with rotary blades directly mounted on the axle, although widely used in upland cultivation, bog down in lowland conditions.

To prevent sinkage, wheel floats were developed. Totally enclosed hollow cylinders with hexagonal hubs fit the tiller axle. These floats fit the outer end of the axle and rotary blades the inner end (Fig. 1). A blade canopy on each side prevents splashing and helps break soil being cut.



1. Lightweight tiller with wheel floats. IRRI, 1984.

Initial tests show wheel floats prevent sinkage on semiwet soil, such as on newly harvested fields. On soft fields, however, the tiller still bogs down and the blades cut deeper into the hardpan. To improve flotation, a front skid adjusted to hardpan depth was considered. Modified puddling wheels will be used instead of rotary blades when working on soft fields.

Intermediate drive. Farmers with small landholdings prefer a power tiller which can accept not only a rotary tiller but other implements, particularly plow, harrow, harvester, and trailer. Implements should be easily installed without altering the basic power unit.

An intermediate drive to permit easy attachment of a rotary tiller to a power tiller was developed. The PTO shaft of the power tiller and the input shaft of the rotary tiller attachment, both splined, are inserted into splined hubs of the driving and driven sprockets (Fig. 2).

Drive elements are enclosed in a sealed oil bath casing for clean and long service operation. The casing is supported by ball bearings and bolted to the power tiller frame. To install, the assembly unit is pushed into position until the two shafts are fully inserted and the retaining bolt tightened.

A dog clutch permits engaging the rotary tiller drive. The clutch shifting ring is actuated by an eccentric provided with a roller to minimize abrasion. The eccentric shaft extends upward to the power tiller handlebar to bring the clutch handle to the operator (Fig. 3).

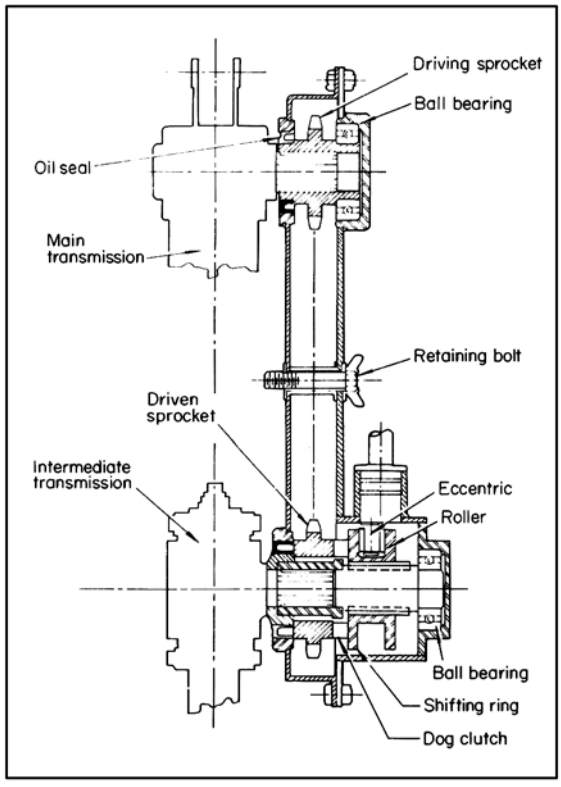
Field testing showed only minor problems, such as misalignment that prematurely wears some parts.

Cable-powered subsoiler for strip tillage. Using a subsoiler for strip tillage at 40-cm depth requires more draft than animal power or 2-wheel tractors can provide. A 4-wheel-drive tractor has enough power but compacts the soil.

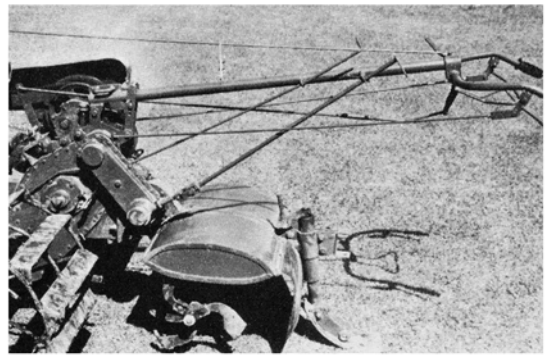
A cable-powered subsoiler was designed and built. Unlike a tractor, this unit converts almost all power input to drawbar power. A 10-hp unit, for example, can pull a 1,000 kg load on wet soil; a 60-hp tractor would slip.

The machine's steel frame supports the engine, transmission gear box, and cable winch (Fig. 4). The frame is supported by four pneumatic wheels, with ball bearings, mounted on fixed axles. A V-belt transmits power to the gear box. An idler pulley mounted on an overcenter pivot serves as clutch.

Flexible coupling connects the output shaft of transmission to input of the winch gear reducer. Transmission has three forwards and one reverse. With engine at 3,000 rpm rated speed, average ground speed is 0.75 km/h in 1st gear, and 1.5 km/h in reverse.



2. Intermediate drive for rotary tiller. IRRI, 1984.



3. Rotary tiller attached to power tiller through intermediate drive. IRRI, 1984.

A 4-bar linkage hitches the implement at the rear. Tillage depth is adjustable.

Steel cables are attached to each half of the winch drum; as the drum rotates, one cable winds and the other unwinds. Figure 5 shows the field layout and machine operation.

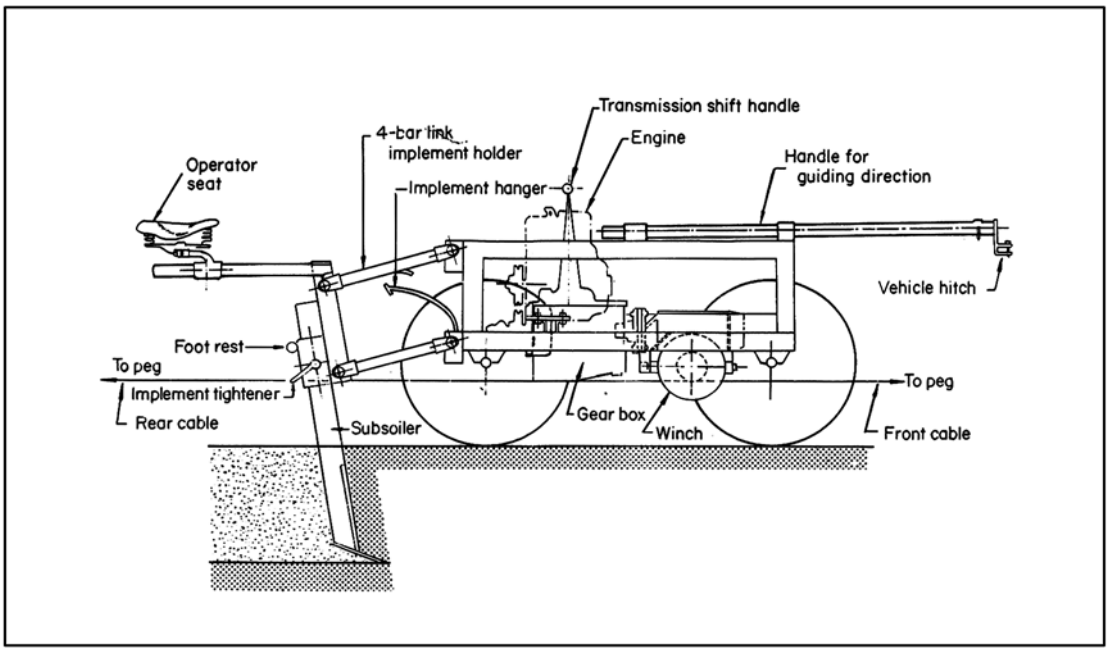
In forward gear, the rotating winch winds the front cable, pulling the machine, and the subsoiler penetrates soil at desired depth, leaving behind a narrow strip with some shattering. To reverse, cables are slipped to the next beam guide, the subsoiler is lifted with the implement hanger, and the reverse gear engaged. Moving the beams and pegs allows full field coverage.

SEEDING AND TRANSPLANTING

Direct seeder for lowland paddies. In 1969-71, Agricultural Engineering developed two seeders for pregerminated paddy. The first six-row seeder had a common hopper with a seed-metering roller with six flutes. Seeds were metered from hoppers to furrows through a distributor pan connected to six long seed tubes. This machine was top-heavy and difficult to operate.

The second seeder had six hoppers, each with a wooden metering roller. Hoppers were mounted on a sheet metal skid, with V-shaped furrow openers under the skid for depositing seeds. A centrally mounted wheel powered the rollers and moved the machine. Philippine companies sold about 300 seeders before discontinuing production.

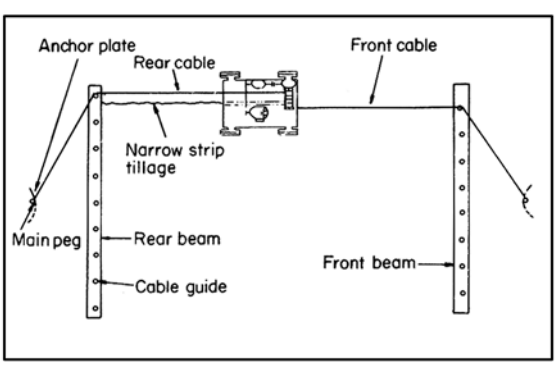
In 1980, a new seeder used six metering rollers with small spikes. Mounted on a single shaft, rollers



4. Cable-powered subsoiler. IRRI, 1984.

were driven directly from two ground wheels, one at each end. The large-diameter wheels supported the machine on soil hardpan. Seeding rate was adjusted by spike protrusion, and spikes helped pull entangled pregerminated seeds out of hoppers, reducing seeding rate variation. This machine, weighing 16 kg, was convenient to operate in fields with 5- to 20-cm deep hardpan, but difficult to pull in deeper hardpan.

The machine could not place seeds properly on uneven hardpan. In deep hardpan, the machine had to be pulled intermittently, dropping seed unevenly.



5. Field layout for cable-powered subsoiler. IRRI, 1984.

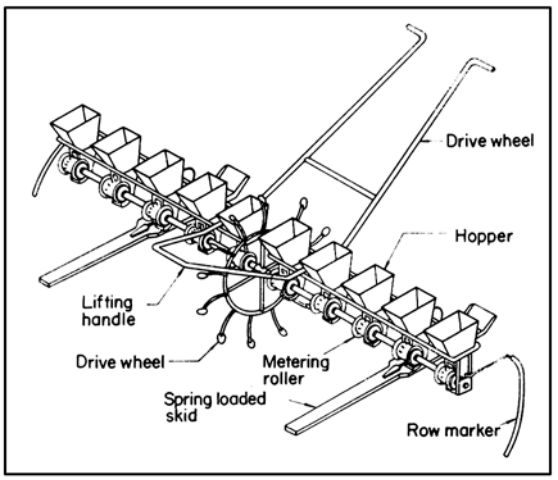
Some seed from two central hoppers dropped into operator's footprints and failed to root.

To overcome these problems, a 10-hopper seeder was designed (Fig. 6). Discharge chutes of middle hoppers are 28 cm apart to prevent seeds from falling into footprints. Spring-loaded skids on each end support the machine on puddled soil, eliminating undulation and irregular movement; seed placement is more precise. A small-diameter wheel drives the metering rollers. The 10-row machine weighs 12 kg and is easier to pull than earlier models. A new handle design allows the operator to walk backward or forward. The centrally mounted drive wheel allows U-turns without lifting the machine.

Rice transplanter adoption. To facilitate rice transplanter adoption, operators were trained in the Philippines, primarily in Bicol and Iloilo. Training covered seedbed and seedling preparation, operation, maintenance and adjustments of machine, and trouble shooting. After training, all transplanters used were purchased by farmers who sent trainees.

The machine design is simple, but fabrication requires precision. To minimize fabrication errors, jigs and fixtures were provided to manufacturers.

To meet farmer requests, an 8-row model (Fig. 7)



6. Ten-row machine for seeding pregerminated paddy on puddled soils. IRRI, 1984.

was designed and released to manufacturers in late 1984.

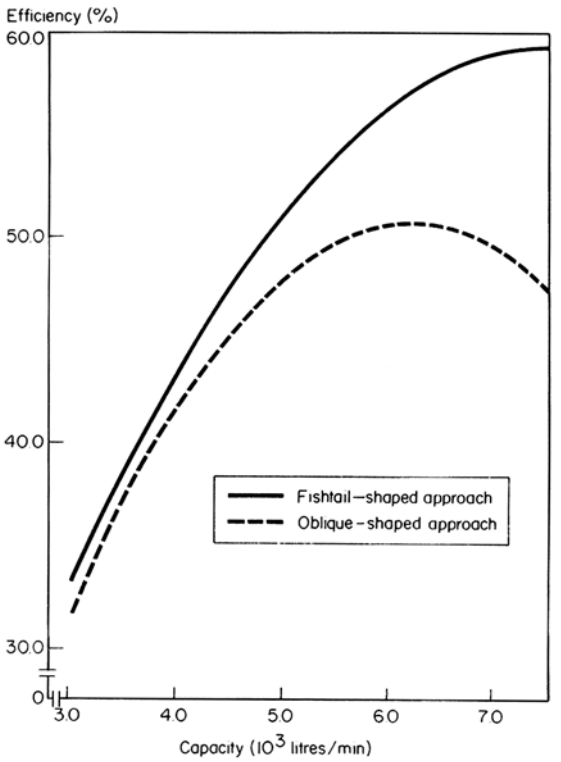
PUMPING

Axial-flow pump. The study on how design parameters affect axial-flow pump performance is complete. Parameters researched include the impeller vane discharge angle, the diffusion vane angle, the clearance between impeller and stator casing, the impeller spacing between stages, and the shape of inlet.

The impeller vane discharge angle directly affects pump capacity (Q) and power input (bhp). Q varies with the vane discharge angle. Consequently, bhp increases as Q increases. Research determined the relationship between Q and the discharge vane angle. At an angle greater than 22.5°, Q can increase, but only by increasing bhp.



7. TR5 8-row rice transplanter. IRRI, 1984.



8. Effect of inlet shape on efficiency of axial-flow pump. IRRI, 1984.

Variations of diffusion vane angle from 40 to 60° have little effect on pump performance. The optimum vane angle is 47°. Straight diffusion vanes, though simple to fabricate, performed poorly.

Clearance between impeller and stator casing relates to losses in Q due to leakage. The Q available at pump discharge is smaller than that passing through the impeller by the amount of leakage. Leakage increases as clearance increases, reducing efficiency. A 4-mm clearance is optimum for a 20-cm diameter impeller. Deflection of the pump shaft reduces efficiency of smaller clearances.

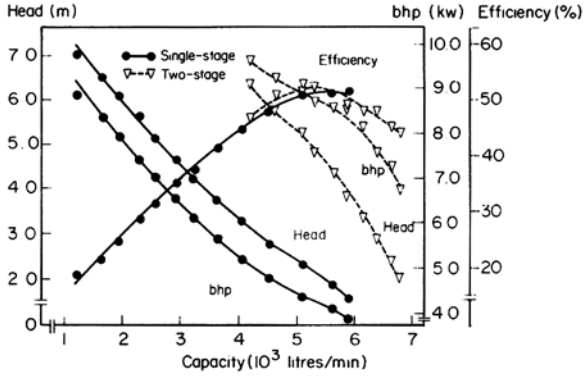
Two shapes of inlet approach were compared: the original oblique shape with a 60° cut across the cylindrical column, and a fishtail shape with a 40-cm radius of curvature at the flared sides. Figure 8 shows efficiency curves of these shapes. The fishtail-shaped inlet had higher peak efficiency at

higher capacity than the oblique-shaped inlet. Its design provides more uniform velocity distribution as water approaches the pump suction, compared to the sharp turn of the oblique-shaped approach.

Spacings of impellers between stages did not significantly affect capacity, but bhp was significantly greater at spacing greater than 150 mm. The interstage leakage was greater as spacing between stages increased.

Costs of single-stage and two-stage pumps were compared at 3 pumping levels: 2.0-m, 2.5-m, and 3.0-m lifts. At 2.0-m lift, the single-stage pump cost less than the two-stage pump up to 40% discount rate. At 2.5-m lift, the two-stage pump was cheaper up to 30% discount rate, but the single-stage had lower cost at 40% discount. The calculated cross-over discount rate was 39.2%. At 3.0-m lift or higher, the two-stage pump was cheaper for lifting water.

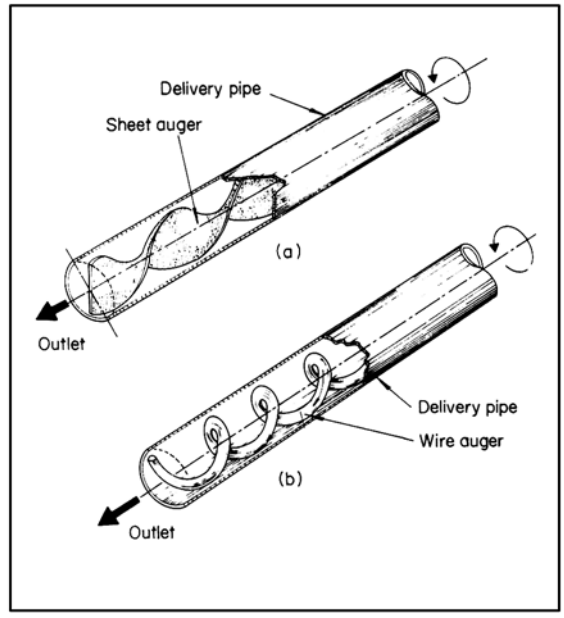
Figure 9 compares the 2 designs. At 2.0-m head, the single-stage pump reached peak efficiency. The two-stage pump reached its peak efficiency at a head twice the optimum for the single-stage pump. At pumping level twice the optimum head, the single-stage pump efficiency dropped almost 10%.



9. Performance of single-stage and two-stage axial-flow pumps at 1800 revolutions/min. IRRI, 1984.

FERTILIZER PLACEMENT

Wire and sheet augers for metering and injection. *Laboratory study.* A laboratory study evaluated the performance of wire and sheet augers (Fig. 10) for horizontal dry metering and vertical injection of prilled urea in flooded soil. A fertilizer metering stand and an injection test stand were fabricated to assess performance under simulated field conditions. Coarse and fine prilled urea (PU) was used. Augers were 19 mm in diameter and 275 mm long.



10. Sheet (a) and wire (b) augers used in fertilizer applicators. IRRI, 1984.

Performance tests of the two augers had these results:

- The wire auger metered and injected more fine and coarse PU than did the sheet auger. The wire auger's hollow core permitted free flow, especially of free-flowing coarse granule fertilizer. Flow was freer when the wire auger was vertical.
- The wire auger metered fertilizer more consistently when horizontal.
- The sheet auger injected fertilizer in puddled soil more precisely when vertical.
- Pitch of both augers had little influence on metering rate with fine PU. With coarse PU, a pitch/diameter (P/D) of 1 for sheet auger and 1.25 for wire auger gave higher delivery.
- The sheet auger gave a fairly consistent injection rate in puddled soils with both fine and coarse fertilizer.
- P/D rate of 1 for sheet auger and 1.5 for wire auger in vertical position gave maximum injection in puddled soil.

Field study. Because metering and injection are independent functions, field testing is not comparable to laboratory testing and results may differ.

A standard 2-row auger fertilizer applicator was used alternately with wire and sheet augers having P/D of 2.38. Augers were tested in soft clay field with 15- to 20-cm-deep hardpan, and 3- to 5-cm-deep floodwater.

Application rates with coarse and fine PU appear in Table 1. With coarse PU, the wire auger varied less in application rate (9.7%) compared to the sheet auger (16%). Variation was largely due to fertilizer size. With either auger, application rate decreased steadily for subsequent replications, perhaps because of upward moisture seepage in the fertilizer tube and progressive wetting of auger tip. More moisture accumulated at delivery opening with greater floodwater depth and longer operation. Granules crushed between auger flights and delivery tube walls stuck to the augers. This may further explain reduced discharge rate in subsequent tests.

Both augers varied more in application rate with fine PU than with coarse PU (Table 1); however, the sheet auger (30.2%) varied less than the wire auger (40.2%). Fine PU is more hygroscopic, which can influence rate.

Application rate for coarse PU was 3.1-3.5 times higher than for fine PU with either auger. With coarse fertilizer, application rate varied more with sheet auger than with wire auger.

Results are inconclusive. Neither auger metered fertilizer precisely. Auger applicators need a separate metering mechanism to maintain uniform application rate when fertilizer of different prill sizes is applied.

Table 1. Application rate of wire and sheet metal augers using coarse and fine PU in a farmer's field, Philippines, 1984.

Hopper	Auger	Coarse PU		Fine PU	
		Application rate[a] (kg N/ha)	CV (%)	Application rate[a] (kg N/ha)	CV (%)
Left	Sheet	117.0	14.5	34.5	20.6
Right	Sheet	110.3	17.6	30.8	40.8
Left	Wire	112.4	10.2	35.2	45.8
Right	Wire	109.9	9.6	35.6	35.8

[a] Av of 12 readings.

Performance summary. The wire auger has an open core, the sheet auger a closed core, affecting performance. Fertilizer in the wire auger core moves because of friction; in the sheet auger, it does so because of flight movement. Generally the wire auger's delivery varies more. Since its central core is not pushed, external factors influence fertilizer movement, such as inclination, resistance at outlet, and friction of fertilizer, which is in turn affected by granule size and moisture.

When the wire auger is horizontal, with unrestricted outlet, the core and periphery generally move together, producing accurate metering. But if it is inclined or vertical, it has less control over core movement — fertilizer in the core will move faster than in the periphery or suddenly drop out because of gravity. This free flow is greater with coarse than with fine fertilizer. This is why, in early testing, wire applicators did not place fertilizer uniformly, and crops grew unevenly.

In sheet augers, the flights push the fertilizer. Maximum push is at the periphery, decreasing toward the core. Some churning at the center reduces delivery. Outlet resistance can change wire auger delivery more than sheet auger delivery because the wire auger's central core moves slower when the outlet is under pressure.

Intakes differ, affecting fertilizer movement. With a wire auger, fertilizer falling through the intake opening can readily fill much of the cavity, moving more fertilizer with a given intake size. With sheet augers, fertilizer falling through the intake opening fills only half the auger cavity. The sheet auger must be rotated at optimum speed to achieve maximum filling. On the other hand, wire thickness blocks slightly more of the intake than does sheet thickness.

For sheet augers to have intake openings large enough for easy flow, openings can be flared, especially at the 3-5 o'clock positions for clockwise rotating augers. Alternatively, offset mounting of the auger in a larger semicircular trough can expose more of it to incoming fertilizer, improving intake.

When operating in puddled soils, the wire auger's open core decreases tip wetting. The sheet auger can pick up more moisture all across the flight tip, partially blocking the opening with sticking fertilizer; however, a central notch at the tip end of the flight of the sheet auger alleviates that.

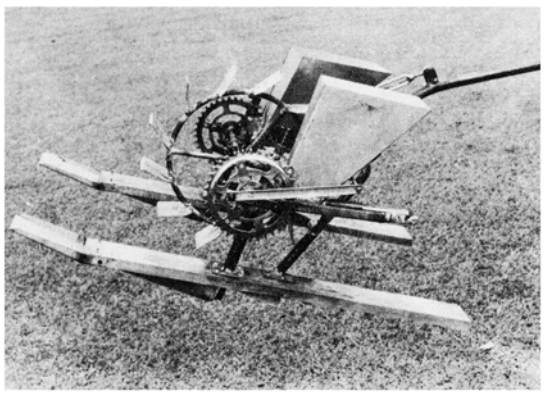
The sheet auger may also lose delivery due to aging, because the sheet may rust, increasing friction. Stainless steel can avoid that.

The plunger-auger fertilizer injector. Based on experience with the spring auger and oscillating plunger applicators for PU, a hybrid machine (Fig. 11) was designed, combining the metering and injecting features of the two machines. The machine uses a plunger for metering and a sheet auger for injecting fertilizer into flooded soils. This 2-row pushed machine can inject and seal PU or ammonium sulfate (AS) 4-5 cm deep in flooded soils without transferring it to floodwater.

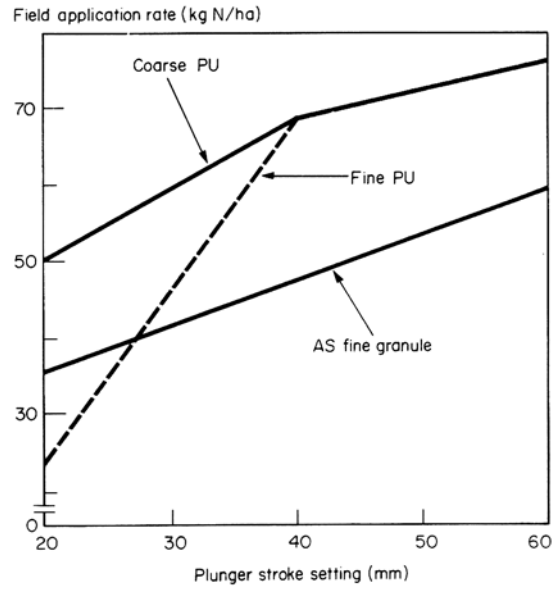
The machine's two hoppers, each with a reciprocating plunger, meter fertilizer at five rates by changing the plunger stroke length. Hoppers have wire agitators to ensure smooth fertilizer flow into the plungers. Metered fertilizer is delivered to two sheet augers housed in fertilizer tubes.

When the machine moves on flooded soils, the skids displace floodwater from the soil surface while the augers inject fertilizer through holes in the skids. Small furrow openers, ahead of fertilizer tubes, open V-shaped furrows to ensure placement 4-5 cm deep. Furrow closures, at the trailing side of fertilizer tubes, push soil back into furrows to seal the fertilizer.

Although the prototype machine performed well, it was heavy, had a complicated design, and did not meter fertilizer consistently. In the new design, the plunger and agitator are driven directly from groundwheel-driven sprockets. Auger and plunger tubes serve as structural members, simplifying the design and reducing machine weight.



11. Two-row plunger-auger applicator for deep placement of PU and ammonium sulfate. IRRI, 1984.



12. Field application rate of plunger-auger applicator with fine and coarse PU and fine AS at plunger stroke settings. IRRI, 1984.

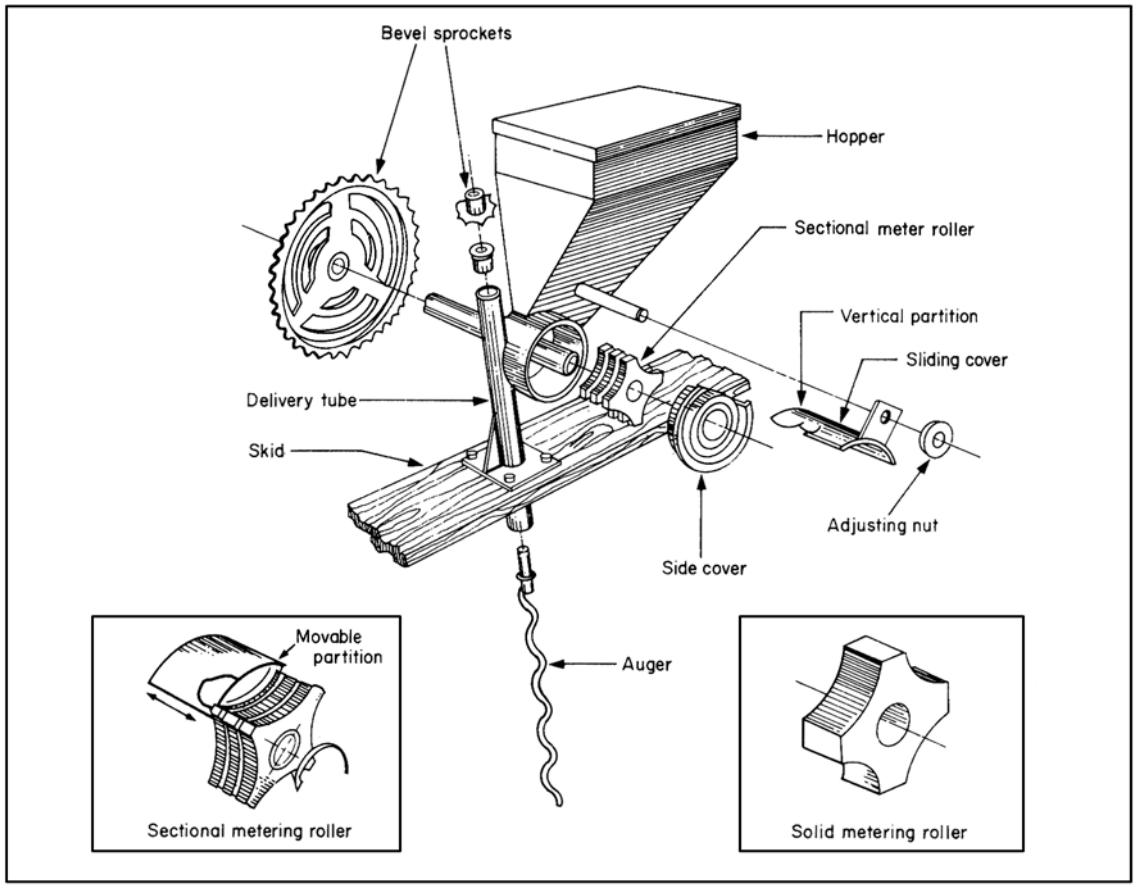
Field calibration tests with fine, medium and coarse urea and AS indicated good metering at the 5 plunger settings, with less than 10% variation.

The machine was released to the Test and Evaluation group to independently verify performance. Based on those tests, stroke length settings of 20, 30, 37, 55, and 70 mm were adapted to provide more realistic farm application rates. Figure 12 gives rates obtained with this machine using PU and AS.

The plunger-auger now successfully met all original design and operating criteria. Extensive farm evaluation will now assess farmer reaction, field and service problems, machine durability, and manufacturing requirements.

Roller auger applicator for prilled urea. The spring auger applicator (Annual report for 1983), tested in many Philippine locations with different fertilizers, has not applied rates consistently. It uses one auger for metering and injection.

To achieve more precise metering, a new applicator uses a roller metering mechanism coupled with a wire auger for injection (Fig. 13). In the



13. Roller auger applicator with rotary metering mechanism. IRRI, 1984.

prototype, a solid fluted groundwheel-driven metering roller was mounted directly on the axle, so that the wire auger coils meshed with the four flutes of the roller to dislodge accumulated fertilizer from the flutes.

Initially, fertilizer rate was adjusted with a sliding cover on the roller; however, that was not effective, especially with free flowing coarse urea. For more accurate metering, designers changed the metering cavity volume rather than the size of the flow opening.

The roller flutes were therefore divided into three sections by cutting grooves on the roller. A moon-shaped vertical baffle, matching the cross section of the flutes, was attached to the end of the sliding gate. This baffle could be positioned in any groove to divide flutes into three size cavities. This change improved the metering rate, but the baffle could only be shifted from one groove to another when the baffle and roller grooves were precisely indexed. Therefore, design improvements continue.

Field testing of deep placement applicators. Deep placement applicators developed at IRRI were tested by Agricultural Engineering, Agronomy, and Training and Technology Transfer Departments.

Results of Agricultural Engineering 1984 dry season (DS) and wet season (WS) tests appear in Table 2. The spring auger PU applicator was tested in farmers' fields in Laguna. In DS, fertilizer use efficiency was higher at the lower applicator rate of 49 kg N/ha (83%) than at 88 kg N/ha (46%). This applicator averaged 66% more fertilizer use efficiency than farmers' application methods in 14 farmer trials. During WS, fertilizer use efficiency increased 48% at 35 kg N/ha in 8 farmer trials.

Agronomy tested the deep placement applicators

Table 2. Yields and fertilizer efficiency with deep placement machines. Philippines, 1983-84.

	Machine used	Av yield (t/ha)		Av increase (%) in fertilizer efficiency of machine deep placement over farmer split	
Agronomy trials[a]		*IRRI*	*Maligaya*	*IRRI*	*Maligaya*
1984 DS					
PU	Spring auger	3.6	6.2	24	76
USG	Press wedge	4.2	5.2	33	38
1984 WS					
PU	Spring auger	3.8	3.9	26	67
USG	Press wedge	4.0	3.8	52	67
Agricultural Engineering trials			*Laguna*		*Laguna*
1983 WS[b]					
PU	Spring auger		4.7		50
USG	Press wedge		4.6		51
1984 DS[c]					
PU	Spring auger		5.2		66
1984 WS[d]					
PU	Spring auger		3.6		48

[a]Av of 4 replications at each site. PU = prilled urea, USG = urea supergranules. [b]Av of 3 replications at 9 farmer locations. [c]Av of 14 farmer trials. [d]Av of 3 replications at 8 farmer locations.

at IRRI and at Maligaya Rice Research and Training Center farms. Results are summarized in Table 2. The yield range was 3.6-6.2 t/ha, using applicators for PU and urea supergranules (USG).

Farmers prefer to machine-apply the first dose and follow with topdressing. Based on farmers' feedback, the machine should apply at least one 50-kg bag of urea per hectare.

Agricultural Engineering is assessing combinations of machine application with topdressing at different stages of plant growth in farmers' fields. Agronomy is continuing testing at IRRI, at Maligaya, and in farmers' fields.

Embedding depth and N transfer to floodwater. Laboratory experiments examined the thickness of soil cover required to adequately seal PU for minimal N transfer to floodwater in Maahas clay. PU was embedded at different depths in puddled soil and the soil later flooded to 5-cm depth. After fertilizer was embedded, floodwater samples were taken for 5 d to assess N transfer to floodwater.

Results show high N transfer at 1 and 2 cm embedding depth. N transfer was substantially reduced at 3-cm depth, and uniformly low when embedded 4-8 cm.

The results indicate that placement depth of 3-4 cm minimizes N transfer to floodwater during deep placement of PU in puddled Maahas clay. This confirms earlier findings.

GRAIN DRYING

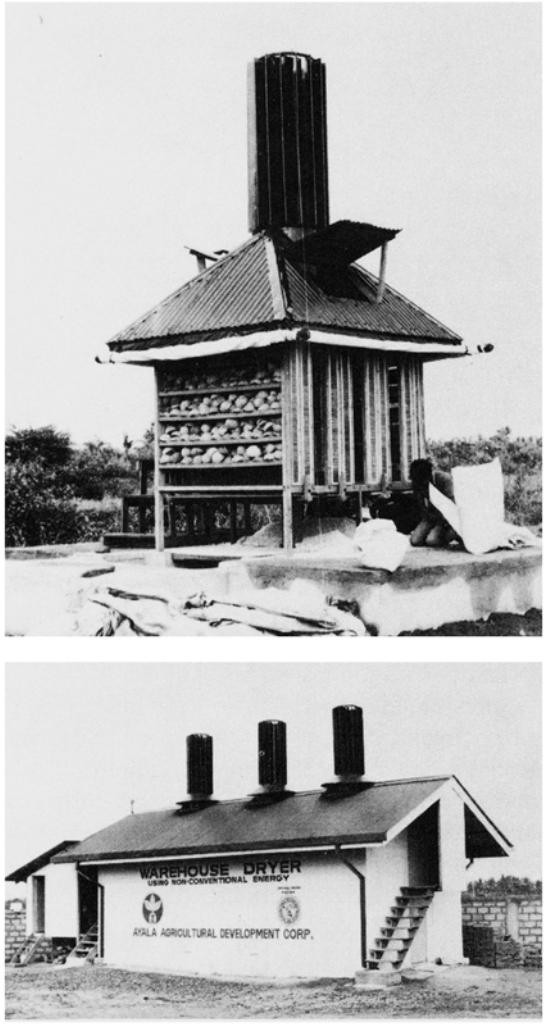
Warehouse dryer design changes. *Drying trays.* The vertical tray design is being improved to further reduce labor required for loading and unloading, to increase tray capacity, and to improve airflow between trays. To reduce construction cost, coconut midribs woven with nylon strings are replacing mesh wire.

Warehouse. Warehouse structures of varying sizes were constructed in Mindanao, Philippines. A tent dryer (Fig. 14) with 2-t capacity was constructed with adjustable canvass enclosure; it can be used with natural air drying. The tent dryer and an 8-t capacity commercial maize dryer will be evaluated under farm conditions.

Furnace. Efficient heating systems are being developed and tested. A direct-fired furnace fueled with rice hull charcoal briquets performed satisfactorily. This simple furnace can be constructed of soil bricks or hardened clay mixed with rice hull ash. Rice hull charcoal provides a low-cost fuel, with heating value comparable to that of coconut shell charcoal.

INDUSTRIAL EXTENSION

Philippines. The Industrial Extension Program in the Philippines continued to work with the Ministry



14. Warehouse dryers constructed in Mindanao, Philippines, 1984.

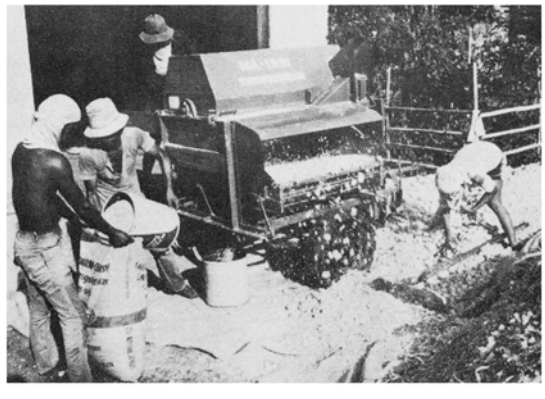
of Agriculture and Food (MAF) to develop and promote small farm equipment. MAF-employed project engineers in 12 regions implement this program. Trained at IRRI and on the job, they demonstrate equipment to farmers and prospective manufacturers, and provide technical assistance on fabrication and operation. The program now has over 250 manufacturers as cooperators.

In 1984, the program promoted the PT5 hand tractor, 1.0-m reaper, seed and fertilizer applicator, transplanter, axial-flow pump, axial-flow thresher, thresher/sheller, *tapak-tapak* pump, and chipping machine.

The thresher/sheller (Fig. 15) aids the national program to increase yellow maize production. Since the IRRI-designed paddy thresher is readily available in many areas, it was modified to shell maize. A removable baffle in the discharge section directs cobs and kernels downward to the oscillating tray cleaner where kernels are separated from cobs. Performance is outstanding in capacity (3.5-5 t/h) and purity (99+%). Two government organizations tested the machine. Small shops can modify the machine at a cost of about $50, thus providing a double-purpose machine at low cost. Six manufacturers helped fabricate the machine and two are marketing it.

The *tapak-tapak* pump (Fig. 16) is a low-cost water pump for small farms not serviced by irrigation systems. The pump design is based on a foot-operated treadle pump developed in Bangladesh by the Rangpur Dinajpur Rehabilitation Service. The pump has three main advantages: 1) it is powered by the legs and body weight rather than arm and back muscles, 2) it can be fabricated in small shops with local tools and materials, and 3) it costs less than $20. The pump was adapted to Philippine conditions and program engineers were trained in fabrication and installation. Farmer acceptance is strong where vegetables are grown during DS after rice harvest. The design has been disseminated to programs in Burma, Egypt, India, Indonesia, Sri Lanka, and Thailand.

The program continued to collaborate with IRRI and MAF on field tests of the rolling injection planter (RIP). A MAF regional office purchased 100 units for on-farm evaluation. IRRI provided technical assistance to local manufacturers. Field



15. Thresher/sheller adapted for maize. IRRI, 1984.



16. *Tapak-tapak* pump. IRRI, 1984.

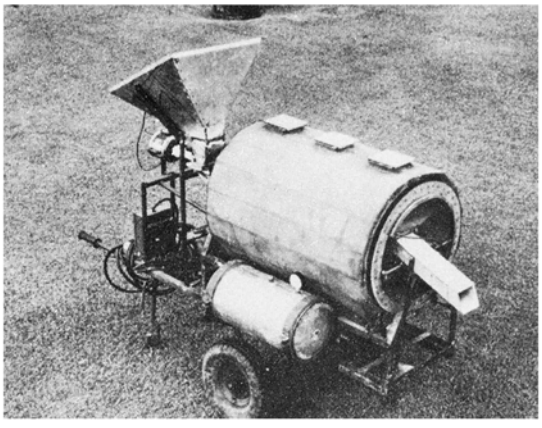
tests show the RIP enables better crop establishment than farmers' practice for upland crops planted after rice.

The program has been developing a paddy dryer for WS use. A prototype rotary drum dryer was designed, fabricated, and tested at IRRI (Fig. 17). The dryer should be able to quickly reduce moisture content of freshly harvested paddy to a level suitable for safe storage (18% moisture content) until weather permits sundrying. The dryer must be low cost, have simple and compact design, and be able to use rice hull as fuel. Testing will be completed in 1985.

Burma. Tillage implements and animal-drawn implements have been developed, including two types of plowshares fitted with replaceable shares.

A lightweight, sturdy ox cart was developed, for drawing by one animal.

Hand weeders were developed and 1,000 modified Dutch hoes ordered.



17. Rotary drum paddy dryer for wet season use. IRRI, 1984.

Wooden multicrop seeders are being tested. Research is under way on a seeder for zero tillage.

High-capacity, low-lift pumps are greatly needed; 10- and 12-inch pumps are being tested.

Indonesia. In cooperation with the International Labor Organization, a study "Diffusion and Commercialization of Rice Postharvest Equipment" was conducted in West Sumatra. Although threshers are increasing in use, major constraints are lack of credit for farmers and lack of investment capital for manufacturers. A 30-min video tape (Indonesian language) was developed to improve extension efforts.

Thailand. The inclined-plate planter, cyclone seeder, RIP, transplanter, direct paddy seeder, improved buffalo plow, hand jab planter, and reaper were widely demonstrated and introduced in the northeast region. An improved plow was tested in farmers' fields and introduced. Although northeast farmers like the improved implements, they are poor and adoption is slow.

India. In the first full year of operation, equipment was procured.

A reaper was fabricated by a local manufacturer and is being tested.

A transplanter is greatly needed in the Coimbatore area. Threshers and transplanters will be fabricated locally and tested.

Associated training programs

IRRI's educational and training programs are designed to help developing countries create a cadre of well-trained and highly motivated scientists working on rice and rice-based cropping systems programs. The criteria for selection of participants in these programs are described in *Brief Information on Research and Training Fellowship Programs of IRRI*, available at the Office of the Director for Research and Training.

IRRI'S TRAINING AND EDUCATIONAL PROGRAMS

	No. of participants in 1984
Research oriented programs	
• Postdoctoral and senior research fellowships, visiting research fellowships	71
• Degree (MS and Ph D) scholarships	180
• Nondegree scholarships	33
Nondegree short-term training programs	
• Agricultural Engineering (Ag. Eng'g.)	
28 May-15 Jun	18
19 Nov-7 Dec	13
• Farming Systems Socioeconomics Research Training (FSSR) 15 Oct-14 Dec	26
• Cropping Systems Training Program (CSTP) 6 Feb-15 Jun	28
• Genetic Evaluation and Utilization (GEU) 6 Feb-26 May	20
• Integrated Pest Management (IPM) 23 Jul-20 Nov	21
• Irrigation Water Management (IWM) 13 Aug-21 Sep	23
• International Network on Soil Fertility and Fertilizer Evaluation in Rice (INSFFER) 6 Feb-26 May	26
• Rice Production Training Program (RPTP) 23 Jul-14 Dec	17
• Upland Rice Training Course (URTC) 23 Jul-9 Nov	18
Special courses	
• Farm Managers Course (FMC) 9-26 Jul	1
Cropping Systems (CS)	
• Varietal Improvement of Upland Crops 5 Nov 1984-1 Mar 1985	3
• Insect Pest Management 5 Nov-7 Dec 9 Dec-4 Jan	4
• Plant Disease Management 29 Oct-28 Dec	2
• Preproduction Practices 29 Oct-28 Dec	3
• Pest Management for Deep Water Rice (DWR) Thailand, 8-19 Oct	10
Total	517

The distribution of scholars and fellows by training programs and by country is shown in Tables 1 and 2.

COLLABORATIVE GRADUATE EDUCATION PROGRAMS

IRRI has collaborative graduate degree (MS and Ph D) education programs with 22 universities. Under those programs, the students complete their course work at these universities but come to IRRI to conduct thesis research. The university grants the degree.

Cairo University, Egypt
University of Calabar, Nigeria
University of Dar-es-Salaam, Tanzania
Bangladesh Agricultural University, Bangladesh
University of the Philippines at Los Baños, Philippines
Central Luzon State University, Philippines
Visayas State College of Agriculture, Philippines
University of Cantho, Socialist Republic of Vietnam
Indian Agricultural Research Institute, India
Universiti Pertanian Malaysia, Malaysia
Institut Pertanian Bogor, Indonesia
Post-Graduate Institute of Agriculture, Sri Lanka
Kasetsart University, Thailand
Asian Institute of Technology, Thailand
Justus Liebig Universitat Giessen, West Germany
Agricultural University of Wageningen, The Netherlands
University of Gent (RUG), Belgium
Catholic University of Leuven (FLKU), Belgium
Cornell University, USA
University of California Davis, USA
University of Florida, USA
Utah State University, USA

Table 1. Total number of scholars and fellows in degree programs, by country, 1984.

Country	Senior research fellow	Post-doctoral fellow	Visiting research fellow	Research scholar (MS)	Research fellow (Ph D)	Nondegree
Australia	–	–	–	1	–	–
Bangladesh	–	–	–	26	11	4
Belgium	–	–	–	–	2	–
Brazil	–	–	–	2	–	–
Burma	–	–	–	6	–	–
Chile	–	–	–	1	–	–
China	–	5	16	19	3	8
Colombia	–	–	–	1	–	–
Cuba	–	–	–	–	–	2
Ecuador	–	–	–	1	–	–
Egypt	–	2	–	–	1	–
France	–	1	–	–	–	–
Gambia	–	–	–	1	–	–
Ghana	–	1	–	1	–	–
Guyana	–	–	–	1	–	–
India	9	19	–	1	5	–
Indonesia	–	–	–	1	3	5
Japan	–	3	–	2	2	–
Kenya	–	–	–	–	–	2
Mexico	–	–	–	2	–	–
Nepal	1	–	–	4	3	–
Netherlands	–	–	–	3	–	–
Nigeria	–	–	–	–	1	–
Pakistan	1	1	–	8	5	–
Peru	–	–	–	1	1	–
Philippines	2	6	–	6	7	4
Sierra Leone	–	–	–	–	1	–
Somalia	–	–	–	–	–	1
South Korea	–	2	–	1	11	–
Sri Lanka	–	–	–	5	1	–
Taiwan	–	–	–	–	–	1
Tanzania	–	–	–	3	–	–
Thailand	–	1	–	8	7	–
United Kingdom	–	1	–	–	–	2
United States	–	–	–	–	5	2
Vietnam	–	–	–	2	–	2
West Germany	–	–	–	–	4	–
Total	13	42	16	107	73	33

SPECIAL COURSES FOR SENIOR OFFICIALS

In response to requests of international funding agencies and national organizations for research and development, IRRI offers training and orientation courses for senior officials to acquaint them with overall production processes and how these influence national programs and policies. A program for officers of the Indian Ministry of Agriculture was held on 21 to 25 May 1984, with participants from Assam, Bengal, Bihar, Madhya Pradesh, Orissa, and Uttar Pradesh. From 18 Jun to 7 Jul 1984, 10 senior officials of West African countries took this course at IRRI.

ASSISTANCE TO NATIONAL PROGRAMS

IRRI helps national programs to package and present training courses. In 1984, training specialists of IRRI visited Bhutan and India to help develop and offer 2-wk rice production courses.

SYMPOSIUM ON EDUCATION FOR AGRICULTURE

The Institute, in collaboration with the Committee on Science and Technology in Developing Countries (COSTED) and the Asian Association of Agricultural Colleges and Universities (AAACU) sponsored the Symposium on Education for Agri-

Table 2. Participants in nondegree training programs, by country, IRRI, 1984.

Country	Regular course										Special course			Total
	GEU	INSFFER	CSTP	Ag. Eng'g I	Ag. Eng'g II	URTC	IPM	RPTP	IWM	FSSR	FMC	DWR	CS	
Bangladesh	–	2	6	–	–	–	–	–	5	4	–	1	–	18
Bhutan	–	–	–	1	–	–	–	–	1	1	–	–	–	3
Burma	4	2	2	–	–	1	1	1	–	–	–	–	–	11
China	4	5	2	–	–	–	2	–	–	2	–	–	–	15
Ethiopia	–	–	–	–	–	–	–	2	–	–	–	–	–	2
Ghana	–	–	–	1	–	–	–	–	–	–	–	–	–	1
India	3	4	–	3	–	4	2	5	4	2	–	2	–	29
Indonesia	–	1	–	1	1	3	1	–	–	3	–	2	3	15
Iran	2	–	–	–	–	–	–	–	1	–	–	–	–	3
Jamaica	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Japan	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Kenya	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Korea	–	–	1	–	–	–	1	–	–	–	–	–	–	2
Malaysia	1	1	1	–	–	1	3	–	–	1	–	–	–	8
Nepal	–	1	2	–	–	2	1	1	–	1	–	–	–	8
Nigeria	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Pakistan	–	–	–	–	–	–	1	–	–	1	–	–	–	2
Philippines	–	2	6	5	4	3	3	1	5	5	–	–	4	38
Sierra Leone	1	–	–	–	–	–	–	–	1	1	–	–	–	2
Sri Lanka	2	2	3	4	5	–	2	3	4	2	–	–	3	30
Tanzania	–	–	–	–	–	–	1	1	1	–	–	–	–	3
Thailand	2	2	4	2	2	2	2	1	2	2	1	5	2	29
Vietnam	–	3	1	1	1	1	1	1	–	1	–	–	–	10
Total	20	26	28	18	13	18	21	17	23	26	1	10	12	233

culture from 12 to 16 Nov 1984. The 36 participants from 17 countries included vice chancellors and presidents of agricultural colleges and universities, and representatives of ministries of agriculture and educational agribusiness sectors, international agencies supporting training programs, and farmer organizations. Participants gave recommendations on how international and national agricultural research centers can collaborate with agricultural universities in offering nondegree training programs and meeting the quality and quantity of agricultural manpower requirements of government, the private sector, and universities. The applications of computer technology to teaching methods and management of training programs was also discussed. Printed proceedings will be released May 1985.

NEW COURSES IN 1985

The Academic Council met on 28 Feb and 2 Aug 1984 and approved these courses for 1985:

- *Statistical procedures and computer applications in agricultural research.* This 2-mo course to be offered on 4 Feb to 5 Apr 1985 will familiarize statisticians at national research centers with new statistical procedures and research techniques and their application to agricultural research. It covers the use of microcomputers in agricultural research.
- *Rice genetic resources conservation and utilization.* In this 1-yr diploma associateship course, participants first spend 3 mo collecting germplasm in fields in their home country. At IRRI, lectures cover the academic and operational aspects of genetic conservation, and field and laboratory work to characterize the collection. The course will be offered from Oct 1985 to Sep 1986. It includes GEU course participation.
- *Systems analysis and simulation in rice production and its use in research and technology transfer.* This course provides knowledge and practical experience on the application and adaptation of simulation models related to

research and extension in national programs. It covers a) preparation and study of course material and data collection in home countries, b) 8 wk of lectures and exercises on systems analysis and simulation at the University of Wageningen, The Netherlands, c) 9 mo in home country to apply gained skills, and d) a 2-wk workshop at IRRI to evaluate participant progress in applying techniques. The course will be offered Sep 1985 to Jan 1987.

- *Improving the income and employment potential of rice farming systems.* This 10-d course for senior research scientists, administrators, and planners will familiarize them with concepts and research findings on production technology to reduce cost and maximize profit, crop-livestock and crop-fish integration, rice biomass utilization for increased employment and income generation, and project design and implementation. First offering is on 21-30 Jan 1985.
- *Agricultural communications.* The 4-mo course covers technical writing, editing, and publications production. Participants will bring home-country material for producing a 16-page publication. First offering is on 5 Aug 1985.

INSTRUCTION RESOURCE DEVELOPMENT

The Training and Technology Transfer Department helps units document the content, practical exercises, and special research topics in each course. Based on written materials, autotutorial modules are being prepared to facilitate self-learning.

The Department has prepared training manuals in Integrated Pest Management and Upland Rice Training. A total of 63 training modules on rice production have been prepared.

SCHOLARS AND FELLOWS WHO COMPLETED TRAINING IN 1984

An asterisk (*) indicates completion of the MS degree and two asterisks (**), the Ph D degree.

RESEARCH SCHOLARS

Agricultural Economics

Ian Coxhead.* Australia. The economics of wet weeding: inducements to and consequences of some recent changes in Philippine rice cultivation.

Roxanne Nacario.* Philippines. Measuring income distribution in changing village economies.

Agricultural Engineering

Md. Muzzamil Haq.* Bangladesh. Performance study of three types of animal-drawn plows.

Zahid Mahmood.* Pakistan. Analysis of augers for metering prilled urea and for injecting it in flooded soil.

Somporn Saitan.* Thailand. The effect of tractor use on the structure of income and income distribution on small rice farms: a case study of Suphanburi Province, Thailand.

Agronomy

E. M. Balasubramanian.* Sri Lanka. Nitrogen fertilizer management and weed control methods in rainfed lowland and upland rice.

B. M. S. Basnet.* Nepal. Chemical manipulation of seed and seedlings for increasing grain yield in transplanted rice.

Rachmatia Thahir Muda.* Indonesia. Interaction between potassium and zinc in lowland rice.

K. K. Shrestha.* Nepal. Effects of tillage intercropping and plant density on yields and weed growth in maize and upland rice-based cropping patterns.

Tin Maung Soe.* Burma. Increasing efficiency of fertilizer nitrogen by manipulating time and method of fertilizer application and water management in lowland rice.

Cereal Chemistry

Aminul Kabir Khander.* Bangladesh. Effect of moisture and temperature during extrusion on the quality of rice noodles.

Entomology

Quazi Mohammad A. Razzaque.* Bangladesh. Resistance of *Oryza* species to rice green leafhoppers, *N. nigropictus* (Stal) and *N. virescens* Distant.

International Rice Germplasm Center

Sheng-Xiang Tang.* China. Flowering response of rice cultivars to photoperiod and temperature.

International Rice Testing Program

Alicia Rocha.* Peru. Effect of hot water treatments on the quality of rice seeds (*Oryza sativa*).

Multiple Cropping

S. Samarakoon.* Sri Lanka. The effects of paddy soil surface channelling on performance of mungbean.

Plant Breeding

A. W. Julfiquar.* Bangladesh. Genetic divergence among some maintainer and restorer lines in relation to hybrid breeding in rice (*O. sativa* L.).

Anwarul Kabir.* Bangladesh. Inheritance of resistance to brown planthopper in some rice varieties.

U Hla Min.* Burma. Genetics of resistance to bacterial blight in some rice varieties.

Khin Than Nwe.* Burma. Behavior of photoperiod sensitivity in three rice crosses.

T. Rajapakse.* Sri Lanka. Inheritance of resistance to bacterial blight in some rice varieties.

R. Srilingam.* Sri Lanka. Inheritance of resistance to blast in some rice varieties.

Plant Pathology

Khamiso Khan Baloch.* Pakistan. Seedling and adult plant resistance to brown spot.

Aung Baw.* Burma. Assessment of disease scoring systems to evaluate varietal resistance to rice bacterial blight.

Zhu Ze Da.* China. Production and properties of *Xanthomonas campestris* pv. *oryzicola* bacteriocin and its biological activity.

May May Khin.* Burma. Virulence analysis of *Pyricularia oryzae*.

Plant Physiology

Keelita Jayaweera.* Sri Lanka. Effects of salinity on submergence tolerance of rice.

Amara Wiengweera.* Thailand. Effect of seedling age on the grain yield of rice cultivars at different light intensities.

Rice Farming Systems

S. M. Rezaul Karim.* Bangladesh. Performance of selected cowpea *Vigna unguiculata* (L.) Walp varieties on triple purpose crops.

Soil Chemistry

Gamani Jayaweera.* Sri Lanka. Influence of salinization and pre-drying on the chemical kinetics of two coastal peat soils and the growth of rice.

Statistics

Jin Zhiqing.* China. Assessing climatic suitability for rice production in China.

RESEARCH FELLOWS

Agricultural Economics

Pervaiz Amir.** Pakistan. Technical relation and resource productivity in rice-based cropping systems in the Punjab Province.

Carol Ferguson.** USA. Returns to irrigation intensification in Philippine Gravity System.

Sagrario Floro.** Philippines. The structure of informal credit market in Philippine agriculture.

Roberto Rañola.** Philippines. Cropping systems and determinants: factors influencing cropping patterns, productivity and fertilizer use.

Chaudhri Serwar.** Pakistan. Impact of technical change on employment and income distribution in the Pakistani rice sector.

Chung Hyuk Suh.** Korea. An analysis of farming household labor use and cropping systems with special reference to farm mechanization in South Korea: their interrelationships.

Kiatichai Vesdapunt.** Thailand. Thailand rice policy model: a simulation analysis.

Vute Wangwacharakul.** Thailand. Effect and indirect impact of new CS on a community economy: the case of Oton and Tigbauan municipalities, Iloilo, Philippines.

Agricultural Engineering

Zahid Abutaher.** Bangladesh. Simulation of climatic risk minimization investment: an application to rice drying system design and management.

Patricia Boyland.** USA. Measuring effects of mechanized tillage in Indonesia, the Philippines, and Thailand.

Irrigation Water Management

Simeon Ogunwale.** Nigeria. Constraints to effective communal irrigation in Bicol, Camarines Sur.

Alfredo Valera.** Philippines. Comparison of management and performance of three intensities of irrigation system management.

Plant Breeding

Tae Sook Kwak.** Korea. Classification of varietal resistance to rice blast.

A. K. Saha.** Bangladesh. Genetic analysis of resistance to Philippine pathotypes of bacterial blight in some rice varieties.

Cesar Flores Ventura.** Peru. Effect of biparental mating on linkage relationship in rice (*O. sativa* L.).

Plant Physiology

Philippe Koole.** Belgium. The effects of calcium peroxide on the field emergence of soybeans.

NONDEGREE SCHOLARS AND FELLOWS

Agricultural Engineering

Ajay Markanday. United Kingdom. Analysis of data from consequences of small mechanization project.

Dermot Shields. United Kingdom. Summary report for Thailand: consequences of small rice farm mechanization project.

Agronomy

Sun Siu-Ting. China. Fate and efficiency of nitrogen fertilizer in wetland rice soil.

Communication and Publications

Winifred Oyuko. Kenya. Graphics design and production.

Entomology

Zhang-Zhi Tao. China. Resistance of *O. sativa* and selected wild rice species to brown planthopper, *N. lugens.*

International Rice Germplasm Center

Rashid Anwar. Bangladesh. Management of gene bank.

Nguyen Thai Son. Vietnam. Rice seed production and quality control.

Nguyen Ngoc Trang. Vietnam. Rice seed production and quality control.

Cun-Shan Ying. China. Management of gene bank.

Plant Breeding

Sudiaty Silitonga. Indonesia. On-the-job training in hybrid rice.

Plant Pathology

Abdalla Ahmed Mohamed. Somalia. General research on bacterial fungal aero/virus rice diseases.

Nunung Achmad. Indonesia. Comparative effectiveness of five isolates of *Trichoderma* spp. on damping-off of mungbean caused by *Rhizoctonia solani* Kuhn and *Sclerotium rolfsii* Sacc.

V. Vingnanakulasingham. Sri Lanka. Survey and grouping of mycorrhizae in the rice-based cropping systems site.

Wan Hae Yeh. Korea. Partial resistance to blast.

Wei Da Wei. China. (1) Rice sheath blight and similar disease caused by *Rhizoctonia* spp. (2) The pathogens from two types of lesion of rice sheath blight and their distribution.

Plant Physiology

Ling Ding Hou. China. Use of cell and tissue culture in developing disease-resistant varieties of rice.

Soil Chemistry

Aminata Niane. Senegal. Response of rice to nitrogen application on a saline soil.

Hiroko Yamauchi. Japan. Effects of excess silica on clay minerals.

Statistics

Maria Amador Gene. Cuba. Statistical procedures and computer applications for plant breeding research.

Nurul Islam. Bangladesh. Application of statistical procedures in an agricultural research institution.

Hazrat Ali Mondal. Bangladesh. Application of statistical procedures in an agricultural research institution.

Rafiqul Quader. Bangladesh. Application of statistical procedures in an agricultural research institution.

VISITING RESEARCH/POSTDOCTORAL AND SENIOR RESEARCH FELLOWS

Agricultural Engineering

Yong Woon Jeon. Korea. Evaluation of a multi-

purpose dryer using non-conventional energy sources.

T. Pongsrikul. Thailand. (1) An ex ante evaluation of small rice farm mechanization policies in Thailand. (2) Impacts of small farm mechanization on Indonesia rice economy: a simulation analysis. (3) An evaluation of agricultural policies in Thailand.

Banshi D. Shukla. India. Parboiling of paddy with heated sand.

Agronomy

Chen Rong Ye. China. ^{15}N balance at different water depths in wetland rice; estimates of ammonia volatilization loss from wetland rice field as affected by nitrogen and water management.

S. Sankaran. India. Herbicide-moisture relationship in upland and direct-seeded flooded rice.

M. Thangaraj. India. (1) Response of rice roots to water stress. (2) Effect of water stress during post-anthesis stage in rice.

Cereal Chemistry

Lou Yukun. China. Quality assessment of Chinese rice.

International Rice Germplasm Center

Jean Christopher Glaszmann. France. A varietal classification of Asian cultivated rice (*Oryza sativa* L.) based on isozyme polymorphism.

Plant Breeding

Muhammad Akbar. Pakistan. Inheritance of salinity tolerance in rice.

B. B. Shahi. Nepal. Breeding for cold tolerance.

Bambang Suprihatno. Indonesia. On-the-job training in hybrid rice.

Yuan Long Ping. China. Developing a manual for hybrid rice training course.

Plant Pathology

S. M. Haroon Usmani. Pakistan. Establishment of *Trichoderma* on rice and on grain legumes after rice in the field.

Plant Physiology

J. S. Chauhan. India. (1) Ratoon tiller development in IR44. (2) Evaluation of hybrid rice for ratooning ability. (3) Genetic analysis of rice ratooning.

M. Yamauchi. Japan. Physiology of hybrid rice.

Zhang Zhen Hua. China. Genetics of resistance to bacterial blight in rice and anther culture.

Soil Chemistry

Li Jin Pei. China. Amelioration of an acid sulfate soil in the Philippines.

Statistics

Satyabrata Pal. India. Evaluation of experimental designs for rice field experiments.

LIST OF TRAINEES
1984

CROPPING SYSTEMS TRAINING PROGRAM
(26 Sep 1983-3 Feb 1984)

Bangladesh

1. Mukhlesur Rahman Ahmed
2. Md. Hazrat Ali
3. Md. Usman Ghani
4. A. B. M. Nurul Imam
5. Md. Badirul Islam

Bhutan

1. Pirthiman Pradhan

Burma

1. U Kyaw Sein
2. U Mauk Nyunt

China

1. Lu Zheng Qing
2. Jin Qing Zhu

India

1. Rajib Lochan Nayak
2. Abdul Rafey
3. Mohinder Singh Sidhu
4. K. K. Subbiah

Indonesia

1. Gunardi
2. Haryanto Hardiwikarta

Korea

1. Si Chool Noh

Pakistan
1. Nazir Ahmad Sidhu

Philippines
1. Adelaida L. Aguinaldo
2. Marlene C. Cubero
3. Flora D. Gagni
4. Danilo C. Rodriguez
5. Artemio P. Sagun

Sri Lanka
1. W. D. Atukorala
2. G. D. S. W. Gamini
3. A. M. H. Patham Piyasena
4. Saravanamuttu Sinnathurai
5. Nallathamby Sivayogarajah
6. P. G. Thurairatnam

Thailand
1. Husachai Pramote
2. Manat Leechawengwongs
3. Pannee Poramarapornkard
4. Yongyut Suvanarerk

CROPPING SYSTEMS TRAINING PROGRAM
(6 Feb-15 Jun 1984)

Bangladesh
1. Ahamed Ali
2. Motiur Reza Choudhury
3. Satish Chandra Dham
4. A. F. M. Dazlur Rahman
5. Md. Abdur Rahman Mondal
6. Md. Abdus Sabur

Burma
1. U Kyi Aung
2. U Tint Lwin

China
1. Zheng Jianchu
2. Cao Yu

Korea
1. Woo Gun Lee

Malaysia
1. Mohamad Bin Ismail

Nepal
1. Durga Nand Chaudhary
2. Babu Ram Pathak

Philippines
1. Pio Adan A. Cenas
2. Emilio M. de la Cruz
3. Ismael S. Fronda
4. Rodolfo C. Gallardo
5. Jose O. Penuela
6. Danilo B. Tumamao

Sri Lanka
1. W. W. S. R. M. R. Ananda
2. K. M. C. Bandara
3. Hewadewage Sunil Kumara

Thailand
1. Pacharee Niamrichand
2. Prasong Wongchanapai
3. Sutjarit Niyomdej
4. Poom Yungyuenyong

Vietnam
1. Doung Van Chin

AGRICULTURAL ENGINEERING I
(28 May-15 Jun 1984)

Austria
1. Alois Bertsch

Bhutan
1. Lhaba Dorji

Ghana
1. Daniel K. Cheku

India
1. Ramaswami Aravindhan
2. Annamalai Shanmugham
3. S. S. Tomar

Indonesia
1. Asparmin Junus
2. Prastowo B. Ramelan
3. Dahlan Wiwoho

Philippines
1. Jessie Abrigo

2. Quirino de Sagun
3. Bonifacio A. Cabahug
4. Henrico C. Icatlo
5. Josephus C. Tarranza
6. Renato Bacalocos
7. Jose Beduya
8. Reynaldo Malibiran
9. Rodrigo Trio

Sri Lanka
1. H. A. Abeyaratne
2. A. Amirthanesan
3. Patikiri Jothipala
4. M. D. Ratnepala
5. Philip Samarasinghe
6. S. G. J. Senewiratne
7. K. H. Steinmann
8. P. Velauthapillai

Thailand
1. Wisuthi Amaritshui
2. Kanoksak Eam-o-pas
3. Sutin Sakranukit

Vietnam
1. Phan Dinh Lan
2. Nguyen Minh

AGRICULTURAL ENGINEERING II
(19 Nov-7 Dec 1984)

Indonesia
1. Dahlan Wiwoho

Philippines
1. Bonifacio A. Cabahug
2. Quirino P. De Sagun
3. Henrico C. Icatlo
4. Josephus C. Tarranza

Sri Lanka
1. Abeyaratne H. A. Abeyaratne
2. Jon Bickel
3. Surendra Joseph Senewiratne
4. Karl Heinz Steinman
5. Ponniah Velauthapillai

Thailand
1. Wisuthi Amaritsu
2. Suvit Therdteppitak

Vietnam
1. Nguyen Minh

IRRIGATION WATER MANAGEMENT TRAINING
(13 Aug-21 Sep 1984)

Bangladesh
1. Md. Ali Akbar
2. Hamidur Rahman Molla
3. K. M. Shahidullah
4. Md. Yeasin Ali
5. Md. Abul Kashem Khan

Bhutan
1. Ugyen Galay

India
1. Palaniappan Kandaswamy
2. Krishan Lal Khera
3. R. K. Kulandaivelu
4. Purna Chandra Mohapatra

Iran
1. Jafar Babapur Golafshany

Philippines
1. Benjamin F. Bayani
2. Protacio C. dela Cruz
3. Adolfo V. Encila, Jr.
4. Emilio C. Gacal, Jr.
5. Ricardo V. Joson

Sri Lanka
1. Rajindra de Silva Ariyabandu
2. Malgaha Gamage Dhanapala
3. Sarange Dona Rani Wanniarachchi
4. Piven Sentriga Wijesuriya

Tanzania
1. Christopher Ntarebala

Thailand
1. Wutthikrai Smitthimadhindra
2. Santi Tongpumnuk

FARMING SYSTEMS SOCIOECONOMICS RESEARCH TRAINING
(15 Oct-14 Dec 1984)

Bangladesh
1. Md. Rezaul Karim
2. Muhammad Nurun Nabi
3. Md. Eusuf Harun
4. Wasefa Akhter Zahan

Bhutan
1. Nim Dorji

India
1. Mruthyunjaya
2. S. D. Suryawanshi

Indonesia
1. Muhammad Nadjib Noor
2. Bambang Rahmanto
3. Ketut Tastra

Malaysia
1. Abdul Halim Bin Hamat

Nepal
1. Yam Prasad Gautam

Pakistan
1. Muhammad Yusuf

Philippines
1. Yolanda S. Fajardo
2. Fe Maderal Llanes
3. Mira M. Mayo
4. Filomena A. Ronduen
5. Vivencio C. Tabulina

Sierra Leone
1. Patrick Kormawa

Sri Lanka
1. P. Mallawaarachchi
2. Gunasena Wijewardana

Vietnam
1. Bui Ba Bong

GENETIC EVALUATION AND UTILIZATION
(6 Feb-26 May 1984)

Burma
1. Daw Cho Cho Maung
2. U Khin Maung Nyunt
3. Daw Nyunt Nyunt Sein
4. Daw Tin Win

China
1. Li Chuanguo
2. He Guangcun
3. Zheng Jin Gui
4. Lai Xiao Ming

India
1. Rabindra Nath De
2. Fasih Uz Zaman

Jamaica
1. Maurice Malcolm Russell

Malaysia
1. Tengku Nazri T. Zainal

Sri Lanka
1. Don Pium Pandukabaya Jayakody
2. Ranjith Sumanadasa

Thailand
1. Chaiyanam Dissataporn
2. Sommai Seewisut

RICE PRODUCTION TRAINING PROGRAM
(23 Jul-14 Dec 1984)

Burma
1. U Saw Ngwe Gaing

Ethiopia
1. Adugna Kefeni
2. Tesfagiorgis G. Kristos

India
1. Ashoke Kumar Bondyopadhyay
2. K. Maharudrappa
3. Sunirmal Maiti
4. Nirupam Majumdar
5. Rudraraju Appala Raju

Japan
1. Yoichiro Umeki

Nepal
1. Jageshwar Lal Das

Philippines
1. Reynold F. Fontanilla

Sri Lanka
1. R. R. M. R. U. Medagama
2. M. W. S. A. de Silva
3. Mithrasena A. H. G.

Tanzania
1. Charles H. A. N. Mallisa

Thailand
1. Jaran Choorak

Vietnam
1. Nguyen Tri Hoan

INTERNATIONAL NETWORK ON SOIL FERTILITY AND FERTILIZER EVALUATION IN RICE
(6 Feb-26 May 1984)

Burma
1. U Hla Maw
2. U Thaung Tun

China
1. Guo Xi Cheng
2. Fu Jianrong
3. Liuliangxue
4. Sun Peiliang
5. Lei Yongzhen

India
1. J. D. Naphade
2. Sheo Prakash Shukla
3. K. R. Sonar

Indonesia
1. Dwi Pudjo Leksono

Malaysia
1. Ismail Che Haron

Nepal
1. Badri N. Suwal

Nigeria
1. Wilfred A. Osinaike

Philippines
1. Rodolfo A. Eugenio
2. Eriberto Rodriguez

Sri Lanka
1. Wijepala M. Bandara
2. Herath M. S. Wijayaratna

Thailand
1. Nikool Rungshichol
2. Jarunan Tuntiwarawit

Vietnam
1. Nguyen Minh Hanh
2. Nguyen Thi Hien
3. Vo Minh Kha

UPLAND RICE TRAINING COURSE
(23 Jul-9 Nov 1984)

Burma
1. Net Sein

India
1. Prem Chandra Agrawal
2. A. Amirtha Deva Rathinam
3. Satya Pal Singh
4. Kolla Srinivasulu

Indonesia
1. Syahrial Abdullah
2. Nursal Jalid
3. Nasrun D.

Kenya
1. Walter Malinga Kirui

Malaysia
1. Ku Yahaya B. Ku Hashim

Nepal
1. Surya Narayan Sah
2. Ram Chandra Sharma

Philippines
1. Nida A. Cabradilla
2. Vicente Ta. Binoya
3. Fernando A. Española

Thailand
1. Suchit Chaichit
2. Aunnop Kasivivat

Vietnam
1. Luu-Van-Sang

INTEGRATED PEST MANAGEMENT
(23 Jul-20 Nov 1984)

Burma
1. U Hla Myint

China
1. Ye Zhi-Hua
2. Zhu Wei-Hua

India
1. K. A. Pathak
2. Jaswant Singh

Indonesia
1. Ishak Manti

Korea, South
1. Yong Heon Kim

Malaysia
1. Mohd Puzi B. Abdul Aziz
2. Abdul Hamed Bakir
3. Ho Yuen Tong

Nepal
1. Duku Raj Rawal

Pakistan
1. Mohammad Abdul Rahim

Philippines
1. Artemio R. Eugenio
2. Leopoldo D. Hernandez
3. Lucio U. Pulupol

Sri Lanka
1. Nayana Devika Delpachitra
2. Padmini Mylvaganam

Tanzania
1. Edward Paul Miti

Thailand
1. Chirapanthu Chandratat
2. Supang Lowsoponkul

Vietnam
1. Tran Huy Tho

Cooperative research

Although IRRI has always emphasized cooperative research at many different levels, in 1984 we gave explicit recognition to this key area of IRRI's activities by designating program area 1100 to deal with cooperative research.

Our research and dissemination programs use seven major pathways of cooperation: global research services, networks, cooperative country projects, collaborative research, collaboration with advanced institutions, training and technology transfer, and knowledge sharing (Table 1).

GLOBAL RESEARCH SERVICES

Germplasm collections. Global services, such as the International Rice Germplasm Center (IRGC) and the azolla and blue-green algae collections, team with scientists of international and national research programs to conquer genetic erosion. In 1984, special rice germplasm collection expeditions centered on Bhutan, Sri Lanka, and Indonesia. The azolla collection, maintained in controlled growth chambers, contain 6 species and 170 strains. The blue-green algae collection includes 78 strains. Scientists receive samples from these collections at no charge. All rice scientists throughout the world have access to these genetic resources. IRRI considers itself as the custodian, not the owner, of this priceless human heritage.

Data management. National agricultural research organizations are using more on-farm trials to test new technologies. Because of differing physical, environmental, social, and economic conditions, on-farm trials are conducted at many sites. Information collected includes performance of new technologies and descriptions of local farming conditions.

Speedy data analysis is essential for on-farm trials to be successful. We initiated a cooperative project with the Philippine Ministry of Agriculture and Food (MAF) to develop a data management system for on-farm trials in national programs. The system uses a microcomputer to store, analyze, and report the farm trial results.

Table 1. Pathways of cooperation between IRRI and other scientists and institutions.

Pathway	Examples
Research services	International Rice Germplasm Center, azolla germplasm
Networks	International Rice Testing Program, International Network on Soil Fertility and Fertilizer Evaluation for Rice, Asian Rice Farming Systems Network
Country programs	Resident scientists
	Scientist–scientist
Cooperative research	Hot spot screening
	Shuttle breeding
	Farm machinery
Collaboration with advanced institutions	Organizations (United States Agency for International Development, Institute for Research in Tropical Agriculture of France, German Agency for Technical Cooperation, Overseas Development Agency of the United Kingdom, etc.)
	Universities and institutes
	International centers (International Institute of Tropical Agriculture, West Africa Rice Development Association, International Centre of Insect Physiology and Ecology, International Food Policy Research Institute, International Fertilizer Development Center, etc.)
	Individual scientists
Training and technology transfer	Los Baños
	In-country
	Joint
Knowledge sharing	Seminars, monitoring tours
	Bibliographic services
	Publications

Four Philippine agricultural regional offices are using the system.

NETWORKS

Networking promotes institutional and individual interaction and communication. The International Rice Testing Program (IRTP) (pp. 143-154) completes 10 yr of service to the global scientific community working on rice in 1985. Ten years ago, it had 12 nurseries and contact scientists in 46 countries. In 1984, it had 24 nurseries with 2,500 entries and trials in 53 nations. Hundreds of national scientists have participated in meetings and monitoring tours in Asia, Latin America, and, most recently, East Africa, where they observe local conditions, rate nursery entries, and learn more about each other and mutual problems.

The International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) (pp. 305-314) conducts fertilizer evaluation trials in a dozen Asian countries in a multitude of sites, soils, and cultural conditions. In response to increasing emphasis on adverse environments, INSFFER has added three collaborative trials in upland rice soils. Its major emphasis now is on integrated nutrient supply systems involving optimum blends of mineral fertilizer, organic manure, and biofertilizers like azolla.

The Asian Rice Farming Systems Network (ARFSN) (pp. 441-450), develops and tests component technologies for farming systems. The goal is to intensify farming, thereby producing more food, income, and jobs.

COOPERATIVE COUNTRY PROJECTS

Work plan meetings were held during the year with scientists of the national research systems of Bhutan, Burma, China, Ethiopia, India, Indonesia, Iran, Korea, Madagascar, Malaysia, Pakistan, Sri Lanka, Thailand, and Vietnam. At these meetings, the results of on-going collaborative work were reviewed and programs for the following year developed. Through this mechanism, a beneficial match is achieved between the needs of each national agricultural research center and IRRI's capability to meet them.

IRRI has also liaison scientists located in the International Institute of Tropical Agriculture (IITA) in Nigeria, Bangladesh Rice Research Institute, Agricultural Corporation in Burma, Rice Research and Training Project in Egypt, Agency for Agricultural Research and Development in Indonesia, Centro Internacional de Agricultura Tropical in Colombia, and Thai Department of Agriculture in Bangkok, Thailand. The liaison scientist in Indonesia also helps in the implementation of collaborative research in Malaysia.

In the Philippines, there is a continuous feedback relationship between IRRI and the scientists of the Ministry of Agriculture and Food, Philippine Council for Agriculture and Resources Research and Development (PCARRD), University of the Philippines at Los Baños (UPLB), and other universities. Two technology transfer workshops held during the year — one in March and another in October — reviewed programs for adaptive trials and on-farm testing during the monsoon and dry seasons, respectively.

COLLABORATIVE RESEARCH

Cooperative in-country research allows us to take advantage of the wide variability in rice growing and socioeconomic environments in different nations. We can test varieties for insect and disease resistance and adverse soils tolerances at hot spot locations, and carry on shuttle breeding to rapidly develop varieties suitable for adverse environments.

For example, we have a long-term collaborative breeding program for cold tolerance with Korea. In summer, varieties are screened for cold tolerance in Korea. In winter, their progeny are grown in low temperature in Banaue, Philippines. Thus, new varieties can be developed and tested twice as fast as they could at only one location.

At the annual work plan meeting between the Chinese Academy of Agricultural Sciences (CAAS) and IRRI, it was decided to initiate a shuttle breeding program for the purpose of developing early maturing, disease- and insect-resistant varieties with good grain quality. Under this program, segregating material will be grown alternately in China and in IRRI.

We also cooperate with several national programs in machinery development and testing. In Burma, we successfully tested and modified the

IRRI 6-row transplanter and a reaper based on a Chinese prototype. Egypt and Indonesia also cooperate in machinery development and testing.

COLLABORATION WITH ADVANCED INSTITUTIONS

We regularly work with developed-country organizations such as the United States Agency for International Development (USAID) and the German Agency for Technical Cooperation (GTZ) that fund special research and information dissemination programs. In 1984, GTZ helped establish new physical sciences laboratories at IRRI. GTZ is a long-time collaborator in soils-related research. The agency also helped sponsor, for the second year, a book exhibit at the Frankfurt Book Fair that included publications of 22 international agricultural research centers from around the world. We also actively collaborate with the Australian Center for International Agricultural Research (ACIAR) and the International Development Research Centre of Canada (IDRC) in several projects of mutual interest.

We work with scientists and programs of national research organizations including the Institute for Research in Tropical Agriculture of France on upland rice research, the Asian Vegetable Research Development Center on component crops for farming systems, the International Fertilizer Development Center on chemical fertilizers and nutrient losses and in the INSFFER Program, IITA on rice, cowpea, and other grain legumes, the International Center of Insect Physiology and Ecology on planthopper physiology, the International Food Policy Research Institute on rice policy research in Asia, and the International Center for Maize and Wheat Research on rice-wheat rotation.

We also cooperate with institutes and universities such as UPLB, the University of Reading, the University of Durham, the University of California at Davis, and the Tropical Agriculture Research Center at Tsukuba in Japan.

TRAINING AND TECHNOLOGY TRANSFER

More than 3,000 national rice scientists have attended IRRI's instruction courses emphasizing research methodology and rice production techniques. Nondegree courses include agricultural engineering, agroeconomics, cropping systems, integrated pest management, plant breeding, and upland rice.

We also help national programs set up training programs in areas such as rice production and germplasm collection and maintenance. In 1984, we helped Bhutan establish training for extension workers, and we worked with Indonesia and other countries in germplasm collection.

In the Philippines, we exchange information with regional MAF representatives in a biannual technology transfer workshop. We inform regional workers about new technologies, and they tell us how previously recommended technologies are performing and what the significant new field problems are.

MS and Ph D students receive instruction at UPLB, and carry out thesis and dissertation research at IRRI. Many students return to their home countries to become leaders in national programs. The IRRI Academic Council including representatives of several academic institutions guides the degree training.

PROSPERITY-THROUGH-RICE DEMONSTRATION

The greatest challenge before agricultural scientists and policy makers is to develop technologies, services, and policies which can produce more food for urban dwellers and also generate more income and employment for rural families. To demonstrate how this can be done in rice growing areas, UPLB and IRRI began in 1983 a demonstration and training program on the theme Prosperity Through Rice.

The program, which is financially supported by the Asian Development Bank, emphasizes improving rice yields at lower cost, using multiple cropping and mixed farming to maximize resources and returns, and using the whole rice plant.

Using the whole rice plant. The demonstration shows the uses of rice straw, rice bran, and rice hull. Rice straw can be a source of manure when soil incorporated, substrate for mushroom culture, balanced animal nutrition for stall-fed animals, biogas and subsequent composting, methanol, and paper and building board production. Rice bran has many uses in food, feeds, and manufactured products. Rice hull or husk is a source of energy in

grain drying, fuel for charcoal production, animal feed after fortification; and has many other uses in building products and chemical production.

Rice-based farming systems. The farming systems component of Prosperity Through Rice demonstrates what can be done on a 2-ha farm to increase farm income and employment by integrating crop, livestock, and household activities. The project stresses best use of the farm's limited resources to benefit the household and landless workers. Activities demonstrated in 1984 included crop intensification, crop-livestock integration, energy generation, organic fertilizer production, and mushroom culture.

Cropping patterns. Cropping patterns evaluated were one, two, and three crops of rice, and one or two rice crops followed by upland crops such as maize, soybean, mungbean, wheat, and tomato. Patterns are selected on the basis of varietal tolerance for major insects and diseases, nonoverlapping pest sensitivity among crops grown in succession, potential for biological nitrogen fixation in the case of legumes, ability of root systems to extract moisture and nutrients from different soil depths, opportunities for profitable crop marketing, management techniques to efficiently use purchased inputs like fertilizer, pesticides and water, and home-grown inputs substituted for purchased ones.

Pest management. The project uses integrated pest control on recommended varieties of crops, given optimum cultural management to ensure maximum growth and productivity. Pest populations are regularly monitored to determine need for additional control. Pesticides are chosen for bioefficacy, low cost, and least disruption to other biotic forms, especially the beneficial ones.

Livestock, poultry, and fish production. Integrating animal production into a rice farming system can add income and employment. This project uses cattle, goats, pigs, broilers, and layers. Rice straw, maize stover, and legume straws are chopped and fed to ruminants. To enrich rice straw, it is stored in a silo made of bricks from rice hulls. Hog, cattle, and goat manure is used with straws to generate biogas and/or make compost for fertilizer, while chicken manure is used in the fish project. Fish in concurrent cultivation with paddy help recycle nutrients and aerate and fertilize paddy. Some species control algae and weeds; others control pests and predators. Fish culture increases paddy yield about 10% and farmers also benefit from protein, minerals, and vitamins from fish.

Biogas production. The biogas generation project was established in collaboration with the Korean Office of Rural Development. It uses rice straw and animal manure to generate methane. The project uses various mixtures of cow dung, pig and chicken manure, and night soil. The rice straw:cow dung substrate has produced 1.5 m^3 methane/d at a constant rate for about 35 d. Methane gas can be used for cooking, lighting, and running small engines.

Mushroom culture. Mushroom cultivation can contribute high-protein food and help dispose of inedible organic wastes. Almost all cultivated mushrooms can be grown on rice straw in the field after harvest. Rice straw on which mushrooms have been grown and harvested is rich in NPK. In many Asian countries, these mushroom spent-composts are mixed with soil to make organic fertilizer. The project demonstrates technologies of using rice straw in cultivating tropical mushrooms either as backyard projects or for commercial production. The project also provides training in producing mushroom spawns.

Thus, the IRRI-UPLB-ADP cooperative project of Prosperity Through Rice demonstrates ecological and economically sustainable production and postharvest technologies which can help to produce not only more rice and other associated crops or fish or livestock products but can provide more on-farm and off-farm employment in rural areas.

KNOWLEDGE SHARING

Seminars and conferences at IRRI and in other rice growing nations bring together national and international scientists, broadening perspectives in technology development.

Some of the important workshops and conferences held during the year were the:

- Workshop on the characterization, classification, and utilization of wetland soils (26 Mar-5 Apr),
- Intercenter seminar on international agricultural research centers (IARCs) and biotechnology (23-27 Apr),
- Workshop on nitrogen fixation in the rhizosphere of rice (28 Apr-3 May),

- Workshop on remote sensing and rice (30 Apr-2 May),
- Workshop on indigenous plant material and pest control (6-10 Aug),
- Workshop on microcomputer applications in agricultural research (24-27 Sep), and
- Symposium on education for agriculture (12-16 Nov).

In addition to these workshops and symposia, IRRI organizes the annual International Rice Research Conference (IRRC) to bring together rice scientists from national research systems and IRRI to exchange data and material and to identify additional avenues for strengthening purposeful collaboration. Starting in 1984, the IRRC is held alternately in a national research system and in IRRI. Under this arrangement, an IRRC with specific attention to rainfed lowland rice was held in October 1984 in Bhubaneswar, India, in collaboration with the Indian Council of Agricultural Research.

In addition to collaborating with countries listed under Cooperative Country Projects, IRRI regularly shares its knowledge with nations involved in the West Africa Rice Development Association (WARDA).

Through IRTP monitoring tours and INSFFER soil classification tours and workshops, scientists and extension workers evaluate new varieties and lines, and management practices.

IRRI's bibliographic and library services collect and disseminate information often unavailable in other libraries. Each year we publish supplements to the *International bibliography of rice research*, widely circulated among world libraries. Additional bibliographies include the *International bibliography on cropping systems* and one on azolla.

Through its Tokyo office, the IRRI library translates many journal articles and books from Japanese to English, facilitating worldwide use.

Books and newsletters aid communication of rice knowledge. In 1984, we distributed more than 62,000 books and released 22 major publications. IRRI educational materials were exhibited in book fairs in China, Germany, Mexico, India, and the United States. To encourage international distribution, IRRI, in cooperation with the Consultative Group for International Agricultural Research (CGIAR), published a book catalog describing more than 1,000 titles from the IARCs.

Through a survey of translators and publishers of non-English editions of IRRI books, we found that at least 116 editions had been or were being copublished in 34 languages by 48 agencies in 25 countries. The most popular titles for copublication were *A farmer's primer on growing rice* and *Field problems of tropical rice.*

Information resources, experimental farm, and service laboratories

LIBRARY AND DOCUMENTATION CENTER

Bibliographies. The 1983 supplement to the *International Bibliography of Rice Research* was published in 1984, the fourth supplement produced by computer. Most of its 6,800 references to scientific rice literature appeared in journals in 1983. Classifying references by subject matter, this bibliography provides worldwide coverage, with author and keyword indexes. The 1983 supplement includes literature written in 24 languages and a list of 120 rice literature translations, mostly from Chinese to English.

In 1984, the library acquired an IBM-3278-1 Display terminal, a 3274-31 D terminal control unit, and a 3287-2 Bi-directional Dot Matrix printer. Current rice information is continuously stored, and retrospective information from 1971 to 1983 was stored. Rice information covering 1961-70 is ready to enter into the system.

The library envisions a computerized literature search system to provide interested scientists and scholars everywhere quick access to IRRI's collection of the world's literature on rice.

The 1984 supplement to *Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute* was also produced. The supplement lists 132 titles, bringing this collection to 1,507 items.

The library issued the *International Bibliography on Azolla,* supplementing the 1979 bibliography. The 1984 volume adds 950 items published between 1980 and 1983, plus those produced earlier but not included in the basic 1979 volume. Entries follow a classified arrangement, with author and keyword indexes.

All new bibliographies were sent to agricultural libraries and documentation centers of rice-producing regions. Citations are available at IRRI.

Reference and circulation. Again in 1984, more users requested literature on genetics and breeding than on all other aspects of rice culture. Requests on azolla and tissue culture increased markedly. The library processed requests for short, specific-subject bibliographies. The requests for rice literature came mostly from India, Bangladesh, and Malaysia, with some from Latin American countries and Africa.

The library gave some overseas and local libraries help in library organization and management, selection and acquisition of agricultural materials, and processing of special materials such as microfilm, maps, and pamphlets.

Within the Institute, books and journals borrowed reached an all-time high. Researchers and students from the Los Baños complex, Metro Manila, and as far as Central Luzon used the library facilities. Use went beyond rice literature and into other disciplines.

Library holdings. With the addition of 4,067 books, pamphlets and reprints, the monograph collection reached 70,595. Maps, translations, and microfilm were added, plus 172 serial titles from subscriptions, exchanges, and gifts.

Other library activities. To inform scientists of the latest rice literature, tables of contents of newly received journals were circulated within IRRI and to several stations in Indonesia, Bangladesh, and Africa. Similarly, the monthly acquisitions list was more widely distributed to overseas addresses.

The library continued to purchase books and bind volumes for staff and visiting scholars and trainees.

COMMUNICATION AND PUBLICATIONS DEPARTMENT

CPD distributed more than 62,000 copies of major publications in 1984. About 31% were free, mostly to key Third World libraries, and the remainder were sold.

Major publications. Twenty-two major publications were released in 1984:

- *A Decade of Cooperation and Collaboration Between Sukamandi (AARD) and IRRI, 1972-82*
- *A Farmer's Primer on Growing Rice* (editions in Cebuano, French, and Ilocano)
- *Annual Report for 1983*
- *CHEMRAWN II: Chemistry and World Food Supplies: Perspectives and Recommendations*

- *Cropping Systems in Asia: On-farm Research and Management*
- *Field Problems of Tropical Rice* (revised editions in Spanish, Tagalog, and Vietnamese)
- *International Bibliography of Rice Research Cum Indexes 1976-80*
- *International Directory of Rice Workers*
- *Major Weeds of Rice* (Urdu ed.)
- *Organic Matter and Rice*
- *Publications on International Agricultural Research and Development*
- *Basic Procedures for Agroeconomic Research*
- *An Overview of Upland Rice Research*
- *Research Highlights for 1983*
- *Statistical Procedures for Agricultural Research* (2d ed.)
- *Terminology for Rice Growing Environments*
- *Workshop on Judicious and Efficient Use of Insecticides on Rice*
- *International Workshop on Research Priorities in Tidal Swamp Rice*

Serial publications. Four issues of the *IRRI Reporter* were published and distributed to about 15,000 rice workers. Six issues of the *International Rice Research Newsletter* and the *Subject Index for 1983* were published. Two issues of the *IRRI Research paper Series* came out:

No. 99 Soil sickness caused by continuous cropping of upland rice, mungbean, and other crops

No. 100 Changes in input use and grain yields in lowland rice farms in three Philippine provinces

Book exhibits. In 1984, IRRI exhibited in seven book fairs — in China, Germany, Mexico, India, and USA.

For the second time, IRRI and the German Agency for Technical Cooperation (GTZ) co-sponsored an exhibit of books from the international agricultural research centers (IARCs) at the 1984 Frankfurt Book Fair 3-7 Oct. Twenty-two Centers and cooperating agencies displayed about 600 books, periodicals, slide sets, and films.

IRRI published a catalog listing 1,100 books, periodicals, slide sets, and films on behalf of the CGIAR Centers; distributed it at Frankfurt; and now handles its world distribution.

Copublication. To document copublication, translators and publishers of non-English editions of IRRI books were surveyed, and records of the CPD were analyzed.

At least 120 non-English editions of IRRI books had been or were being copublished in 34 languages by 48 agencies in 25 countries (Table 1). About 21% of the translated editions were in Chinese.

At least 75 editions of *A Farmer's Primer on Growing Rice* and the first and revised editions of *Field Problems of Tropical Rice* had been or were being copublished.

Through in-depth personal interviews with translators and publishers in 9 Asian countries, and questionnaires mailed to 3 countries, data were gathered on 71 copublished editions of 17 IRRI books.

At least 680,000 non-English copies of 17 of the books had been printed — more than 3 times the number of the same books that IRRI printed in English. *Field Problems of Tropical Rice* and *A Farmer's Primer on Growing Rice* accounted for almost 90% of the total non-English copies.

Agricultural research organizations published more than half of the translated editions. Translators contacted the publishers to initiate publication of 69% of the editions.

Table 1. Copublication status of 19 IRRI books.

Title	Copublished editions (no.)	
	Printed	In press
Farmer's primer on growing rice	25[a]	15
Field problems of tropical rice (1st edition)	10[b]	0
Field problems of tropical rice (2nd edition)	7[c]	21
Production of seedlings	4[d]	0
Rice improvement	4[e]	0
Fundamentals of rice crop science	1[f]	3
Illustrated guide to integrated pest management	0	5
Others	18	7
Total	69	51

[a] Bahasa Indonesian (2 editions), Bahasa Malaysian, Bengali, Burmese, Cebuano, Chinese (2 editions), French, Gujarati, Hiligaynon, Ilokano, Kannada, Nepali, Oriya, Parsi, Spanish (2 editions), Swahili, Tagalog, Tamil, Thai (2 editions), Urdu, Waray. [b] Bahasa Indonesian, Bengali, Burmese, Hindi, Nepali, Tagalog, Tamil, Telegu, Urdu, Vietnamese. [c] Bengali, French, Spanish, Tagalog, Thai, Vietnamese, Waray. [d] Gujarati, Gujarati and Hindi, Hindi, Telegu. [e] Chinese, Korean, Spanish, Vietnamese. [f] Chinese, Japanese, Spanish, Vietnamese.

EXPERIMENTAL FARM

Relocation of the Mabacan irrigation canal solidified blocks 700 and 1000 and increased block 700 by 1 ha.

A 5-ha upland area belonging to UPLB was converted into a lowland farm. IRRI will use it for 3 yr without paying rent. It has been planted by the Experimental Farm, the Korean seed multiplication project, and the International Rice Germplasm Center.

To reduce soil erosion in blocks UW and UO, the drainage ditch will be widened and deepened after removing the fence separating the IRRI upland farm from the Institute of Plant Breeding farm. This will redirect rainwater toward the creek.

Using the three 4-wheel drive Iseki tractors purchased in late 1983 held down land preparation costs on lowland ricefields. Two 4-wheel drive 90-hp Isekis were purchased for 1985 upland preparation.

The maximum yield experiment in UB-2 requires low-boron irrigation water. To provide it, an underground pipeline was constructed to reach the low-boron water available in the UT reservoir.

The Experimental Farm maintains azolla propagation plots as N sources for production plots.

The Experimental Farm prepared and planted 186 ha of irrigated lowland during 1984 wet and dry seasons, a decrease of 4 ha from 1983. Major users were Plant Breeding (41%), Agronomy (12%), and Experimental Farm (12%). Of 98 upland ha, Rice Farming Systems used 18%, Multiple Cropping 18%, Agronomy 17%, Experimental Farm 16%, and IRGC 14%, or 81% of the total area.

About 22 ha was used for seed multiplication of IR50, IR56, IR58, IR60, IR62, IR841, IR2061-522-6-9, IR2061-522-6-2-9, IR3259, IR5716-18-1, IR8866-30-3-1-4-2, IR8866-30-30-1-4, IR9201-5-2-2-2, IR9202-5-60-3-1-3, IR9758-1-2, IR13155-60-3-1-3, IR13540-56-3-2-1, and IR15579-135-3.

The Experimental Farm produced 44 t of rice for seed and 46 t for milling. IRRI departments turned over to Experimental Farm 169 t of rice for milling.

In 1984, the Experimental Farm used 176 t of fertilizer valued at $37,178, only slightly more than last year's. Ammonium sulfate accounted for 47%; urea, 22%; solophos, 16%; 14-14-14 complete, 9%; and muriate of potash, 5%.

The Experimental Farm spent $66,554 for insecticides and sticker, almost the same as in 1983. However, the $8,602 spent for herbicides was only 57% of the 1983 expense. The $264,823 spent for contract labor was $45,542 above the 1983 level; almost 60% of it went to birdboys. The Experimental Farm continued war on rats, killing 35,372.

Farm income was $47,491, $14,602 more than in 1983, and derived mostly from sale of rice for seed, rice for milling, milled rice, green supersweet maize, flint maize for feed, glutinuous rice, sorghum, tomato, and rice bran.

ANALYTICAL SERVICE LABORATORIES

Chemical Analysis Laboratory. The Chemical Analysis Laboratory ran 119,651 analyses on 53,041 samples of soil, plants, and solutions (Table 2). The laboratory continues to improve its analytical procedures and computerization of data.

Research on applications of the North Star Horizon microcomputer indicated that it can be used for on line data acquisition from the Technicon AutoAnalyzer II system. Upgrading that computer to a multiuser multiprocessor system will make possible simultaneous real time data acquisition

Table 2. Summary of analyses done by the Chemical Analysis Laboratory, IRRI, 1984.

Property analyzed	Determinations (no.) on samples		
	Soil	Plant	Water
Total elements (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, Zn)	–	23,951	13,753
Total N	3,721	–	–
N + protein	–	26,929	–
EC	537	–	322
CEC	1,753	–	–
Exchangeable Ca, K, Mg, Na	7,105	–	–
Available Al, P, B, Zn	5,532	–	–
Organic C	2,519	–	–
Perchloric acid Cu, Fe, K, Mg, Mn, P, Zn	1,233	–	–
pH	2,297	–	187
Ammonium-N and urea-N	–	–	28,598
Particle size	1,214	–	–
Total analyses	25,911	50,880	42,860
Samples	4,304	27,750	20,987

from several autoanalyzers, spectrophotometers and balances.

Mass Spectrometer Laboratory. The Mass Spectrometer Laboratory analyzed 9,950 soil, plant and floodwater samples for $^{15}N/^{14}N$ ratio. The Hewlett Packard HP41CV programmable calculator enabled rapid calculation of data.

Radioisotope Laboratory. The Radioisotope Laboratory analyzed 3,559 labeled soil, plant, gas, and insect samples. The analyses included sample preparation, fractionation, and ^{14}C activity measurements in either the Packard Liquid Scintillation Counter or the Varian Vibrating Reed Electrometer. The laboratory acquired a Packard sample oxidizer and a Radiogas chromatograph.

PESTICIDE RESIDUE LABORATORY

The Pesticide Residue Laboratory received 698 samples for complete analysis in 1984, 46% more than in 1983.

Of the 414 samples from the Entomology Department, 303 were insecticide formulations of isoprocarb, BPMC, diazinon, carbaryl, monocrotophos, deltamethrin, cypermethrin, edifenphos, and carbofuran. The remainder were submitted for a laboratory experiment on carbofuran loss in paddy water.

The Agronomy Department submitted 104 soil samples for butachlor analysis. From the IRRI Experimental Farm waterways, 108 samples were tested for residues of carbofuran, isoprocarb, BPMC, diazinon, carbaryl, monocrotophos, chlorpyrifos, and butachlor.

The Cereal Chemistry Department submitted samples for analysis of carbofuran, monocrotophos, diazinon, and acephate in rice straw and grain. It also submitted 128 samples for injection and quantitation: 89 were aldononitrile derivatives of cell wall sugars, and 39 were extracts from rice plants for determination of insect resistance factors.

PHYTOTRON

Fifty-five research projects from 11 IRRI units used the phytotron in 1984. Glasshouse rooms had highest use (91%), followed by naturally lighted (84%) and artificially lighted cabinets (82%). Use of other rooms ranged from 61 to 67%. The screenhouse was used to full capacity all year, and 50% of cold room space was used to store Rapid Generation Advance seeds. The drying oven was heavily used.

A new artificially lighted cabinet (KG type) was installed for the photosynthesis laboratory.

A 1-h course in Apr 1984 familiarized 36 participants with use of phytotron facilities.

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SEMINARS

The seminars held at IRRI during 1984 are grouped as Thursday seminars, Saturday seminars, and special seminars. The Saturday seminars report ongoing IRRI research. Unless otherwise stated, the speakers were staff members.

Thursday seminars

The hill rices of Thailand. Dr. T. T. Chang.

The Overseas Development Administration's scientific units. Dr. R. K. Cunningham, undersecretary in charge of Natural Resources Division, Overseas Development Administration, United Kingdom.

The scope of manipulation of insect behavior for pest management. Dr. K. N. Saxena, principal research scientist and agricultural programme leader - CPRP, International Centre of Insect Physiology and Ecology, Mbita, Kenya.

Genetic engineering: promises, practice, and limitations. Dr. T. H. Alton, visiting assistant professor, Institute of Biological Sciences, University of the Philippines at Los Baños, Laguna, Philippines.

N management in rice and rice-based cropping sequences. Dr. O. P. Meelu, senior research fellow, Multiple Cropping Department.

International studies on nutrition and serum lipoproteins in children, with special reference to children in San Pablo Region, Philippines. Prof. Dr. J. G. A. J. Hautvast, chairman, Department of Human Nutrition, Agricultural University, Wageningen, The Netherlands.

Pictorial observations on the human geography of Bangladesh. Dr. R. E. Huke, visiting geographer, Agricultural Economics Department.

Raw starch-digesting amylase: production and its application. Dr. P. Q. Flor, senior science research specialist, National Institutes of Biotechnology and Applied Microbiology, University of the Philippines at Los Baños, Laguna, Philippines.

Tissue and cell culture techniques in the improvement of crops: facts and perspectives. Dr. D. S. Brar, senior research fellow, Tissue Culture Facility, IRRI.

Upland rice breeding: constraints and hopes. Mr. M. Arraudeau, visiting scientist, Plant Breeding Department.

Rice research and production activities in Pakistan. Dr. M. Akbar, senior research fellow, Plant Breeding Department.

From yellow pad to printed page. Mr. E. A. Tout.

NEA rural energy generation thru dendro thermal project. Ms. A. S. Adriano, project manager, Dendro Thermal Development Office, National Electrification Administration, Quezon Avenue, Quezon City.

The challenge of nutrition in everyday family meals. Mrs. Ma. P. S. del Rosario, assistant professor, College of Human Ecology, University of the Philippines at Los Baños, Laguna, Philippines.

Small farmer technology generation and dissemination at the CLSU: a Philippine case experience. Dr. F. T. Rivera, senior research fellow, Irrigation Water Management Department.

Soil health of the IRRI farm. Dr. F. N. Ponnamperuma.

Present status and prospects of agriculture and food production in China. Professor Lu Liangshu, president, Chinese Academy of Agricultural Sciences, Beijing, China.

Biochemical basis of *Anabaena azollae-azolla* symbiosis. Dr. J. K. Ladha, associate soil microbiologist.

Floodwater ecosystem manipulation for increasing N_2-fixation in wetland rice. Dr. I. F. Grant, visiting associate scientist, Soil Microbiology Department.

Biotechnology for the improvement of livestock. Dr. A. K. Alton, visiting assistant professor of Genetics, Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines at Los Baños; and consultant and project leader, National Science and Technology Authority-BIOTECH, Project in Molecular Biology, Genetic Engineering, and Hybridoma Research, National Institutes of Biotechnology and Applied Microbiology, College, Laguna, Philippines.

Economic policies and Philippine agriculture. Dr. C. C. David.

Integrating forages with cropping systems. Dr. L. R. Humphreys, head, Department of Agriculture, University of Queensland, Australia.

Bean golden mosaic virus: application of basic studies in virus disease diagnosis. Dr. M. B. Bajet, postdoctoral fellow, Plant Pathology Department.

The construction program at IRRI. Mr. H. T. Murphy.

The programmes of the FAO Food Policy and Nutrition Division, Dr. P. Lunven, director, Food Policy and Nutrition Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

The current status of wildlife conservation in the Philippines. Prof. D. Rabor, special consultant, Wildlife Biology and Management, University of the Philippines College of Forestry, Laguna, Philippines.

Portrait of Bangladesh. Dr. N. Ahmed, consultant, ADB, FAO, and World Bank.

Off-farm employment and cropping intensity in South Korea: their interrelationship. Mr. Suh-Chong Hyuk, research fellow, and Dr. E. C. Price, Agricultural Economics Department, IRRI.

Multiple cropping in the plain area of Zhejiang Province (Lower Yangtze River Valley) and its prospect. Dr. Wang Zhao-Qian, associate professor, Zhejiang Agricultural University, China advisor, National Yangtze River Valley, Regional Development Research Program and research associate professor, China National Rice Research Institute, China.

Bivariate analysis and stability assessment for intercropping data. Dr. R. Mead and Ms. J. Riley, Department of Applied Statistics, University of Reading, Berkshire, England.

Varietal improvement and the development of better rice-based farming systems in the Zanzibar Islands, Tanzania. Dr. A. J. Carpenter, Rice Irrigation Project, UNDP/FAO/URT, Ministry of Agriculture, Zanzibar, Tanzania.

The structure of informal credit in the Philippine sector. Ms. M. S. Floro, research scholar, Agricultural Economics Department.

Hybrid rices research in the United States. Dr. A. G. Calub, project leader, senior rice breeder, and station manager at Ring Around Co.

Popular software for your desktop microcomputer. Dr. E. Tryon, visiting scientist, Training and Technology Transfer Department.

Monitoring rice insects and insecticide use on IRRI farm. Dr. B. M. Shepard.

The PADAP Zamboanga del Sur Development Project and its Multicropping Program. Dr. H. J. Nesbitt, research agronomist, Australian Development Assistance Programme, PADAP, Zamboanga del Sur, Philippines.

The IRRI Computer Center. Mr. S. E. O'Connor.

Risk management. Mr. G. Winternitz, president and general manager, System Safety Incorporated, Legaspi Village, Makati, Philippines.

IRRI and the global agricultural scenario. Dr. M. S. Swaminathan.

Herbicide degradation in soil. Dr. R. J. Zimdahl, visiting scientist, Agronomy Department.

Pardon me, your slide is showing! — a guide to improving science photography. Ms. E. A. Maurer, visiting associate editor, Communication and Publications Department.

Rural proverty alleviation: the direct attack approach. Mr. P. B. Ghate, Economics Office, Asian Development Bank, Manila.

Seed pathology and seed production. Dr. R. L. Gabrielson, Western Washington Research and Extension Center, Washington State University, USA.

Performance evaluation of three types of small-scale irrigation systems in the Philippines. Mr. S. Ogunwala, research fellow, Irrigation Water Management Department, IRRI.

The Philippines economic crisis revisited. Dr. L. Ilag, agricultural economist, College of Development Economics and Management, University of the Philippines at Los Baños, Laguna, Philippines.

Saturday seminars

The perennial weed *Scirpus maritimus* and its control in wetland rice. Mr. P. Bernasor.

Organizational structure and effectiveness of irrigation systems, Philippine national and communal systems. Dr. N. E. Tapay, postdoctoral fellow, Irrigation Water Management Department.

An assessment of physical and quality losses in alternative rice post-production technologies. Dr. Z. Toquero, postdoctoral fellow, Agricultural Engineering Department.

Production, income, and employment effects of mechanization in selected villages of Nueva Ecija, Philippines. Mr. D. Shields, research fellow, Agricultural Engineering Department.

Comparative tests of animal-drawn plots. Mr. M. M. Haq, research fellow, Agricultural Engineering Department.

Research in the Multiple Cropping Department. Dr. R. A. Morris.

Intercropping in rice-based cropping systems. Mr. W. A. Herrera.

Isozyme polymorphism in Asian cultivated rice. Dr. J. C. Glaszmann, postdoctoral fellow, International Rice Germplasm Center.

Cropping pattern testing in the Philippines. Mr. R. V. Labios and Mr. E. C. Godilano.

Cowpea and soybean improvement in rice-based farming systems, IRRI-IITA Collaborative Research. Dr. R. K. Pandey, visiting scientist, Rice Farming Systems Program.

Genetic analysis of cold tolerance in rice. Dr. B. B. Shahi, senior research fellow, Plant Breeding Department.

Genetic analysis of resistance to bacterial blight in rice. Dr. A. K. Saha, research fellow, and Dr. G. S. Khush, plant breeder, Plant Breeding Department; and Dr. T. W. Mew, plant pathologist, Plant Pathology Department.

Biochemical aspects of varietal resistance to rice stem borer *Chilo suppressalis* (Walker). Dr. D. Dale, senior research fellow, Cereal Chemistry Department.

Characterization of adult plant resistance of rice to bacterial blight. Ms. Z. Qi, research fellow, Plant Pathology Department.

Sorghum management for rice-based cropping systems. Mr. B. T. Samson.

The contribution of a short-duration green manure crop to rice grain yields and N uptake. Mr. R. E. Furoc.

Herbicides-moisture relationship in upland and direct-seeded flooded rice. Dr. S. Sankaran, senior research fellow; and Dr. S. K. De Datta, agronomist, Agronomy Department.

Crop modeling: its role in direction of soil-plant-water relations research. Dr. J. C. O'Toole.

Biochemical basis of *Anabaena azolla-Azolla* symbiosis. Dr. J. K. Ladha.

Weed population changes in upland rice-based cropping patterns as affected by tillage and weed control. Mr. P. P. Pablico, and Dr. K. Moody, Agronomy Department, IRRI; and Dr. E. C. Paller, Jr., associate professor, University of the Philippines at Los Baños, Laguna, Philippines.

Technologies for utilizing biological nitrogen fixation in wetland rice: potentialities, current usage, and limiting factors. Dr. P. A. Roger, visiting scientist, Soil Microbiology Department.

N_2-fixation of bacteria associated with sterile rice seedlings. Ms. Ma. L. Daroy.

Spores of blue-green algae. Dr. P. M. Reddy, postdoctoral fellow, Soil Microbiology Department.

^{15}N dilution method to assess varietal differences in N_2-fixation. Ms. G. O. Buenaventura.

Farmers organization and its viability in pump irrigation systems — a case study in Bicol. Mr. M. M. Hossain, graduate student, Irrigation Water Management Department.

Irrigation and cropping schedule effects on the management of a pump irrigation system in Bicol. Mr. D. F. Tabbal.

The drainage problems and their effects in a pump irrigation system in Bicol. Mr. M. M. Agua.

Hand watering multicrop structures and processes: the case of Luzon, Philippines. Dr. F. T. Rivera, senior research fellow, Irrigation Water Management Department.

Varietal differences in properties of extruded rice products — extrusion-cooked rice and noodles. Dr. M. Baragaño de Mosqueda, visiting scientist, Cereal Chemistry Department.

Protein requirements of preschool children consuming rice-based diets. Ms. M. I. C. Santiago, senior science research specialist, Nutritional Evaluation Laboratory, Food and Nutrition Research Institute, NSTA, Manila.

Cytogenetics of planthoppers associated with rice *Oryza sativa* L. and a weed grass, *Leersia hexandra* Swartz. Ms. A. A. Barrion, research fellow; and Dr. R. C. Saxena, associate entomologist (IRRI/ICIPE), Entomology Department.

Epidemiology of rice tungro disease in Malaysia. Mr. H. Bottenberg, research fellow, and Dr. J. A. Litsinger, entomologist, Entomology Department; Dr. P. Kenmore, FAO; and Dr. R. S. Rejesus, CHEVRON Chem.

Buprofezin: selective insecticide for planthopper and leafhopper management. Mr. S. L. Valencia, Mr. R. P. Basilio, Dr. O. Mochida, and Dr. E. A. Heinrichs.

Resistance to the brown planthopper *Nilaparvata lugens* (Stal) in the world collection of rice. Mr. F. Medrano and Dr. E. A. Heinrichs.

Morphological studies in the reproductive phase of the rice plant. Ms. Xue-Bin Xu, special research fellow, Dr. B. S. Vergara, and Mr. R. M. Visperas, Plant Physiology Department.

Thailand rice policy model, a simulation analysis. Mr. K. Vesdapunt, research fellow, Agricultural Economics Department.

Production and use of ^{14}C-labeled rice straw in decomposition studies of organic straw in tropical soils. Mr. R. Capistrano.

Varietal reactions to Zn deficiency. Mr. V. Quimsing.

Varietal reactions to P deficiency. Ms. M. Orticio.

Tillage in a rainfed lowland cropping sequence. Ms. S. Maghari.

Establishment of *Trichoderma* on rice and on grain legumes. Dr. S. M. Usmani, postdoctoral fellow, Plant Pathology Department.

Rice virus disease diagnosis: problems and prospects. Dr. N. Bajet, postdoctoral fellow, Plant Pathology Department.

Pathological and bacteriological variation of *Xanthomonas campestris* pv. *oryzae*. Ms. C. M. Vera Cruz and Dr. T. W. Mew.

Biological control: status and potential against insect pests of rice. Dr. B. M. Shepard, entomologist; and Dr. M. Rombach, postdoctoral fellow, Entomology Department.

Salinity tolerance program in the Plant Physiology Department. Ms. G. Cabuslay, research assistant; M. A. Chaudhry, research fellow; Dr. A. T. Abuo-Zeid, research fellow; Ms. E. Abrigo, research assistant; Ms. A. Novero, research aide; Mr. F. T. Parao, assistant scientist; Dr. F. J. Zapata, associate plant physiologist; and Dr. B. S. Vergara, plant physiologist.

Anther culture in rice: a) callus induction, b) cytology of regenerated plants. Dr. S. T. Mercy Dale, senior research fellow; and Dr. F. J. Zapata, associate physiologist, Plant Physiology Department.

Special seminars

The Ti-plasmid of *Agrobacterium tumefaciens* as vector for genetic engineering in plants. Prof. M. Van Montagu, University of Ghent, Belgium.

The scope of manipulation of insect behavior for pest management. Dr. K. N. Saxena, principal research scientist and agricultural programme leader - CPRP, The International Centre of Insect Physiology and Ecology, Mbita, Kenya.

Cultivation techniques and labor requirements for wet and hill paddy in Sarawak, Malaysia. Dr. M. Hoki, visiting professor, Agricultural Engineering Department, Michigan State University, USA.

Terminal report of the Small Farmers Organization Project. Ms. C. J. Soliman and Ms. M. Perfianco, Research Training and Development Agency for Community Educational Services Foundation, Inc., Quezon City.

Some interdisciplinary thoughts. Dr. A. R. Michaelis, editor, Interdisciplinary Science Reviews (ISR), London, England.

A proposed approach to yield — favorable chemical growth modification of maize. Dr. R. Kent Crookston, professor, Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minnesota, USA.

The electronic manuscript and other technological developments in scientific communication. Mr. I. Montagnes, assistant director, University of Toronto Press, Canada.

Microcomputer tools from scientists in developing nations. Prof. R. D. Stevens, Department of Agricultural Economics, Michigan State University.

Some physiological approaches for enhancing solar energy utilization efficiency of crops. Dr. S. Akita, Laboratory Chief of Carbohydrate Metabolism, National Institute of Agricultural Resources, Tsukuba Science City, Yatabe, Ibaraki, Japan.

Biotechnology's impact in agriculture: a socioeconomic perspective. Mr. M. Kenney, Research Association, Cornell University, Ithaca, NY, USA.

Editorial work at the U.S. Department of Agriculture. Mr. H. Sherman, editor, Agricultural Research Service, USDA, Oakland, California, USA.

Biocentration potential of pesticides in fish. Dr. J. Kanazawa, National Institute of Agro-Environmental Sciences, Ibaraki, Tsukuba, Japan.

Present status and prospects of agriculture and food production in China. Prof. Lu Liangshu, president, The Chinese Academy of Agricultural Sciences, Beijing, China.

Relationship between insects and fungal pathogens on rice. Dr. S. C. Lee, visiting scientist, Plant Pathology Department.

Early detection of health impairment of pesticide user. Dr. N. Cortes-Maramba, pediatric consultant, Department of Pediatrics, and pharmacology and toxicology consultant, Department of Medicine, Philippine General Hospital, Manila.

Field experimentation in the study of plant disease epidemics. Dr. J. Krantz, professor, Tropteninstitut fur Phytopathologie and Angew. Entomologie, Justus Liebig-Universitat, Giessen, Germany.

Food security is national security. Dr. B. T. Oñate, past president, Philippine Agricultural and Economic Development Association (PAEDA).

Recent concepts and measurement of malnutrition. Prof. P. V. Shukatme, Department of Biometry, Maharashtra Association for the Cultivation of Science, Poona, India.

Use of simulation models to evaluate the consequences of pests and diseases. Dr. R. Rabingge, Department of Theoretical Production, Ecology Centre for Agrobiological Research, Wageningen, The Netherlands.

Banking for the landless. Dr. M. Yunus, 1985 Ramon Magsaysay Awardee for Community Leadership, Bangladesh.

Pesticide monitoring. Dr. N. P. Cortes-Maramba, pediatric consultant, Department of Pediatrics, and pharmacology and toxicology consultant, Department of Medicine, Philippine General Hospital, Manila.

Nearest Neighbor (NN) analysis for field experiments. Prof. G. Wilkinson, Waite Agricultural Research Institute, The University of Adelaide, Australia.

Biogas production technology and plant systems. Dr. Young Dae Park, director, Agricultural Chemistry Division, Institute of Agricultural Sciences, ORD, Suweon, Korea.

Crop productivity as related to water use. Dr. T. C. Hsiao, professor of water science and plant physiologist, Department of Land, Air, and Water Resources, University of California, Davis, California, USA.

Local rice cultivars in Brunei. Dr. T. Imai, plant breeder, Tropical Agriculture Research Centre/Kilanas Agricultural Research Centre, Brunei.

Expression of the *Phaseolus vulgaris* seed storage protein gene 'Phaseolin' in foreign plant tissues after transfer via T-DNA vectors. Dr. J. L. Slightom, Advanced Research Division, Agrigenetics Corporation, Madison, Wisconsin, USA.

The construction of a disarmed octopine-type plasmid vector for use of expression of genes in regenerated plants. Dr. P. Chee, research scientist, Agrigenetics Corporation, Madison, Wisconsin, USA.

Application of hybridoma technology in plant virology. Dr. Hei-ti Hsu, plant virologist, American type culture collection, Maryland, USA.

Organogenesis in vitro: structural, physiological, and biochemical aspects. Dr. T. Thorpe, professor, Department of Biology, University of Calgary, Canada.

The IARCs: evidence of impact on national research and extension programs and on national crop yields. Dr. R. E. Evenson, Yale University, USA.

Finances

Summary of financial support to IRRI core and special projects received in 1984[a]

	Core		Special Projects	Total
	Unrestricted	Restricted		
United States Agency for International Development	$ 5,301,007.00	$ –	$1,760,781.78	$ 7,061,788.78
Japanese Government	–	3,331,320.14	199,959.19	3,531,279.33
United Nations Development Programme	–	1,530,200.00	320,264.57	1,850,464.57
European Economic Community	–	1,412,708.50	–	1,412,708.50
Canadian International Development Agency	1,233.920.00	–	133,157.19	1,367,077.19
International Fund for Agricultural Development	–	1,300,000.00	–	1,300,000.00
International Bank for Reconstruction and Development	1,120,000.00	–	–	1,120,000.00
Overseas Development Administration, United Kingdom	920,890.00	–	–	920,890.00
IBM World Trade Americas	–	–	762,582.61	762,582.61
International Development Research Centre	–	148,867.00[b]	489,325.52	638,192.52
Federal Republic of Germany	456,772.50	27,676.00[b]	127,074.85	611,523.35
Australian Government	515,691.00	–	–	515,691.00
Government of Sweden	368,856.95	–	–	368,856.95
Ford Foundation	150,000.00	–	120,633.60	270,633.60
Government of the Philippines	164,532.19	–	45,609.17	210,141.36
Government of Denmark	190,305.02	–	–	190,305.02
Government of Brazil	150,000.00	–	–	150,000.00
Swiss Federal Council	–	148,526.56[b]	–	148,526.56
Government of Belgium	115,524.75	–	17,773.04	133,297.79
Government of the Netherlands	–	94,951.92	14,432.96	109,384.88
Government of China	100,000.00	–	–	100,000.00
Soil Management Support Services of the University of Hawaii at Manoa	–	–	83,600.00	83,600.00
International Institute of Tropical Agriculture[c]	–	–	78,005.74	78,005.74
International Centre of Insect Physiology and Ecology[c]	–	72,856.09[b]	–	72,856.09
Office of Rural Development, Korea	–	–	59,000.00	59,000.00
International Fertilizer Development Center[c]	–	–	57,917.53	57,917.53
Government of Italy	52,593.00	–	–	52,593.00
Rockefeller Foundation	–	–	52,000.00	52,000.00
International Food Policy Research Institute[c]	–	–	38,550.69	38,550.69
Government of Spain	25,000.00	–	–	25,000.00
Asian Development Bank	–	–	19,700.00	19,700.00
Government of Islamic Republic of Iran	–	–	19,315.73	19,315.73
Government of New Zealand	16,605.00	–	–	16,605.00
Government of India	2,252.00	–	–	2,252.00
Others[d]	–	–	207,785.11	207,785.11
	$10,883,949.41	$8,067,106.21	$4,607,469.28	$23,558,524.90

[a]Receipts are accounted for on a cash basis. [b]Transferred projects since 1983. [c]Funds received in support of collaborative research. [d]Other donors were Resources Management International, Inc., Indonesia, $72,840; International Board for Plant Genetics Resources, $33,300; Food and Agriculture Organization of the United Nations, $31,778.21; Norsk Hydro A. S., $17,778; Imperial Chemical Industries, $10,000; International Potash Institute and the Potash Phosphate Institute, $9,000; Hoechst, $5,025.13; Ciba-Geigy, $5,000; Monsanto, $4,020.67; Du Pont Far East Inc., $3,015.08; FMC International, $3,000; SKW Trosborg, $3,000; Stauffer Chemicals, $3,000; Shell Chemicals Co., $2,532.93; American Cyanamid, $2,000; KenoGard, $1,000; Nippon-Kayaku Co., Ltd., $995.09; Wacker-Chemie GmbH, $500. USAID donated excess property of an indeterminable value. Briggs and Stratton, Corporation, USA, donated 11 Briggs and Stratton gasoline engines of assorted horsepower. The governments of France (ORSTOM and IRAT) and the Netherlands provided the Institute with visiting scientists; the value of their services cannot be quantified.

Staff changes

January

Ms. Ellen A. Maurer, instructor, Department of Agricultural Journalism, University of Wisconsin - Madison, joined IRRI as visiting associate editor at the Communication and Publications Department.

Dr. Felix N. Ponnamperuma, principal soil chemist, assumed his post after completing his sabbatic leave.

Mr. Salvador C. Labro, senior research assistant, Agricultural Engineering Department, joined the Institute's Cooperative Project in Egypt as mechanization specialist.

Dr. Laurian J. Unnevehr, former research associate, Agricultural Economics Department, rejoined IRRI as visiting associate agricultural economist.

Dr. Merle B. Shepard, formerly professor of the Department of Entomology, Fisheries, and Wildlife, Clemson University, joined the Institute staff as entomologist.

Dr. Ian F. Grant, Boyce Thompson Institute for Plant Research, Cornell University, left IRRI after completing a 1-yr assignment as visiting associate soil microbiologist.

Dr. Shouichi Yoshida, principal plant pathologist of the Institute, died.

Dr. Sang-Won Ahn, plant pathologist, CIAT, arrived for a 1-yr sabbatic assignment.

Mr. Sean O'Connor, Royal Hongkong Jockey Club, arrived for a 1-yr assignment as consultant with the Computer Center.

February

Dr. Martin E. Raymundo, formerly project leader of the Benchmark Soils Project, Philippine Operations, University of Hawaii, joined IRRI for a 10-wk assignment as consultant on the INSFFER project.

Mr. John T. Perfect and Dr. Anthea Cook left after completing their assignment as visiting scientists at the Entomology Department.

Dr. Mercedes B. de Mosqueda, titular professor, Department of Food Science and Technology, Universidad Central de Venezuela, arrived to spend a 6-mo sabbatic leave with the Cereal Chemistry Department.

March

Atty. Zosimo Q. Pizarro, manager, Personnel and Legal Offices of the Institute, assumed his post after completing a 6-mo study leave in the USA to develop a patent policy for the Institute.

Dr. Amanda Te, former research associate, rejoined IRRI as visiting associate agricultural economist.

Dr. T. Yamamoto, plant pathologist, Tropical Agriculture Research Center, Japan, arrived 1 Mar as visiting plant pathologist and left 20 Mar after completing his assignment.

Dr. Robert E. Huke, professor of geography, Dartmouth College, left after completing a 4-mo assignment as visiting scientist at the Agricultural Economics Department.

Mr. Faustino M. Salacup, director, Protocol and Liaison of the Institute, began a 6-mo sabbatic leave at the University of Washington, Seattle.

Dr. Joyotee Smith, former research associate, rejoined IRRI as visiting associate agricultural economist.

April

Dr. Bienvenido O. Juliano, chemist of the Institute, returned from a 1-yr sabbatic leave at the University of California, Berkeley, and as visiting scientist at the Southeast Asian Regional Center for Graduate Study and Research in Agriculture.

Dr. Julian A. Lapitan, researcher, Multiple Cropping Section, Department of Agronomy, UPLB, joined IRRI as visiting associate field specialist at the Training and Technology Transfer Department.

Dr. J. Ritchie Cowan, retired IRRI liaison scientist in Indonesia, rejoined IRRI as consultant for administration.

May

Dr. D. Hammond Murray-Rust, assistant professor, Department of Biological and Agricultural Engineering, Rutgers University, joined the Irrigation Water Management Department as associate agricultural engineer.

Dr. Ian F. Grant, Boyce Thompson Institute for Plant Research, Cornell University, rejoined IRRI as visiting associate soil microbiologist.

Dr. Robert L. Zimdahl, professor, Department of Botany and Plant Pathology, Colorado State University, joined IRRI as visiting scientist at the Agronomy Department.

June

Dr. V. Seshu Durvasula, IRTP plant breeder, returned from a 1-yr sabbatic leave at Cornell University.

Dr. Chung Ik-Cho, director of Research Coordination Division, Office of Rural Development, Korea, joined as visiting scientist at the Plant Breeding Department.

July

Dr. B. B. Shahi, former senior research fellow, joined IRRI as plant breeder with the IRRI/Malagasy Collaborative Project.

Dr. Roland J. Buresh, soil scientist at IFDC, joined IRRI as visiting scientist to work with the IRRI/IFDC Collaborative Project.

Dr. Seung Chan-Lee, head of the Plant Pathology Department, Office of Rural Development, Korea, left after completing a 1-yr assignment as visiting plant pathologist.

Dr. Clarence J. Miller, agricultural economist, left after completing his work on the BRRI/IRRI Project.

Dr. Martin E. Raymundo, formerly project leader of the Benchmark Soils Project, Philippine Operations, University of Hawaii, left after completing his assignment as consultant on the INSFFER Project.

Dr. Ian R. P. Fillery of IFDC left after completing his assignment as visiting associate soil chemist.

Mr. Glenn L. Denning, visiting associate field specialist, Training and Technology Transfer Department, left to complete his Ph D degree at the University of Reading, United Kingdom, on an extraordinary leave.

Mr. Fred E. Nichols, formerly international development consultant, rejoined IRRI as agricultural engineer in the Institute's Cooperative Project in India.

Dr. Jennie Dey of FAO joined IRRI to work as consultant on the role of women in rice farming systems.

August

Dr. James R. Hoopper rejoined IRRI as agronomist with the IRRI/Malagasy Collaborative Project.

Dr. Howard H. Hagerman, of Lyman Briggs College, Michigan State University, came as a short-term visiting scientist at the Training and Technology Transfer Department to work on cropping systems modules.

Dr. Mercedes B. de Mosqueda, titular professor, Department of Food Science and Technology, Universidad Central de Venezuela, left after completing a 6-mo sabbatic leave at the Cereal Chemistry Department.

Ms. Judith B. Wood, director, Information Systems Specialist Program, George Washington University, completed her assignment as visiting scientist at the International Rice Testing Program.

Dr. Sadiqul I. Bhuiyan, agricultural engineer of the Institute, began a 1-yr sabbatic leave as visiting professor, Agricultural Engineering Department, Cook College, Rutgers University, New Jersey.

Dr. John C. O'Toole, agronomist, resigned to join the Texas A & M University System.

Dr. Jeaninne Webb, director of the Office of Instructional Resources, University of Florida, left after a 3-wk consultancy with the Training and Technology Transfer Department to review and advise on effective evaluation methods and procedures to obtain qualitative feedback on training.

September

Dr. Howard H. Hagerman left after working 3-wk on cropping systems modules.

Dr. Earl H. Tryon, University of Florida, joined IRRI as visiting associate scientist on a 1-yr assignment with the Training and Technology Transfer Department to assist in the editing of educational manuals, slide/tape modules, and similar courseware materials being generated at IRRI.

Dr. Allan J. Carpenter, FAO, arrived at the International Rice Testing Program for a 4-mo sabbatic to familiarize himself with developments in improving the rice crop at high elevations such as those found in East Africa.

Mr. Faustino M. Salacup, director, Protocol and Liaison, assumed his post after completing a 6-mo study leave at the University of Washington, Seattle.

Dr. David J. Finney, professor, Department of Statistics, University of Edinburgh, began a 1-yr assignment as consultant with the Statistics Department to develop and organize a training course in statistics and computing for agricultural research.

October

Ms. Yoshiko Yamamoto of Cornell University began a 9-mo consultancy with the Administration to assist in the preparation of the exhibits for the rice museum in connection with the 25th anniversary celebration of IRRI and to collect lowland artifacts to complement the Ifugao artifacts collected by Dr. Harold Conklin.

Mr. Steven A. Breth, program officer, IADS, arrived for a 60-d secondment to IRRI during October and December to edit a book for the 25th anniversary celebration of IRRI. He left 30 Dec after completing his assignment.

Dr. Benito S. Vergara was appointed head of the Plant Physiology Department with immediate effect 4 Oct as approved by the Board of Trustees in its Executive Session held on that date.

Dr. Michael Loevinsohn joined the Institute staff in Malagasy as consultant for 6-mo on the IRRI/ Malagasy Collaborative Project.

Dr. J. Ritchie Cowan, retired IRRI liaison scientist for Indonesia/ Malaysia, left after completing his consultancy assignment with the Administration under the Director General's Office.

November

Dr. Shigemi Akita, formerly with the National Institute of Agrobiological Resources, Japan, joined the Institute staff as plant physiologist.

Dr. Yong Woon Jeon, formerly postdoctoral fellow of the Agricultural Engineering Department, was appointed visiting associate agricultural engineer to work under the IRRI/ IDRC Collaborative Project on Multi-Purpose Dryers.

December

Dr. D. Senadhira, former senior rice breeder and deputy director of agriculture (research), Department of Agriculture, Sri Lanka, joined IRRI as associate plant breeder.

Dr. Allan J. Carpenter, FAO, left after spending a 4-mo sabbatic leave to familiarize himself with developments in improving the rice crop at high elevations such as those found in East Africa.

Dr. Robert E. Huke, professor of geography, Dartmouth College, joined IRRI as a short-term visiting scientist at the Agricultural Economics Department.

Ms. Ellen A. Maurer, instructor, Department of Agricultural Journalism, University of Wisconsin - Madison, left after completing her assignment as visiting associate editor.

Weather summary

Total 1984 rainfall was 2,170 mm, almost 180 mm above normal for Los Baños. The wet season (WS) lasted from May to November. October was exceptionally wet, with 731 mm rainfall, and an extreme value of 362 mm on 20 and 21 Oct as the southwest monsoon intensified. In the dry season (DS), 31 Oct 1983 to 19 Apr 1984, rainfall totaled 115 mm and only 3 d had more than 10 mm.

Maximum temperature averages were lowest in January (29.0° C at upland farms and 28.0° C at lowland) and highest in April (34.1° C upland and 32.6° C lowland). The highest temperature was 35.7° C on 7 Apr at the upland farm.

Minimum temperature averages were lowest in February (21.7° C lowland and 21.2° C upland) and highest in August (24.0° C upland and 24.3° C lowland). The lowest temperature was 19.0° C on 10 Dec at the upland farm.

Mean relative humidity was lowest in April (65% upland and 70% lowland) and around 79% in WS. Vapor pressure deficit increased to 23 mbars in April at upland at midday (18 mbars at lowland) and dropped to 12 mbars in WS at both sites.

Windspeed, measured at 2 m aboveground, was higher in DS (1.8 m/s upland, 1.5 m/s lowland). In WS, windspeed was 1.5 m/s in upland and 1.3 m/s in lowland.

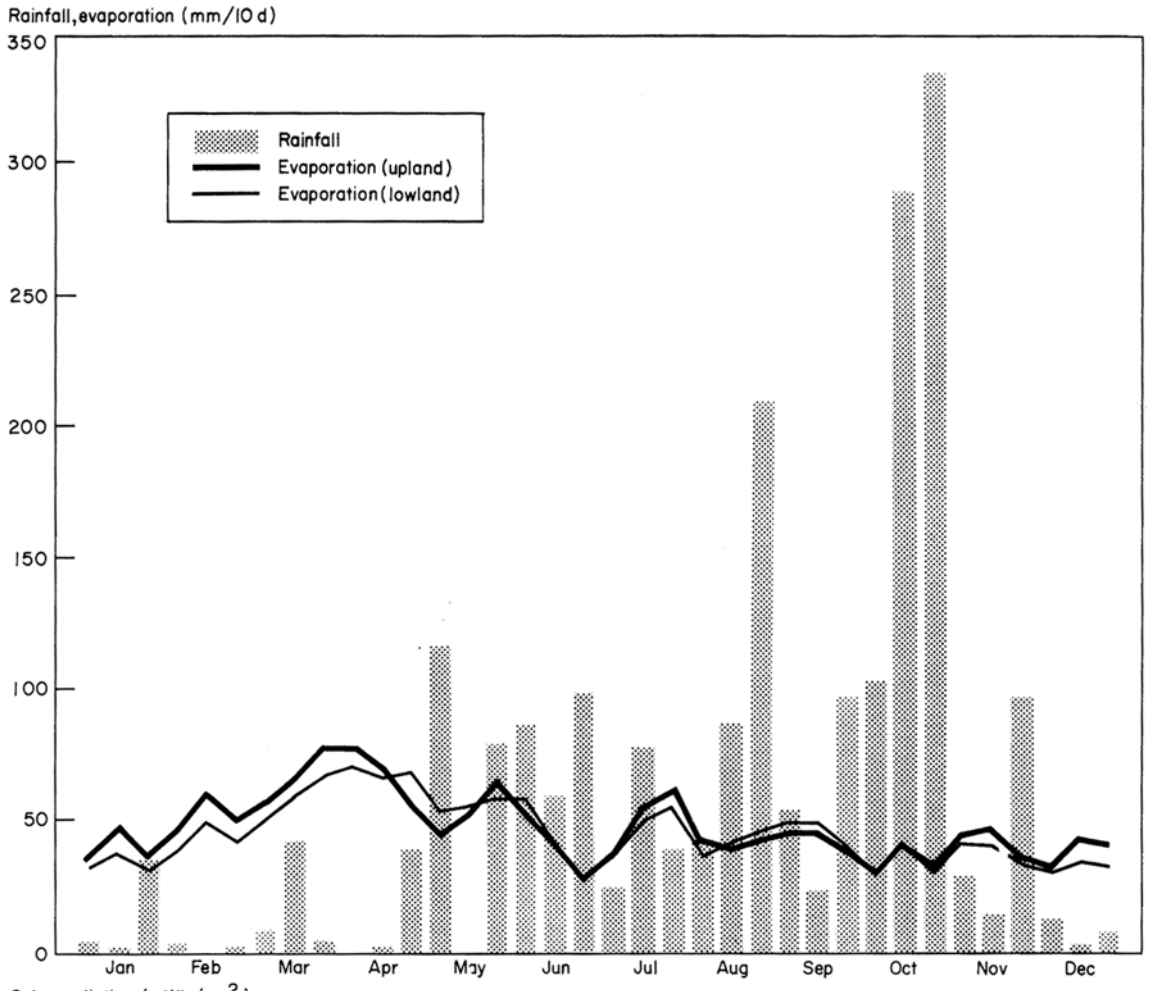
Evaporation from Class A pan was higher at the upland farm. The highest monthly evaporation, 205 mm in April, dropped to 120 mm in WS. Annual evaporation was 1,710 mm at upland and 1,607 mm at lowland. Figure 1 and Table 1 illustrate Los Baños weather in 1984.

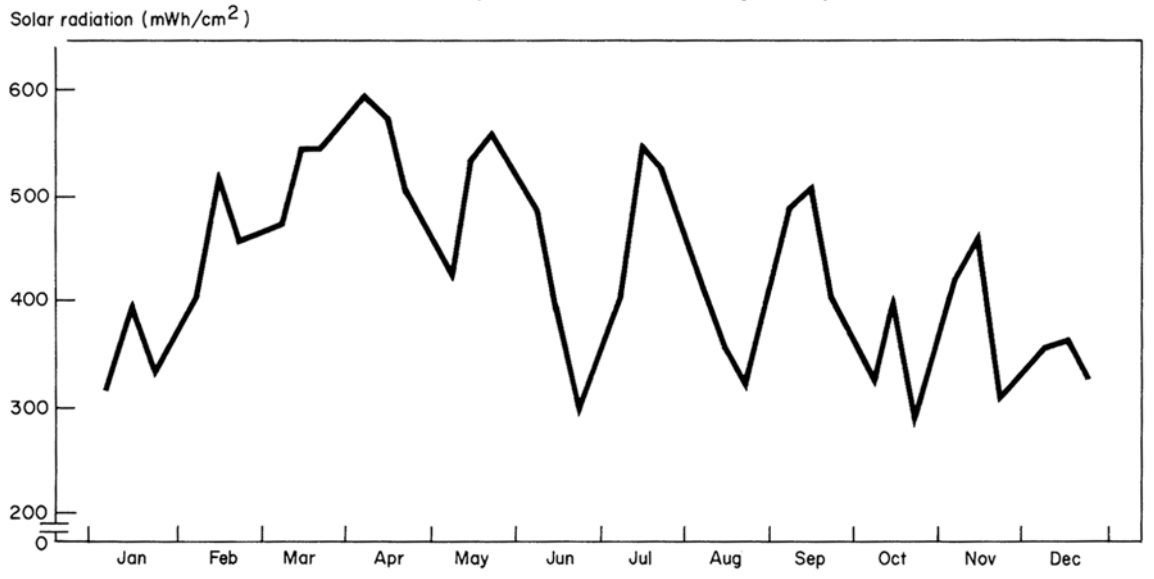
In 1984, 20 tropical disturbances entered the Philippine area, beginning a little later than normal. They did not affect Los Baños directly, but brought 56% of its rainfall. The storms intensified the southwest monsoon, bringing prolonged, heavy rains in August and October.

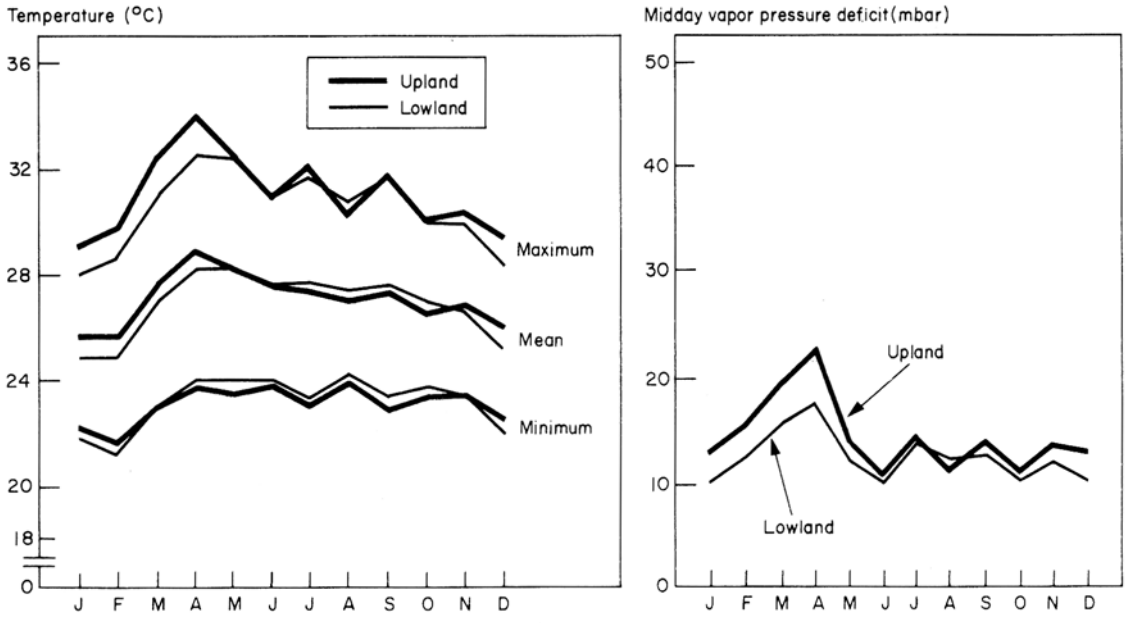
In the Philippines, tropical storm Maring severely damaged northwest coastal areas, and supertyphoons Nitang and Undang extensively damaged the Visayan region and northern Mindanao. Tropical depressions Pasing and Reming were closest to Los Baños, bringing late October rains.

Table 1. Monthly weather data at IRRI, Los Baños (14° 13'N; 121° 15'E), Laguna, Philippines, 1984.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm/mo)	44	6	55	43	212	249	144	341	176	731	143	26	2170
Normal rainfall (mm/mo)	40	18	28	32	180	237	282	255	264	238	257	160	1991
Total radiation (mWh/cm^2 per day)	345	460	520	555	505	390	495	360	465	335	395	345	430
Bright sunshine (h/d)	4.1	6.7	7.2	8.6	6.1	3.9	6.4	2.4	5.9	3.0	5.4	4.3	5.3
Dryland site													
Maximum temperature (°C)	29.0	29.7	32.4	34.1	32.7	31.0	32.0	30.2	31.8	29.8	30.4	29.4	31.0
Minimum temperature (°C)	22.2	21.7	23.1	23.7	23.6	23.9	23.0	24.0	22.9	23.4	23.4	22.5	23.1
Lowest relative humidity (%)	68	62	58	55	71	76	69	73	69	74	69	67	68
Highest vapor pressure deficit (mbar)	12.5	15.5	19.5	22.8	13.5	10.3	14.2	11.4	13.7	10.9	13.4	13.3	14.2
Windspeed (m/s)	1.9	2.1	1.9	1.8	1.1	1.6	1.3	2.3	1.2	1.2	1.5	1.8	1.6
Total evaporation (mm/mo)	120	158	199	205	159	116	150	127	130	105	125	116	1710
Wetland site													
Maximum temperature (°C)	28.0	28.7	31.1	32.6	32.5	30.9	31.8	30.4	31.8	29.9	30.1	28.3	30.5
Minimum temperature (°C)	22.1	21.2	23.1	24.0	24.1	24.2	23.4	24.3	23.5	23.7	23.3	22.1	23.2
Lowest relative humidity (%)	73	67	64	62	73	77	70	72	71	75	71	73	71
Highest vapor pressure deficit (mbar)	10.1	12.7	15.8	17.7	12.2	9.8	13.6	11.9	12.5	10.4	12.4	10.0	12.4
Windspeed (m/s)	1.5	1.8	1.6	1.5	0.9	1.2	1.0	2.1	1.0	1.0	1.3	1.4	1.4
Total evaporation (mm/mo)	98	128	176	205	166	124	143	118	136	99	114	100	1607


Rainfall, evaporation (mm/10 d)
350
300
250
200
150
100
50
0
Rainfall
Evaporation (upland)
Evaporation (lowland)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Solar radiation (mWh/cm2)
600
500
400
300
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



1. Highlights of 1984 weather at IRRI, Los Baños, Philippines.

- Research Highlights
- Genetic Evaluation and Utilization (GEU) Program
- Control and Management of Rice Pests
- Irrigation Water Management
- Soil and Crop Management
- Climatic Environment and Rice
- Constraints on Rice Yields
- Consequences of New Rice Technology
- Cropping Systems Program
- Machinery Development and Testing